WATER STRATEGY AND
HYDRO LICENSING

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August 5, 2022

Electronically Filed

The Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street N.E.
Washington, DC 20426

Subject: **Bad Creek Pumped Storage Project (P-2740-053)**
Filing of Proposed Study Plan for Relicensing Studies

Dear Secretary Bose:

Duke Energy Carolinas, LLC (Duke Energy or Licensee) is the Licensee, owner, and operator of the 1,400-megawatt (MW) Bad Creek Pumped Storage Project (FERC Project No. 2740) (Project), located in Oconee County, South Carolina, approximately eight miles north of Salem. The Bad Creek Reservoir (or upper reservoir) was formed from the damming of Bad Creek and West Bad Creek and serves as the Project's upper reservoir. Lake Jocassee serves as the lower reservoir and is licensed separately as part of Duke Energy's Keowee-Toxaway Hydroelectric Project (FERC Project No. 2503).

The existing license for the Project was issued on August 1, 1977, under the terms of an Original License issued by the Federal Energy Regulatory Commission (FERC or Commission), and the current 50-year operating license for the Project expires on July 31, 2027. Accordingly, Duke Energy is pursuing a new license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5.

On February 23, 2022, in accordance with 18 CFR §5.6, Duke Energy filed the Pre-Application Document (PAD) and Notice of Intent (NOI) with FERC to initiate the ILP. The Commission issued Scoping Document 1 (SD1) for the Project on April 22, 2022. SD1 is intended to advise resource agencies, Indian tribes, non-governmental organizations, and other stakeholders as to the proposed scope of FERC's Environmental Assessment (EA) or Environmental Impact Statement (EIS) for the Project and to seek additional information pertinent to the Commission's analysis. In SD1 and a Comments on the PAD and Study Request letter dated June 16, 2022, the Commission requested that Duke Energy complete an Environmental Justice Study as part of the relicensing.

On May 16 and 17, 2022, the Commission held virtual public scoping meetings. During these meetings, FERC staff presented information regarding the ILP and details regarding the study scoping process and how to request a relicensing study, including the Commission's study criteria. In addition, FERC staff solicited comments regarding the scope of issues and analyses for the EA. A virtual site visit was provided by Duke Energy prior to each public scoping meeting.

Resource agencies, Indian tribes, and other interested parties were afforded a 60-day period (which concluded on June 23, 2022) to request studies and provide comments on the PAD and SD1. During the comment period, a total of eight stakeholders filed letters with the Commission providing general comments, comments regarding the PAD, comments regarding SD1, and/or comments on studies of interest or proposed by Duke Energy in the PAD. Since the scoping meetings, Duke Energy has convened resource committee groups with interested stakeholders to provide an overview of methodology and goals for resources studies covered by the Proposed Study Plan (PSP).

In accordance with 18 CFR §5.11 of the Commission's regulations, Duke Energy is filing the PSP describing the studies that the Licensee is proposing to conduct in support of relicensing the Project.

Proposed Study Plan

Duke Energy has evaluated the study comments submitted by the stakeholders, with a focus on the requests that specifically addressed the seven criteria for study requests as set forth at 18 CFR §5.9(b) of the Commission's ILP regulations. One study request met ILP criteria and was submitted by FERC for the preparation of an Environmental Justice Study.

The purpose of the PSP is to present the studies that are being proposed by Duke Energy and to address the comments and study requests submitted by resource agencies and other stakeholders. At this time, Duke Energy is proposing to conduct the following studies as described in detail in the PSP:

1. Water Resources Study;
2. Aquatic Resources Study;
3. Visual Resources Study;
4. Recreational Resources Study;
5. Cultural Resources Study; and
6. Environmental Justice Study.

Duke Energy is filing the PSP with the Commission electronically and is distributing this letter to the parties listed on the attached distribution list. For parties listed on the attached distribution list who have provided an email address, Duke Energy is distributing this letter via email; otherwise, Duke Energy is distributing this letter via U.S. mail. All parties interested in the relicensing process may obtain a copy of the PSP electronically through FERC's eLibrary system[1], or from Duke Energy's public relicensing website.[2] If any party would like to request a CD containing a copy of the PSP, please contact the undersigned at the address listed below. Note that Critical Unclassified Information [CUI] pertaining to locations of protected archeological sites is being filed separately.

Comments on the PSP, including any additional or revised study requests, must be filed within 90 days of the deadline for filing this PSP, which is no later than November 5, 2022. Comments must include an explanation of any study plan concerns, and any accommodations reached with Duke

[1] https://elibrary.ferc.gov/idmws/search/fercgensearch.asp under docket number P-2740-053
[2] https://badcreekpumpedstorage.com

Energy regarding those concerns (18 CFR §5.12). Any proposed modifications to this PSP must address the Commission's seven ILP study criteria as presented in 18 CFR §5.9(b).

Initial Proposed Study Plan Meeting

In accordance with 18 CFR §5.11(e) of the Commission's regulations, Duke Energy intends to hold an initial PSP Meeting to describe the background, concepts, and study methods described in the PSP. Details for the proposed meeting are provided below. A dial-in number will also be provided upon request.

Date:	Wednesday, September 7, 2022
Time:	9:00 a.m. (until 5:00 p.m., if necessary)
Location:	Duke Energy's Wenwood Operations Center 425 Fairforest Way Greenville, SC 29607

To assist with meeting planning and logistics, Duke Energy respectfully requests that individuals or organizations who plan to attend the meeting in-person please RSVP by sending an email to Alan.Stuart@duke-energy.com on or before August 22, 2022.

Response to Additional Information Requests

As noted above, on June 16, 2022, the Commission issued comments on the PAD, a study request, and requests for additional information. Duke Energy's responses to the additional information requested by FERC staff are provided within the PSP. Duke Energy has addressed (or deferred until a later phase of the relicensing process) all of the Commission's requests. In response to the Commission staff's request, Duke Energy is filing a copy of the Duke Energy (2020) Avian Protection Plan as an Appendix (Appendix J) to the PSP, and additional GIS data requested by Commission staff are being eFiled concurrent with the PSP.

Duke Energy looks forward to working with Commission staff, resource agencies, Indian Tribes, local governments, non-governmental organizations, and interested members of the public throughout the relicensing process. If there are any questions regarding filing, please contact Alan Stuart, Senior Project Manager, Water Strategy & Hydro Licensing at Alan.Stuart@duke-energy.com or via phone at 980-373-2079.

Sincerely,

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Enclosure

cc (w/enclosure): Alan Stuart, Duke Energy
Garry Rice, Duke Energy

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PROPOSED STUDY PLAN

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

Prepared by: HDR Engineering, Inc.

Prepared for: Duke Energy Carolinas, LLC

August 5, 2022

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PROPOSED STUDY PLAN
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
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LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
ºF	degrees Fahrenheit
Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
CFD	computational fluid dynamics
CFR	Code of Federal Regulations
cfs	cubic feet per second
DLA	Draft License Application
DO	dissolved oxygen
Duke Energy or Licensee	Duke Energy Carolinas, LLC
EA	Environmental Assessment
EIS	Environmental Impact Statement
FERC or Commission	Federal Energy Regulatory Commission
FLA	Final License Application
FPA	Federal Power Act
fps	feet per second
ft	foot/feet
ft msl	foot/feet above mean sea level
HDR	HDR Engineering, Inc.
ILP	Integrated Licensing Process
ISR	Initial Study Report
KT Project	Keowee-Toxaway Hydroelectric Project
MW	megawatt
NEPA	National Environmental Policy Act
NGO	non-governmental organization
NOI	Notice of Intent
PAD	Pre-Application Document
PM&E	protection, mitigation, and enhancement
PSP	Proposed Study Plan
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
USR	Updated Study Report

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1 Introduction and Background

1.1 Project Overview

Duke Energy Carolinas, LLC (Duke Energy or Licensee) is the owner and operator of the 1,400-megawatt (MW) Bad Creek Pumped Storage Project (Project) (Project No. 2740) located in Oconee County, South Carolina, approximately eight miles north of Salem. The Project utilizes the Bad Creek Reservoir as the upper reservoir and Lake Jocassee, which is licensed as part of the Keowee-Toxaway (KT) Hydroelectric Project (FERC Project No. 2503), as the lower reservoir.

The existing (original) license for the Project was issued by the Federal Energy Regulatory Commission (FERC or Commission) for a 50-year term, with an effective date of August 1, 1977 and expires July 31, 2027. The license has been subsequently and substantively amended, with the most recent amendment on August 6, 2018 for authorization to upgrade and rehabilitate the four pump-turbines in the powerhouse and increase the Authorized Installed and Maximum Hydraulic capacities for the Project.[1] Duke Energy is pursuing a new license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. In accordance with 18 CFR §5.11 of the Commission's regulations, Duke Energy is filing this Proposed Study Plan (PSP) describing the studies that the Licensee is proposing to conduct in support of relicensing the Project.

1.1.1 Existing Project Description and Location

The Project is located in Oconee County, South Carolina, approximately eight miles north of the Town of Salem, South Carolina. The Project is situated in the northwestern-most portion of South Carolina and is less than two miles from the North Carolina border. The Bad Creek Reservoir is situated immediately northwest of Lake Jocassee, which is used as the lower reservoir for pumped storage operation, and streams draining to this area make up the headwaters of the Savannah River Basin. Downstream of Lake Jocassee is Lake Keowee, which is used as

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[1] *Duke Energy Carolinas LLC*, 164 FERC ¶ 62,066 (2018)

the lower reservoir for the Jocassee Pumped Storage Station and also supplies cooling water for Oconee Nuclear Station. The existing Project Boundary is shown on Figure 1-1.

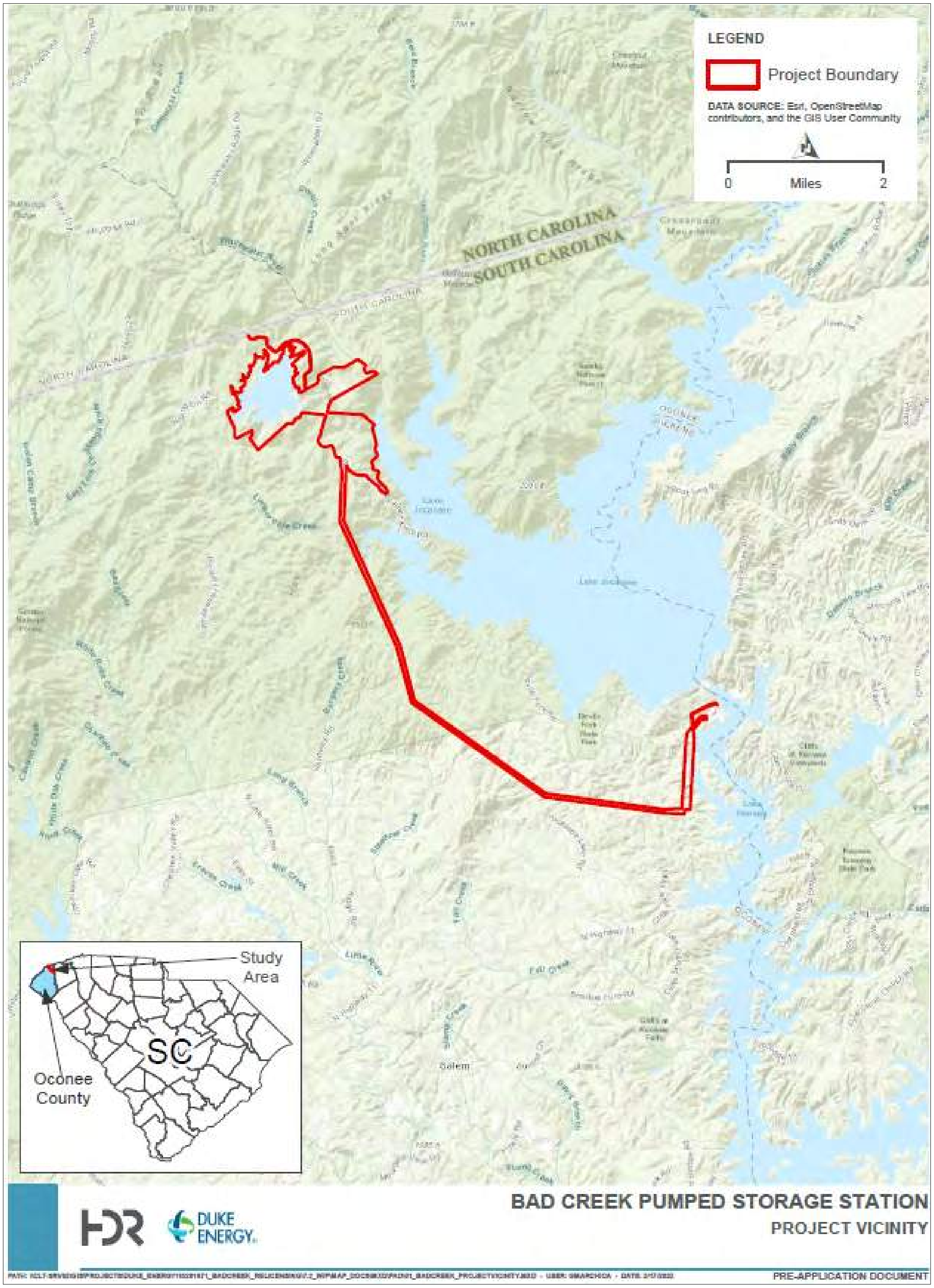

Figure 1-1. Bad Creek Pumped Storage Project Existing Project Boundary

The structures and features included in the Bad Creek Project license include the upper reservoir and dams, inlet/outlet structures in the upper and lower reservoirs, water conveyance system, underground powerhouse, tailrace tunnels, transmission facilities, and an approximately 9.25-mile-long transmission line corridor extending from Bad Creek to the KT Project's Jocassee switchyard. Project features are shown on Figure 1-2. The Bad Creek Reservoir was formed from the damming of Bad Creek and West Bad Creek and serves as the Project's upper reservoir.

Pumping water from Lake Jocassee up to the Bad Creek Reservoir provides a means of storing energy from surplus baseload generation during low demand periods and other non-dispatchable renewables generation during certain periods. Project operation in turbine mode, from the Bad Creek Reservoir to Lake Jocassee, provides power back to the grid when energy demand is higher or renewable generation is not available. The now 30-year-old Project is one of the most powerful and flexible energy generation and storage assets in Duke Energy's system. The Jocassee and Bad Creek facilities combined will, following the completion of ongoing upgrades to the pump-turbine units at Bad Creek by August 2023, provide 2,110 MW of pumped storage capacity.

Bad Creek was originally designed as a "weekly cycle" facility with approximately six hours of generation per day, allowing Duke Energy to utilize approximately 29 hours of storage in the upper reservoir to generate at full load three hours in the morning and three hours in the evening, five days per week, and then pump back for a portion of each night and over the weekend with low cost and available baseload power from Duke Energy's coal and nuclear fleet. Today, Bad Creek operates on more of a "daily cycle" mode, commonly alternating between generating and pumping on a daily basis, with the upper reservoir surface elevation typically maintained in the upper 50 to 60 feet (ft), compared to a maximum drawdown of 160 ft. This operating mode allows Duke Energy to maximize head, energy density, and plant/unit efficiency and utilize the Project like a massive storage battery to help balance the regional transmission system, including rapid consumption or generation of power due to variable solar energy production. As a result of this operating mode, with operation of the upper reservoir in the upper third of the possible drawdown range, only 30 to 40 percent of the storage capacity of Bad Creek is being regularly utilized.

Given the need for additional energy storage and renewable energy generation across Duke Energy's service territories over the Project's new 40 to 50-year license term, Duke Energy is evaluating opportunities to add pumping and generating capacity at the Project. Additional energy storage and generation capacity could be developed by constructing a new power complex (including a new underground powerhouse) adjacent to the existing Bad Creek Powerhouse. Therefore, construction of the 1,400-MW Bad Creek II Power Complex (Bad Creek II Complex or proposed Project) is an alternative relicensing proposal presently being evaluated by Duke Energy.

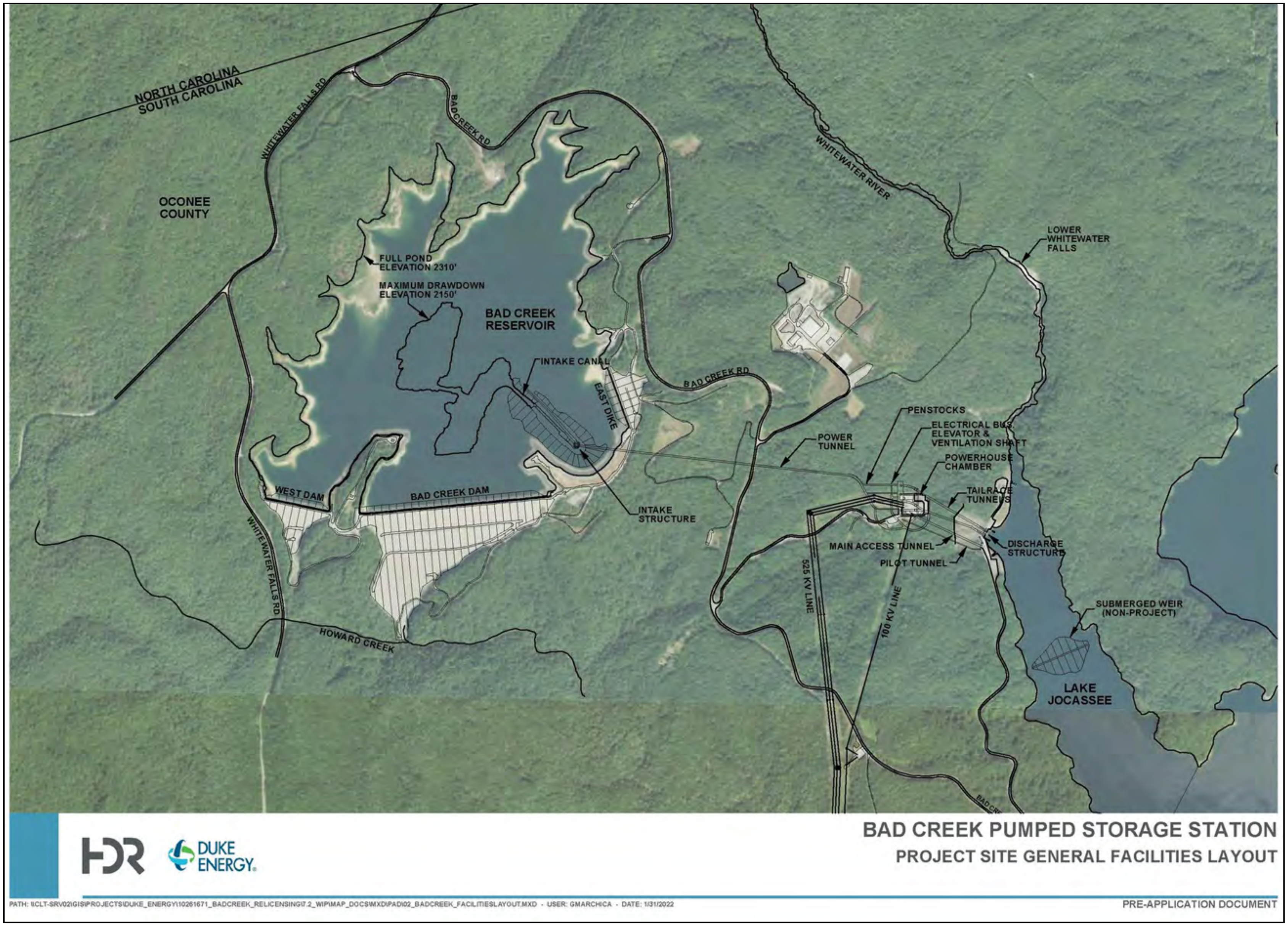

Figure 1-2. Bad Creek Existing Facilities Layout

1.1.2 Bad Creek II Complex Description and Location

Duke Energy will use the ILP pre-filing period to analyze the potential to develop the Bad Creek II Complex. The new facility would consist of a new inlet/outlet structure in the upper reservoir, water conveyance system (i.e., lower and high pressure tunnels, shafts, manifolds, penstocks, and draft tube/tailrace tunnels), underground powerhouse, powerhouse access tunnels, lower reservoir inlet/outlet structure, switchyard, transformer yard, and transmission line (see Figure 1-3).

The Bad Creek II Complex powerhouse would include four new, reversible pump-turbine units with a combined installed generating capacity of 1,400 MW.

The Bad Creek II Complex would utilize the existing Project's upper and lower reservoirs (Bad Creek Reservoir and Lake Jocassee, respectively) and would consist of a new upper reservoir inlet/outlet structure (within the existing upper reservoir), water conveyance system, underground powerhouse, and lower reservoir inlet/outlet structure (along the shoreline of Lake Jocassee). No modifications to the existing upper and lower reservoirs would be required for the Bad Creek II Complex other than construction of an upper reservoir inlet/outlet structure within the Bad Creek Reservoir and a lower reservoir inlet/outlet structure within Lake Jocassee.

In parallel with this relicensing, Duke Energy is conducting a study to further evaluate the technical and economic feasibility of the Bad Creek II Complex. This feasibility study is currently expected to conclude in late 2022. The feasibility study is expected to provide sufficient information to support future decisions by Duke Energy regarding advancement of the proposed project expansion, including conducting more detailed engineering studies. If Duke Energy decides not to pursue the Bad Creek II Complex prior to the filing of the Final License Application (FLA) in 2025, this relicensing alternative would not be further advanced through the relicensing studies or license application documents.

If Duke Energy decides to pursue the Bad Creek II Complex and obtains all necessary regulatory approvals for construction, the period for construction of the Bad Creek II Complex is expected to span approximately 6 years. The construction schedule and sequence are informed by the actual construction schedule for the existing Bad Creek Project (1985-1991). Assuming commencement of construction shortly following New License issuance by July 2027, the Bad Creek II Complex is expected to be fully in service in 2033. Major construction phases and milestones for the Bad Creek II Complex are expected to include the following:

Lower reservoir inlet/outlet:	Jul 2027 – Feb 2032
Upper reservoir inlet/outlet:	Dec 2029 – Aug 2031
Water conveyance system:	Mar 2028 – Mar 2031
Powerhouse:	Oct 2027 – Nov 2032
Transformer yard and switchyard:	Nov 2027 – Nov 2031
Testing and commissioning:	Aug 2032 – Aug 2033

Construction of the Bad Creek II Complex would require modifications to the existing Project Boundary to enclose the new facilities. While Duke Energy owns all property required for the existing Project in fee simple, a portion of the transmission line corridor is currently maintained under a property easement. Duke Energy currently owns or maintains under a property easement all lands that would be required for construction of the Bad Creek II Complex as depicted on Figure 1-3. If additional lands are required to accommodate the selected corridor for the new transmission line, this will be identified and evaluated in the planned transmission line siting study. Duke Energy intends to identify a new project boundary in the FLA that would include all lands necessary for access to, or control of, the expanded project facilities.

If, during pre-filing, Duke Energy determines that it will not include the Bad Creek II Complex in its final licensing proposal, the Licensee proposes instead to continue to operate the project as required by the Existing License.

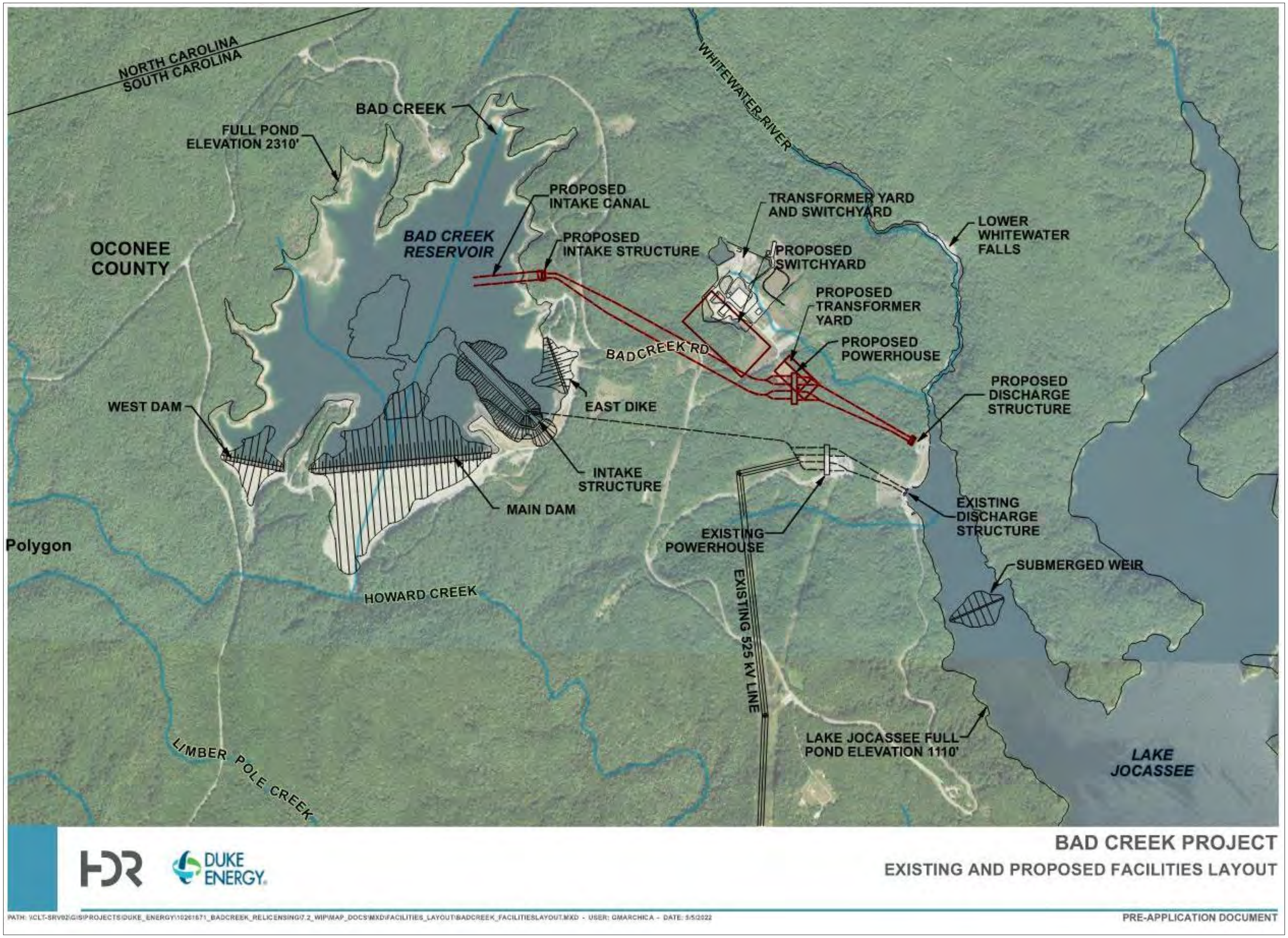

Figure 1-3. Proposed Bad Creek II Complex Facilities Layout (Major Existing Bad Creek Project Facilities are also Shown)

1.2 Study Plan Overview

Duke Energy filed a Pre-Application Document (PAD) and associated Notice of Intent (NOI) with the Commission on February 23, 2022 to initiate the ILP. The PAD provides a description of the Project and summarizes the existing, relevant, and reasonably available information to assist the Commission, resource agencies, Indian Tribes, non-governmental organizations (NGOs), and other stakeholders in identifying issues, determining information needs, and preparing study requests.

The National Environmental Policy Act of 1969 (NEPA), the Commission's regulations, and other applicable statutes require the Commission to independently evaluate the environmental effects of issuing a new license for the Project and to consider reasonable alternatives to relicensing. The Commission will prepare an Environmental Assessment (EA) or Environmental Impact Statement (EIS) that describes and evaluates the site-specific and cumulative potential effects (if any) of issuing a subsequent license, as well as potential alternatives to relicensing. The EA or EIS is supported by a scoping process to identify issues, concerns, and opportunities for resource protection and enhancement associated with the proposed action. Accordingly, the Commission issued Scoping Document 1 (SD1) for the Project on April 22, 2022. SD1 was intended to advise resource agencies, Indian Tribes, NGOs, and other stakeholders as to the proposed scope of the EA or EIS and to seek additional information pertinent to the Commission's analysis. As provided in 18 CFR §5.8(a) and §5.18(b), the Commission issued a notice of commencement of the relicensing proceeding concomitant with SD1.

On May 16 and 17, 2022, the Commission held virtual (call-in) public scoping meetings due to concerns with large gatherings related to COVID-19. During these meetings, FERC staff presented information regarding the ILP and details regarding the study scoping process and how to request a relicensing study, including the Commission's study criteria. In addition, FERC staff solicited comments regarding the scope of issues and analyses for the EA or EIS. Due to the ongoing construction upgrade activities at the Project, the remote location of the Project, and the ongoing COVID-19 pandemic, Duke Energy prepared an overview video orientation of the Project for general viewing by interested parties in lieu of an on-site environmental review site visit. The video can be viewed from a link on the Project's public relicensing website.[2] The virtual environmental site review presentation was given by Duke Energy one hour prior to each scoping meeting, pursuant to 18 CFR §5.8(d).

Resource agencies, Indian Tribes, and other interested parties were afforded a 60-day period to request studies and provide comments on the PAD and SD1. The comment period was initiated with the Commission's April 22, 2022 notice of commencement and concluded on June 23, 2022.

During the comment period, eight stakeholders filed letters with the Commission providing general comments and comments regarding the PAD/NOI and SD1. FERC also submitted comments during the comment period. A summary of stakeholder comments is provided in Appendix A of this document, and copies of the letters filed with the Commission are provided in Appendix B. Only one formal study request was received during the comment period (from the Commission [Environmental Justice]). The ILP requires Duke Energy to file this PSP within 45 days from the close of the June 23, 2022 comment period (i.e., on or before August 7, 2022).[3]

The purpose of this PSP is to present the studies proposed by Duke Energy and to address, as appropriate, the comments and study requests submitted by resource agencies and other stakeholders. This PSP also provides FERC, regulatory agencies, Indian Tribes, and other stakeholders with the methodology and details of Duke Energy's proposed studies. As necessary, after the PSP comment period closes, Duke Energy will prepare a Revised Study Plan (RSP) that will address additional stakeholder comments to the extent practicable. Pursuant to the ILP, Duke Energy will file the RSP with the Commission on or before December 5, 2022, and the Commission will issue a final Study Plan Determination within 30 days, by January 4, 2023.

1.2.1 FERC Study Criteria

FERC's ILP regulations require that stakeholders who provide study requests include specific information to allow the Licensee, as well as Commission staff, to determine a requested study's appropriateness and relevancy to the Project and proposed action. As described in 18 CFR §5.9(b) of the Commission's ILP regulations, and as presented by FERC staff during the May 16

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[2] www.badcreekpumpedstorage.com

[3] If the due date falls on a weekend or holiday, the deadline is the following business day.

and 17, 2022 scoping meetings, the required information to be included in a study request is as follows:

(1) Describe the goals and objectives of each study and the information to be obtained (§5.9(b) (1));

This section describes why the study is being requested and what the study is intended to accomplish, including the goals, objectives, and specific information to be obtained. The goals of the study must clearly relate to a need to evaluate the effects of the Project on a particular resource. The objectives are the specific information that needs to be gathered to allow achievement of the study goals.

(2) If applicable, explain the relevant resource management goals of the agencies or Indian Tribes with jurisdiction over the resource to be studied (§5.9(b) (2));

This section must clearly establish the connection between the study request and management goals or resource of interest. A statement by an agency connecting its study request to a legal, regulatory, or policy mandate needs to be included that thoroughly explains how the mandate relates to the study request, as well as the Project's potential impacts.

(3) If the requester is not a resource agency, explain any relevant public interest considerations in regard to the proposed study (§5.9(b) (3));

This section is for non-agency or Indian Tribes to establish the relationship between the study request and the relevant public or tribal interest considerations.

(4) Describe existing information concerning the subject of the study proposal and the need for additional information (§5.9(b) (4));

This section must discuss any gaps in existing data by reviewing the available information presented in the PAD or information relative to the Project that is known from other sources. This section must explain the need for additional information and why the existing information is inadequate.

(5) Explain any nexus between project operation and effects (direct, indirect, and/or cumulative) on the resource to be studied and how the study results would inform the development of license requirements (§5.9(b) (5));

This section must clearly connect Project operations and Project effects on the applicable resource. This section can also explain how the study results would be used to develop PM&E measures that could be implemented under a new FERC license. The proposed protection, mitigation, and enhancement (PM&E) measures can include those related to any mandatory conditioning authority under Section 401 of the Clean Water Act[4] or Sections 4(e) and 18 of the Federal Power Act, as applicable.

(6) Explain how any proposed study methodology is consistent with generally accepted practices in the scientific community or, as appropriate, considers relevant tribal values and knowledge. This includes any preferred data collection and analysis techniques, or objectively quantified information, and a schedule including appropriate field season(s) and the duration (§5.9(b) (6));

This section must provide a detailed explanation of the study methodology. The methodology may be described by outlining specific methods to be implemented or by referencing an approved and established study protocol and methodology.

(7) Describe considerations of level of effort and cost, as applicable, and why any proposed alternative studies would not be sufficient to meet the stated information needs (§5.9(b) (7));

This section must describe the expected level of cost and effort to conduct the study. If there are proposed alternative studies, this section can address why the alternatives would not meet the stated information needs.

1.2.2 Duke Energy's Proposed Study Plan

Duke Energy has evaluated the study requests and comments submitted by the Commission and stakeholders, with a focus on the requests that specifically addressed the seven criteria set forth in §5.9(b) of the Commission's ILP regulations, as discussed above. Based on Duke Energy's review of the requested study and comments, FERC criteria for study requests under the ILP, and available information (e.g., associated with the previous licensing effort or resulting from ongoing monitoring activities), Duke Energy is proposing a total of six resource studies. These six studies consider stakeholder comments for relicensing of the existing Project as well as studies proposed by Duke Energy in the PAD for construction of Bad Creek II:

- Water Resources Study
- Aquatic Resources Study
- Cultural Resources Study
- Visual Resources Study

[4] 33 U.S.C. §1251 et seq.

- Recreational Resources Study
- Environmental Justice Study

Information regarding each of these studies is provided in Appendices C through H of this PSP.

For each of Duke Energy's proposed studies, this PSP describes:

1) The goals and objectives of the study;
2) The defined study area;
3) A summary of background and existing information pertaining to the study;
4) The nexus between Project operations and potential effects on the resources to be studied;
5) The proposed study methodology;
6) Level of effort, cost, and schedules for conducting the study; and
7) References cited.

FERC's SD1 indicated that Duke Energy intended to complete a geotechnical investigation and geological assessment to identify potential effects of construction and operation of the Bad Creek II Complex and inform mitigation measures to maintain geological stability. Duke Energy has not included this study in this PSP, as it is being completed as part of the ongoing feasibility study. Similarly, a technical report on the development of a three-dimensional computational fluid dynamics (CFD) model to evaluate, among other considerations, shoreline erosion in the Whitewater River arm of Lake Jocassee due to operation of the Bad Creek II Complex. A summary of preliminary findings from these studies is included in Appendix I, and Duke Energy anticipates that a copy of these technical study reports will be included in this same corresponding appendix in the RSP.

Additionally, in SDI, FERC indicated that Duke Energy proposes to conduct a transmission line siting study for the potential Bad Creek II Complex. This study is not included in this PSP, as it will be performed under a separate schedule and process, to comply with requirements pursuant to The South Carolina Utility Facility Siting and Environmental Protection Act, S.C. Code Ann. § 58-33-10 et seq.

1.2.3 Comments on the Proposed Study Plan

Comments on this PSP, including any additional or revised study requests, must be filed within 90 days of the filing date of this PSP (i.e., no later than November 7, 2022). Comments must include an explanation of any study plan concerns and any accommodations reached with Duke Energy regarding those concerns (18 CFR §5.12). Any proposed modifications to this PSP must address the Commission's criteria as presented in 18 CFR §5.9(b).

1.2.4 Proposed Study Plan Meeting

In accordance with 18 CFR §5.11(e), Duke Energy plans to hold a PSP Meeting on September 7, 2022. The purpose of the PSP Meeting will be to clarify the intent and contents of this PSP, explain information gathering needs, and resolve outstanding issues associated with the proposed studies. Additional details regarding the meeting are presented in Section 4 of this document.

2 Execution of the Study Plan

As required by Section 5.15 of FERC's ILP regulations, Duke Energy will prepare ILP study progress reports on a quarterly basis, file an Initial Study Report (ISR), hold an ISR Meeting with stakeholders and FERC staff to discuss the initial study results, and prepare and file an Updated Study Report (USR), and convene an associated USR Meeting as appropriate. Duke Energy will submit all study documents that must be filed with the Commission via FERC's eFiling system.

2.1 Process Plan and Schedule

The Process Plan and Schedule, as appended to FERC's SD1, is presented in Table 2-1. Gray shaded milestones are unnecessary if there are no study disputes. If the due date falls on a weekend or holiday, the due date is the following business day. Early filings or issuances will not result in changes to these deadlines.

Table 2-1. Process Plan and Schedule

Activity	Responsible Parties	Timeframe	Estimated Filing Date or Deadline
File NOI and PAD (18 CFR §5.5(d))	Licensee	Within 5 years to 5.5 years prior to license expiration	Feb 23, 2022
Initial Tribal Consultation Meeting (18 CFR §5.7)	FERC	No later than 30 days following filing of NOI/PAD	Mar 25, 2022
Issue Notice of NOI/PAD and Scoping Document 1 (SD1) (18 CFR §5.8(a))	FERC	Within 60 days following filing of NOI/PAD	Apr 22, 2022
Conduct Scoping Meetings and site visit (18 CFR §5.8(b)(viii))	FERC	Within 30 days following Notice of NOI/PAD and SD1	May 16 and 17, 2022
Comments on PAD, SD1, and Study Requests (18 CFR §5.9(a))	Licensee Stakeholders	Within 60 days following Notice of NOI/PAD and SD1	June 23, 2022
Issue Scoping Document 2 (SD2), if necessary (18 CFR §5.10)	FERC	Within 45 days following deadline for filing comments on PAD/SD1	Aug 5, 2022
File Proposed Study Plan (PSP) (18 CFR §5.11)	Licensee	Within 45 days following deadline for filing comments on PAD/SD1	Aug 8, 2022
PSP Meeting (18 CFR §5.11(e))	Licensee	Within 30 days following filing of PSP	Sep 7, 2022
Comments on PSP (18 CFR §5.12)	Stakeholders	Within 90 days following filing of PSP	Nov 7, 2022
File Revised Study Plan (RSP) (18 CFR §5.13(a))	Licensee	Within 30 days following deadline for comments on PSP	Dec 5, 2022
Comments on RSP (18 CFR §5.13(b))	Stakeholders	Within 15 days following filing of RSP	Dec 20, 2022
Issue Study Plan Determination (18 CFR §5.13(c))	FERC	Within 30 days following filing of RSP	Jan 4, 2023
§5.13(a) Notice of Formal Study Dispute	Mandatory Conditioning Agencies	With 20 days of SPD	Jan 24, 2023
§5.13(1) Study Dispute Determination	FERC	Within 70 days of Notice of Formal Study Dispute	April 4, 2023
Conduct First Season of Studies (18 CFR §5.15)	Licensee	-	Spring-Fall 2023
File Study Progress Reports (18 CFR §5.15(b))	Licensee	Quarterly	Spring 2023 -Fall 2024

Activity	Responsible Parties	Timeframe	Estimated Filing Date or Deadline
File Initial Study Report (ISR) (18 CFR §5.15(c))	Licensee	Pursuant to the Commission-approved study plan or no later than 1 year after Commission approval of the study plan, whichever comes first	Jan 4, 2024
ISR Meeting (18 CFR §5.15(c)(2))	Licensee Stakeholders	Within 15 days following filing of ISR	Jan 19, 2024
File ISR Meeting Summary (18 CFR §5.15(c)(3))	Licensee	Within 15 days following ISR Meeting	Feb 5, 2024
Comments on ISR Meeting and Additional or Modified Study Requests (18 CFR §5.15(c)(4))	Stakeholders	Within 30 days following filing of ISR Meeting Summary	Mar 4, 2024
File Response to Comments on ISR and Meeting Summary (18 CFR §5.15(c)(5))	Licensee	Within 30 days following filing of ISR Meeting Comments	Apr 3, 2024
Resolution of Meeting Summary Disagreements and Issue Amended Study Plan Determination (if required) (18 CFR §5.15(c)(6))	FERC	Within 30 days following filing of response to ISR Meeting Comments	May 3, 2024
Conduct Second Season of Studies (if necessary)	Licensee	-	Spring-Fall 2024
File Updated Study Report (USR) (18 CFR §5.15(f))	Licensee	Pursuant to the approved study plan or no later than 2 years after Commission approval, whichever comes first	Jan 3, 2025
USR Meeting (18 CFR §5.15(f))	Licensee Stakeholders	Within 15 days following filing of USR	Jan 18, 2025
File USR Meeting Summary (18 CFR §5.15(f))	Licensee	Within 15 days following USR Meeting	Feb 3, 2025
Deadline to File Preliminary Licensing Proposal (PLP) or Draft License Application (DLA) (18 CFR §5.16(a))	Licensee	No later than 150 days prior to the deadline for filing the FLA	March 3, 2025
File Comments or Disagreements on USR Meeting Summary (18 CFR §5.15(f))	Stakeholders	Within 30 days following filing of USR Meeting Summary	Mar 4, 2025
File Response to Comments on USR Meeting Summary (18 CFR §5.15(f))	Licensee	Within 30 days following filing of Disputes	Apr 3, 2025
Resolution of USR Meeting Summary Dispute (if necessary) (18 CFR §5.15(f))	FERC	Within 30 days following filing of response to USR Meeting Comments	May 1, 2025

Activity	Responsible Parties	Timeframe	Estimated Filing Date or Deadline
Comments on PLP or DLA (18 CFR §5.16(e))	Stakeholders	Within 90 days following filing of PLP or DLA	June 2, 2025
Deadline to file FLA (18 CFR §5.17)	Licensee	No later than 24 months before the existing license expires	July 31, 2025
Publish Public Notice of FLA Filing (18 CFR §5.17(d)(2))	Licensee	Within 14 days following filing of FLA filing	August 13, 2025

2.2 Proposed Studies and Schedule

Table 2-2 lists the six proposed studies and the proposed schedule for each. Duke Energy expects to report on the progress and results of studies within the framework afforded by the ISR and associated ISR Meeting, as well as the USR and USR meeting. Based on the exact timing of completion of work for each study, Duke Energy may issue draft products between the ISR and USR to the extent practicable. At this time, Duke Energy is proposing to file technical study reports with the Commission and to provide stakeholders access to the study reports consistent with the schedule presented in Table 2-2. As necessary, Duke Energy will update stakeholders of changes in the schedule in quarterly study progress reports.

Table 2-2. Proposed Studies and Schedule

Study	Anticipated Date of Study Completion	Anticipated Date of Initial Study Report
1. Water Resources Study	Fall 2024	January 4, 2024
2. Aquatic Resources Study	Fall 2023	January 4, 2024
3. Cultural Resources Study	Fall 2023	January 4, 2024
4. Visual Resources Study	Fall 2023	January 4, 2024
5. Recreational Resources Study	Fall 2023	January 4, 2024
6. Environmental Justice Study	Fall 2023	January 4, 2024

2.3 Study Area

Consistent with the ILP study requirements, Duke Energy has proposed a study area for each individual study that takes into account existing lands in the Project boundary, potential expansion of the Project boundary for the Bad Creek II Complex, and additional areas where there is the potential for the relicensing to impact specific resources. Duke Energy believes that the tasks and activities within the proposed study areas described in this PSP are sufficient to inform agency recommendations and FERC license conditions for the Project, and focusing the geographic scope of the proposed studies on these Study Areas is consistent with generally accepted practice in the scientific community and within FERC relicensing criteria (ILP Study Criteria No. 6).

3 Stakeholder Study Requests and Responses to Study Requests

Duke Energy filed the PAD for the Project on February 23, 2022. FERC issued SD1 on April 22, 2022 and conducted virtual public scoping meetings on May 16 and 17, 2022. In accordance with ILP regulations, comments on the PAD and SD1 and study requests were due to FERC by June 23, 2022. Duke Energy received one study request from the Commission and comment letters from the following stakeholders:

U.S. Fish and Wildlife Service

U.S. Environmental Protection Agency

South Carolina Department of Natural Resources

Foothills Trail Conservancy

Upstate Forever

Friends of Lake Keowee Society

Fishers Knob Homeowners

Duke Energy has reviewed the stakeholder comments and requested studies included in the FERC record. Study comments received were considered in preparation of each proposed resource study plan. A summary of stakeholder comments is provided in Appendix A.

3.1 Requested Studies Adopted

In the PAD, Duke Energy proposed two studies for the relicensing of the existing Project (Water and Recreational Resources) and three additional studies (Aquatic Resources, Cultural Resources, Visual Resources) if the proposed facility were to be pursued. This PSP assumes that the Bad Creek II Complex will be constructed; therefore, it includes all studies initially proposed in the PAD:

(1) Water Resources Study

(2) Aquatic Resources Study

(3) Recreational Resources Study

(4) Cultural Resources Study

(5) Visual Resources Study

Based on the Commission's study request, a sixth study has been adopted:

(6) Environmental Justice Study

3.2 Requested Studies Not Adopted

No formal study requests (i.e., addressing the FERC ILP study criteria) were received from stakeholders (other than the Environmental Justice Study requested by FERC); therefore, this section is not applicable.

3.3 Requested Studies Adopted with Alteration

No formal study requests (i.e., addressing the FERC ILP study criteria) were received from stakeholders (other than the Environmental Justice Study requested by FERC); therefore, this section is not applicable.

4 Proposed Study Plan Meeting

Pursuant to 18 CFR §5.11(e) of the Commission's ILP regulations, Duke Energy is providing information regarding the PSP Meeting that will be held for the purposes of clarifying the PSP, explaining information gathering needs, and resolving outstanding issues associated with the proposed studies. The Commission's regulations and the approved Process Plan and Schedule require Duke Energy to conduct the PSP Meeting within 30 days of the filing of this PSP. Accordingly, Duke Energy will hold the PSP Meeting on September 7, 2022.

Additional details regarding the meeting are presented below. A dial-in number will also be provided upon request.

Date:	Wednesday, September 7, 2022
Time:	9:00 a.m. (until 5:00 p.m., if necessary)
Location:	Duke Energy's Wenwood Operations Center 425 Fairforest Way Greenville, SC 29607

For additional information, please contact:

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Mail Code EC-12Q
526 South Church Street
Charlotte, NC 28202
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5 FERC Additional Information Requests (AIRs)

By letter to Duke Energy dated June 16, 2022, FERC staff submitted comments on the PAD and requested additional clarification and/or information. Duke Energy's responses are provided in Table 5-1 and the figures and tables that follow in this section.

Table 5-1. Responses to FERC Additional Information Requests

Comment / Request for Information	Duke Energy Response
1. Please file the GIS data shown on the following figures in the PAD: (1) existing project features layout with callout labels (figure 5.4-12; and figure 2 in Appendix E); (2) proposed Complex features layout with callout labels (figure 5.4-13; and figure 2 in Appendix E); (3) potential spoil locations relative to surface waters with spoil area labels and surface water impact callout labels (figure 6.3-7); (4) the estimated riparian and littoral zones from the desktop analysis and wetlands from the field assessment with callout labels (figure 6.6-2); (5) protected species habitat polygons and photo location points (figure 6.6-4); and (6) Foothills Trail layer, parking area and connector trail to the Foothills Trail in the Bad Creek Project boundary, other recreational facilities in the project vicinity, and the state and federal land layers (figure 6.8-1).	Duke Energy compiled a file of GIS data used to make figures in the PAD and transmitted it to FERC electronically on 4/8/2022; a second zip file with the additional requested GIS files is being submitted to the Commission electronically concurrent with the filing of this PSP.
2. Section 4.5 of the PAD provides a description of the existing project facilities. However, for some project features, additional detail is needed (i.e., composition, dimension, etc.) to gain a more complete understanding of project facilities and operations. (1) the composition, method of repair, and frequency of repair, of the Bad Creek Project dam (main dam) flashboards; (2) the length (feet) of the Bad Creek Upper Reservoir (upper reservoir) intake channel; (3) the length and composition of the upper reservoir dewatering dam; (4) the width (feet) of each of the two, sluice gates located in the upper reservoir dewatering dam, as well as a description of the gates' operation, uses, and frequency of use; (5) the total number, dimensions (i.e., length and height)), and clear bar spacing (inches) of the trash rack structure(s) attached to the steel lift gates in the lower reservoir (Lake Jocassee) inlet/outlet structure; (6) the dimensions (i.e., length and diameter) and composition of the manifold tunnel as part of the larger water conveyance system; (7) the number, length,	(1) There are no flashboards on the rockfill dam. (2) The measured length of the centerline in Exhibit L Sheet 1 to the center of the vertical shaft is approximately 1,330 ft. (3) The upper reservoir dewatering dam is approximately 730 ft upstream of the vertical shaft. The dam is made of concrete and approximately 30 ft across the lower part of the intake channel [from both Exhibit L Sheets 1 (general plan) and 2 (upper left plan). Section B02-B02 on Drawing NO. BK-1052-02-00 shows the structure.] (4) The two sluice gates cover the 3.5 feet (42 inch) diameter culverts (from typical section in center of Exhibit L Sheet 3). The purpose of the intake canal sluice gates is to prime the power tunnel with available water in the drawn-down reservoir prior to reservoir refilling. The frequency of use is dependent upon how often the reservoir is dewatered for major outage related activities. As noted, in the time frame of the existing license, the reservoir has only been dewatered two times requiring use of the sluice gates. (Drawing No. BK-1052-01-00 Detail 4 shows the sluice gate as "By Others" and no dimensions.) The gate use is to allow for maintenance to occur without total dewatering of the reservoir; frequency is only during dewatering events (which to date only occurred in 2000 and 2018). [The trash rack is 5'-5 1/2" wide by 6' high. Bars are 1 ft spaced and are 3" x ½" wide flat bars (from Dwg. No. BK-1052-03-00).] (5) The discharge structure splits the two discharge tunnels into two parts. The two arched tunnels have splitter walls creating four openings convey the water. Each half arch section has two racks (upper and

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composition, and uses of, the secondary penstocks; (8) the dimensions (i.e., height and width) of each of the four draft tube gates; and (9) the number, length, and voltage (V) of the project generator lead(s).	lower). The lower portion is rectangular (16.25' high x 18.25' wide); the upper portion has a rectangular bottom and arched top. The bottom width is 18.25' wide. The short side is 9.25' high; the tall side is 16.25' high. The radius of the arch is 32'-4". There are 34 spaces at 6" spacing for a flow area of 17' with this spacing (the sides are slightly smaller because of the trashrack frame). [Details are from Drawing No. BK-1065-01-02] (6) The manifold tunnel is 470 ft (143 m) long and composed of reinforced concrete. The segment from the start at Power Tunnel Station 0+000 to the Unit 1 penstock centerline is approximately 30 m long and 9 m in diameter. From Unit 1 penstock centerline to the Unit 2 penstock centerline is approximately 39.3 m long and 8 m in diameter. From Unit 2 penstock centerline to the Unit 3 penstock centerline is approximately 34.6 m long and 6.36 m in diameter. From Unit 3 penstock centerline to the Unit 4 penstock centerline is approximately 39.3 m long and 4.2 m in diameter. [Details are from Drawing No. BK-1040-01 Rev.4 and BK1040-03 Rev. 12] (7) The four penstocks are concrete-lined and 4.2 m in diameter as they come off the manifold tunnel and reduce to 2.556 m steel-lined penstocks as they approach the turbines in the powerhouse. The total steel-line penstock length is 213' (64.9 m): approximately 40.2 m are 4.2 m in diameter, the reducer cone is 5 m, and approximately 19.7 m are 2.556 m in diameter. The concrete-lined sections vary in length by penstock: Unit 1 is approximately 81 m long; Unit 2 is approximately 61.3 m long; Unit 3 is approximately 44 m long; and Unit 4 is approximately 24.4 m long. [Details on specific sections are from Drawing No. BK-1040-03 Rev.12] The use for the penstocks is water conveyance for generation or pumping. The bypass tunnel (and tailrace bypass tunnel) are not used regularly. (8) The four draft tube gates are identical, rectangular in shape, and 30.5' high by 19.25' wide (from Dwg No. BK-1065-01-00). (9) There are 3 generator leads per unit and 4 units for a total of 12 leads. Leads are rated at 19kV and each lead varies slightly in length, averaging around 50 ft measured from the generator to the corresponding circuit breaker.
3. Clarify: (1) the composition and dimensions (feet) of the weir; (2) if the weir is used for normal project operation; and (3) if the weir is enclosed by the existing project boundary, or will be enclosed within the project boundary, as part of Duke Energy's relicensing proposal.	Existing Weir: Width = 567 ft Length = 455 ft Proposed Weir: Width = 864 ft Length = 765 ft The submerged weir is located approximately 550 meters downstream of the Project discharge and was originally constructed to help minimize the effects of mixing downstream of the Whitewater River arm

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	of Lake Jocassee; it has not been modified since the original construction. The weir is composed of rockfill (i.e., spoil from the original Project construction). The weir is not enclosed in the existing FERC Project Boundary for Bad Creek but is contained in the Project Boundary for the Keowee-Toxaway (KT) Project (Lake Jocassee). If the Bad Creek II Complex is constructed, the weir may be expanded to help mitigate the effects of additional releases in the Whitewater River arm. At this time, Duke Energy is not proposing to include the submerged weir in the FERC Project boundary for the Bad Creek Project and instead prefers to allow it to remain in the KT Project Boundary as part of Lake Jocassee.
4. Clarify: (1) the total maximum hydraulic capacity of the units when operating in pumping mode; and (2) provide the minimum and maximum hydraulic capacity of each of the pump-turbine units in both generation and pumping modes.	(1) The maximum hydraulic capacity for four-unit simultaneous pumping is 16,181 cfs (2) The pump-turbines are hydraulically identical. The four-unit minimum hydraulic capacity in Generate Mode is 12,280 cfs. The four-unit maximum hydraulic capacity in Generate Mode is 19,760 cfs. The four-unit minimum hydraulic capacity in Pump Mode is 12,500 cfs at maximum Total Head. The four-unit maximum hydraulic capacity in Pump Mode, as stated above, is 16,181 cfs at minimum Total Head. Pumping for a reversible single speed pump-turbine must occur at best wicket gate position for a given Total Head. The single unit minimum hydraulic capacity in Generate Mode is 3,070 cfs. The single unit maximum hydraulic capacity in Generate Mode is 4,940 cfs. The single-unit minimum hydraulic capacity in Pump Mode is 3,262 cfs. The single-unit maximum hydraulic capacity in Pump Mode is 4,164 cfs.
5. Clarify whether operation of the proposed Complex features, specifically use of the additional pump-turbine units, would result in any changes to the upper reservoir water surface fluctuation band.	The operating band of the Bad Creek upper reservoir will not change from existing conditions. Clarification has also been added in the Water Resources Proposed Study Plan.
6. Please describe any water quality monitoring that has occurred in Howard Creek or at the project discharge structure during the current license term, and if so, please file the data in Microsoft Excel, or a similar form.	Developing a summary of existing water quality information is an objective of the Water Resources Proposed Study Plan (Task 1). This summary will be included in the Initial Study Report.
7. Describe whether the Complex would result in lower water levels in Lake Jocassee compared to existing operation, and if so, please estimate the magnitude of any additional changes in water level.	The operating bands of the upper and lower reservoirs will not be modified under the new license; additionally, Duke Energy notes that the lower reservoir (Lake Jocassee) operating band is controlled by the Keowee-Toxaway Project license. Developing the information on water exchange is an objective of the operational models and evaluations to be completed and will be addressed through the Water Resources Proposed Study Plan (Task 4).

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8. Please clarify the land uses immediately adjacent to the main dam and confirm whether any cultivated crops or hay/pasture areas occur within the project boundary.	The 30-meter resolution National Landuse Cover Data interprets open areas as hay/pasture and/or cultivated crops. Aerial imagery confirms that 30-meter cells identified by the database as crops and/or hay/pasture are open areas associated with the West dam and East dam downstream faces (rip rap), maintained areas (mowed) around the former construction yard, maintenance areas, helicopter pad, and existing powerhouse complex. Figure 5-1 is provided below comparing the NLCD data vs. aerial imagery.

9. Please provide a detailed description of the management of native and non-native invasive vegetation (vegetation (i.e., any manual, mechanical, chemical, and/or biological) that occurs along project access roads, within the transmission line corridor right-of-way, the area surrounding upper reservoir, and adjacent to other project facilities. If herbicides are used to control vegetation within the project boundary, please provide the location(s), schedule(s), and method(s) of application (e.g., foliar and stump/stem/vine).	**<u>Transmission Line Right-of-Way Vegetation Management</u>**
	• 1J2672, 100kV from Jocassee Sup SW to Bad Creek Hydro (Corridors-Jocassee NW 1 & Oconee NW 1)
	• 5J2817, 525kV from Jocassee Tie to Bad Creek Hydro (Corridor-Jocassee NW 1) Transmission lines in Duke Energy Carolinas West (including the Bad Creek Pumped Storage Project Area) are managed using a "Corridor" concept. A Corridor is a collection of lines or segments of lines, often parallel, combined in a package to facilitate maintenance and herbicide being performed in an efficient manner. Some lines may have segments that lie in separate Corridors, which may mean separate maintenance and herbicide schedules. Below are details for each Corridor.
	• Jocassee NW 1 (1J2672 BP-#7, 1J2672 #13-EP & 5J2817 BP-EP)
	• Oconee NW 1 (1J2672 #7-13)
	    • Last maintenance cycle was 2008 prior to the implementation of Corridor concept. Both lines trimmed back to establish easement edge which is 34 feet from center on 100kV and 100 feet from center on 525kV. The 100kV would have had an additional 16 feet Danger Tree buffer established which removed all trees capable of falling within 10 feet of the conductor at that time. Both lines would have been assessed for Hazard Trees regardless of distance from center (dead, dying, diseased, leaning, structurally compromised).
	    • Lines have been inspected twice annually via aerial patrol. Lines have also been assessed using Lidar. Current records indicate that over the last three years we have had 5 Priority issues consisting of Grow-Ins, Dead Trees, High Brush and Leaning Trees. All defects have been completed.
	    • There are multiple access roads along the path of these lines. These roads were cleared during the maintenance project in 2008. Some have also been cleared periodically as work was needed since 2008 and to facilitate herbicide applications listed below. One access road stemming from Hwy. 130 has been cleared as recently as July 2022 to facilitate an upcoming patrol to be performed in Summer 2022.

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	• **Herbicide applications** are performed on a corridor basis. Details for each Corridor are provided below: • Jocassee NW 1 was last treated in full using a combination of Aerial and Backpack Herbicide in the summer of 2018. The full Corridor consists of 291 total acres. The aerial application focused on remote and rough terrain areas; 125 +/- acres were treated with aerial herbicide. The aerial blend used would have been a mix of Alligare MSO, Arsenal AC, Escort XP, Method and Trycera. This blend will target woody type vegetation, briars, vines and brush in general. The line was noted to have a high concentration of Bi-Color Lespedeza, Pine, Poplar and other native brush at this time. The backpack application focused on the remainder of the Corridor consisting of milder terrain, more accessible areas and road crossings. • Jocassee NW 1 also received an herbicide application in 2021, but not in full due to the successes of the 2018 aerial application. The aerial application in 2018 eliminated a large amount of brush type growth and helped to establish a large amount of desirable allelopathic type vegetation, such as native grasses, wildflower and herbaceous plants. As a result, a more detailed and customized approach was used in the herbicide planning. The result was 85+/- acres treated with aerial herbicide and 10+/- acres treated with backpack. The remainder of the corridor was designated a "No Work Required" due to either a lack of sufficient vegetation to justify herbicide application or natural topography placing the line so far off the ground that herbicide need not be considered. • Oconee NW 1, containing 1J2672 #7-13, was treated in 2019 and again this year in 2022 using the standard backpack application methods. This portion of 1J2672 lies in close proximity to homes, roads and other public use areas making aerial application methods less desirable. This backpack application method only focuses on woody type vegetation that can grow to become a threat to the line. Given the current state of the vegetation and the fact that Duke Energy transmission vegetation management saw a significant number of Grow-In defect defects reported during the last LiDAR flight, the plan is to have Jocassee NW 1 on the 2023-2024 Maintenance cycle. This upcoming maintenance cycle will address trees along the edges of the easement, trees that are growing close to the line and Danger/Hazard Trees that pose a threat to the line due to their potential to fall onto the line. Additionally, 5J2817 will be patrolled on foot as part of an upcoming 2022 inspection to be completed by October 31st, 2022. This patrol will focus on identifying vegetation that may be growing too close to line and Hazard Trees that could fall onto the line. The portion of 1J2672 lying within Oconee NW 1 will be delayed further as the other lines within that Corridor, have been maintained more recently and it currently is not under threat from vegetation issues. Upcoming herbicide applications will be based on

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	timing and need within the areas conducive to aerial applications. Backpack areas will be scheduled every 3 years as 3 years is the standard cycle for backpack applications. **Facility Vegetation Management** The following provides a detailed description of the management of native and non-native invasive vegetation that occurs along project access roads, the area surrounding upper reservoir, and adjacent to other project facilities. • **Access roads on site:** Duke Energy uses a combination of herbicides in these areas. For example, near guard rails a Roundup custom mix ("Glyphosate, N-(phosphonomethyl) glycine, in the form of isopropylamine salt) is used. It is applied with a spray boom attached to small equipment, so it is sprayed mechanically. Duke Energy uses a 2% mix spray which equates to about 2 quarts per acre. In other areas that Duke Energy only desires to control broadleaves, the herbicide Crossbow is used (2,4-dichlorophenoxyacetic acid, butoxethyl ester, Triclopyr BEE). This is applied using the same mix amount and the same mechanical application equipment. • **Reservoir areas**: Duke Energy also uses a Roundup custom mix on the roadways to access the dams as well as the roadways that access each bench on the dam. Duke Energy utilizes a contractor who applies herbicide with a drone on the abutment edges of the dam to prevent encroaching vegetation. Duke Energy also spot sprays the dam faces with the same mixture to control small trees and grasses as they try to pop up on the dam face. This mix is a combination of Roundup custom, Method (potassium salt of aminocyclopyrachlor) and Escort (metsulfuron methyl). It is the same "bare ground mix" used by Duke Energy's transmission department. This mix provides effective brush control as well as grass control since Duke Energy wants these areas to be vegetation free. The mix is applied at the rate of 2 quarts per acre. Duke Energy does not apply any herbicide in, or adjacent wet areas or streams. In the reservoir areas that have steep slopes along the roadways, Duke Energy utilizes the broadleaf selective herbicide Crossbow. It is applied with the machine at 2 quarts per acre.
10. Provide a detailed description of the Monarch Program, Duke Energy's role in this program as it relates to management and operation of the Bad Creek Project, and any measures that are currently implemented to protect monarchs at the project.	Regarding the nationwide Monarch Candidate Conservation Agreement with Assurances (Monarch CCAA), Duke Energy has enrolled 52,200 acres from transmission rights-of way (ROWs) and 10,189 acres from customer delivery ROWs, for a total of 62,389 acres. The business units covered by this agreement will be ensured updates and communication on activities, changes, and status. Within the Bad Creek Pumped Storage Project Area, there are no current Monarch CCAA locations for conservation and/or monitoring. The future enhancement of Monarch and pollinator habitat, within the project area, will be evaluated by the Wildlife & Botanical RC upon better understanding of the transmission project. These areas could then be enrolled into the CCAA acreage of protection.
11. The PAD does not include information about any	Duke Energy currently hold a Special Use Utility Permit (SPUT) with the USFWS-Region 4 (SE US).

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avian interactions that may have been observed with the project transmission line or switchyard (e.g., nest building, perching, electrocutions, collisions, and any outages related to such interactions). Please provide any available data regarding observed/documented avian interactions with the existing project transmission lines and switchyard. Include information about the configuration and maintenance of the project transmission lines and switchyard as they relate to avian protection. Please indicate whether the existing project transmission line poles and conductors are consistent with the Avian Power Line Interaction Committee (APLIC) and the U.S. Fish and Wildlife Service (FWS) guidelines to minimize adverse interactions (i.e., potential avian electrocutions and collisions) (APLIC, 2006 and 2012; and APLIC and FWS, 2005). Please provide detailed descriptions, figures, and/or diagrams of the design of the project transmission lines and any existing avian protection devices installed on them. If any avian protection measures are currently proposed for the existing or new transmission lines associated with the Complex, please provide the specifications and location(s)of these measures and a description of their consistency with APLIC guidelines, if applicable. If Duke Energy has an Avian Protection Plan for the Bad Creek Project, or for all of its hydropower projects that include transmission lines, please file a copy of the current plan.	With this permit, Duke Energy's EHS-Natural Resources department also runs an Avian Hotline that employees and staff can call to report avian interactions at our facilities and assets. In review of the annual SPUT report and our avian incident records, for the last three years, there have been no avian incidents (e.g., interactions, electrocutions, collisions) regarding the Bad Creek Pumped Storage facilities' transmission lines, distribution lines, or switchyard. The original designs of both the 100kV and 525kV transmission structure types, have conductor separation that offer avian protection for the largest birds in the Bad Creek Pumped Storage project area (i.e., bald eagles and turkey vultures). Thus, they are consistent with the Avian Power Line Interaction Committee (APLIC) and the U.S. Fish and Wildlife Service (FWS) guidelines to minimize adverse interactions (i.e., potential avian electrocutions and collisions). As mentioned above, Duke Energy has had no known incidents (i.e., electrocutions and collisions) as these facilities in at least the last three years. Duke Energy will evaluate what avian protection measures will be incorporated in the new transmission line design once a better understanding of the transmission line route is determined. Proposed design standards will be discussed with the Project's Wildlife and Botanical Resource Committee. A photograph depicting the steel lattice, Jocassee SUP SW-Bad Creek 100-kV and the Jocassee Tie to Bad Creek Hydro 525-kV is included as Figure 5-2 below. Duke Energy Carolinas identifies avian-friendly construction as 60 inches of spacing on horizontal structures and 36 inches of spacing for vertical structures, as found on the Bad Creek transmission lines. As requested, Duke Energy's (2020) Avian Protection Plan is including with this PSP filing (as Appendix J).

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12. Table 6.6-7 of the PAD provides a preliminary assessment of potential spoil locations and the estimated impacts to wetlands and surface waters. This table indicates that there are five locations that Duke Energy prefers for spoil disposal (i.e., areas A, B, F, G, and I) and four other locations with the potential for spoil disposal (i.e., C, D, E, and H). However, the PAD does not describe the criteria used to assess the potential spoil disposal areas or provide an explanation of why areas A, B, F, G, and I were selected as preferred locations as opposed to areas C, D, E, H, or other, off-site potential spoil disposal areas. Please file a detailed description of how the potential spoil disposal areas are being identified, sized, assessed, and selected as Duke Energy's preferred locations for this purpose. Please update table 6.6-7 to include a comparison of the estimated acreage of forested uplands and wetlands that would be removed, filled, or otherwise affected at each potential spoil disposal area.	As part of the Bad Creek II Power Complex Feasibility Study, an excavated materials disposal study was conducted to quantify the amount of spoil associated with the excavation and construction of the proposed project facilities. Determining the preliminary spoil areas on Duke Energy-owned property, size of areas, amount of spoil to be placed, and feasibility and costs associated with each were an objective of the Bad Creek II Feasibility Study. Several factors were considered as part of this material disposal study including, but not limited to: (1) site safety considerations; (2) environmental considerations; (3) proximity of spoil area to construction site and haul distance; (4) volume of spoil and spoil area ability to adequately accommodate and contain; (5) previously utilized spoil areas, (6) topography, (7) logistics and costs. Offsite spoil locations were not considered during this phase of the study. Several of the areas evaluated were not selected as "preferred" by Duke Energy for several reasons including low volume area capacity, environmental and safety concerns, or access difficulties. A detailed ranking analysis of each identified sites was not performed as part of the Bad Creek II Feasibility Study. Not that Site H should be considered as a "preferred" site and Table 6.6-7 Table of the PAD has been updated (below as Table 5-2) to the reflect this status. Additionally, the estimated impacts table has been updated per FERC's request to include acreage of impacted forested uplands and is included in Table 5-2 below. An excavated materials disposal study was conducted to quantify the amount of spoil associated with the construction of the proposed project facilities. Table 5-3 provides estimated excavation and spoil quantities for the power complex elements including the upper reservoir I/O area, water conveyance tunnels and shafts, powerhouse and access tunnels/shafts, various construction adits, and lower reservoir I/O area and the assumed spoil locations. Figure 5-3 includes the potential spoil area locations.

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13a. The PAD indicates (Section 6.7.1.1.1 and 6.7.1.1.2) one small cave/den identified in the Project boundary that could be used as winter hibernacula for Indiana or northern long-eared bat, but cannot find any details regarding this cave/den in the PAD or the bat survey. (1) provide a written description of the cave/den including a general location within the project boundary, size, and the estimated proximity to the existing and proposed project facilities, as well as current project operation and maintenance activities; (2) clarify whether the cave/den was surveyed during Duke Energy's 2021 field surveys; and (3) describe any bats or signs of bats that were observed, if applicable.	Upon further assessment, the cave/den that was identified in the PAD could more accurately be described as areas of rock outcrops, crevices, or overhangs. While these areas could still provide potential habitat for bats, there are no definable surface openings in the rockface associated with these areas. A representative photo/example is included in Figure 5-4 below.
13b. Also, it is not clear what, if any, practices Duke Energy currently implements to benefit Indiana and northern long-eared bats. It also is not clear if Duke Energy currently consults FWS prior to tree clearing activities, or if that is strictly a proposal for relicensing with or without the Complex. Please provide a description of any measures that are currently implemented to protect Indiana and northern long-eared bats and/or other bat species at the project, if any. In addition, please note that if the Complex is ultimately proposed as part of the relicensing process, additional information will be needed in the license application regarding the number of trees that would be removed or disturbed during project construction, operation, and maintenance.	The current Duke Energy process for tree cutting in areas that have known documentation of listed bats (e.g., Indiana bat, Northern Long-eared bat) is as follows: The internal tree-cutting project manager (e.g., Bad Creek Pumped Storage facility) contacts Duke Energy's EHS-Natural Resource group (EHS-NR) to conduct a review of the tree cutting or trimming. EHS-NR requests information such as the project description, schedule of activities, type of cutting/trimming equipment, and a activity-specific map. The review includes determining the association of the proposed activity with known and documented occurrences of listed bats (through Duke Energy's Natural Resources GIS Viewer), a known or potential bat roosting habitat review, and possible coordination with the pertinent USFWS-Ecological Field Office. Duke Energy incorporates the following listed bat Best Management Practices regarding tree cutting and trimming: • No potential roost trees shall be cut during the moratorium period of April 1st to October 15th. Roosts trees are identified as any live tree or snag > 5 inches diameter (measured at 4.5 feet above ground) with any cracks, crevices, hollows, and/or exfoliating bark. • Potential roost trees will be marked with blue color paint and a 15-foot buffer set with blue flagging. Any hazard/danger tree within the buffer will also be marked with blue paint. No potential roost trees or trees within the buffer shall be cut during the period of April 1st and October 15th. • GPS Coordinates as well as tree location and description will be recorded. (span #, east/west side of line, dead, live, species etc.)

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	• If a potential roost tree is present that needs to be cut during the tree cutting restriction season (i.e., imminent threat tree), an assessment by a Duke Energy biologist/scientist, can be conducted to determine if bats may be present. • The air temperature must exceed 50 degrees F before cutting/trimming work can take place. • All trees shall be tapped on /knocked on/sounded (with mallet or similar device) before climbing/cutting. • All work shall be immediately stopped if bats are noticed in the project area and Duke Energy Vegetation Management Specialist shall be contacted for further direction. • No aerial saw operations will occur without the approval of Duke Energy and the USFWS.
14. Please clarify whether or not Duke Energy intends to evaluate improvements to the Foothills Trail (including additional parking areas or trailheads) as part of the project's relicensing.	Duke Energy plans to evaluate the 43-mile portion of the Foothills Trail during the trail condition assessment and Recreation Use and Needs studies as part of the relicensing (Recreation Proposed Study Plan).
15. Describe how construction of the Complex would affect access to or use of access roads, parking areas, or trailheads associated with the Foothills Trail. Please also discuss construction-relate effects to the trail itself and trail users, including changes in quality of the recreation experience during construction. Provide a discussion of the timing and duration of any effects in relation to the recreation season and the trail's peak use periods.	Developing this information is one objective of the Recreational Resources Study (Recreation Use and Needs Study task), and results will be included in the Initial Study Report.
16. Provide a description of the anticipated effects of construction on noise (including frequency, duration, and level in decibels), air quality (including airborne debris and dust, as well as heavy vehicle emissions), and traffic (including proposed routes for heavy equipment used for construction or spoil disposal,	Duke Energy understands the requested information may be required to support FERC's preparation of a future Environmental Assessment or Environmental Impact Statement and anticipates including the requested evaluation and information in the draft and final license applications. Duke Energy has not yet advanced the design or plans for the potential Bad Creek II Complex to the extent that such evaluations can be performed at this early stage.
17. Prepare an Environmental Justice Report	The requested Environmental Justice Study is included in this Proposed Study Plan.

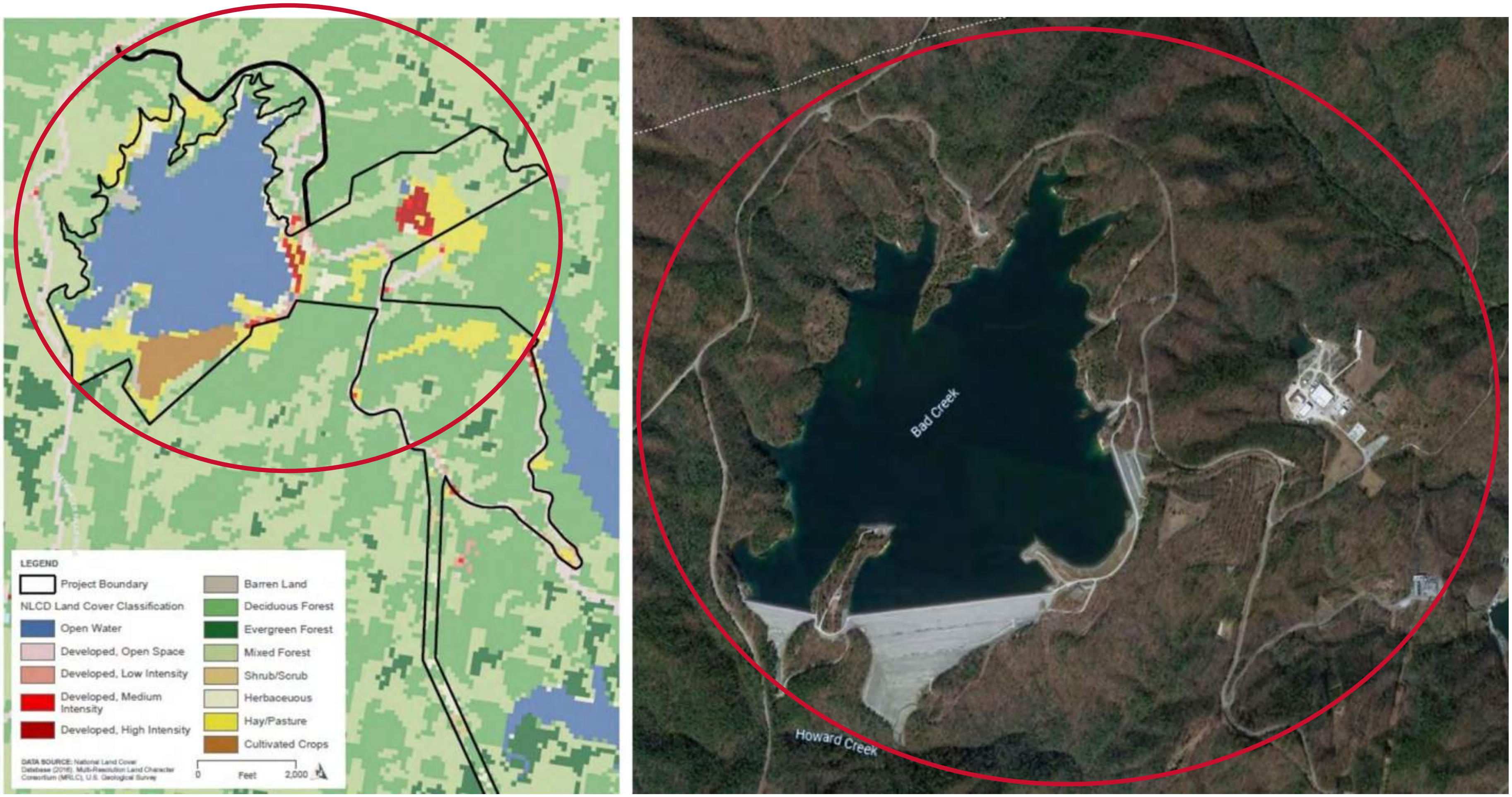

Figure 5-1. Comparison of National Landcover Use Data (30-meter) and Recent Aerial Imagery of the Project Site

Figure 5-2. Steel lattice, Jocassee Set-up SW-Bad Creek 100-kV (left side of ROW) and the Jocassee Tie to Bad Creek Hydro 525-kV (right side of ROW)

Table 5-2. Estimated Impacts to Water Resources by Potential Spoil Location (Updated)

Spoil Area ID	Spoil Area (Acres)	Spoil Area Capacity (Million Cubic Yards)	Impacted Streams	Estimated Stream Impact Length (linear feet)	Estimated Wetlands Impacted	Wetland Impact Areas (acres)	Open Waters Impacted	Open Water Impact Amounts (acres)	Estimated Upland Forested Areas (acres)
A*+	13.90	1.3	0	0	0	0	Lake Jocassee	13.90	0
B*	26.30	1.3	19 P, 20 P, 21 P	1,865	0	0	0	0	24.56
C	9.55	0.7	17 P	286	0	0	0	0	8.84
D	12.48	1.3	13 I, 14 P	996	0	0	0	0	12.32
E	6.16	0.16	0	0	10 N	2.96	0	0	3.20
F*	10.72	0.25	0	0	4 N, 7 N	1.52	0	0	3.93
G*	10.46	1.1	4 I, 4a P	1,484	0	0	0	0	10.03
H*	19.26	1.5	0	0	0	0	Bad Creek Reservoir	19.26	0
I*	3.55	1.1	0	0	0	0	0	0	3.56

*Duke Energy Preferred Spoil Area
P Perennial
I Intermittent
N Isolated Wetlands created by Duke Energy, would not be federally regulated or require mitigation
+ Spoil Area A includes spoil placement along the existing submerged weir in Lake Jocassee

Table 5-3. Estimated Excavation and Spoil Quantities for the Bad Creek II Complex Elements

Upper Reservoir I/O Area	Excavation (CY)		Total Excavation	Spoil - 25% Swell (CY)		Assumed Spoil Location
	Earth	Rock				
Create I/O and Gate Shaft Yard Area - Earth	335,000		335,000	418,750	1,072,500	Approximately 0.1 million cubic yards deposited first in Spoil Area I (to create additional yard area near the upper reservoir I/O) and the remaining 1 million cubic yards deposited in Spoil Area G.
Create I/O and Gate Shaft Yard Area - Rock		31,000	31,000	38,750		
I/O Sinking Cut - Earth	90,000		90,000	112,500		
I/O Sinking Cut - Rock		402,000	402,000	502,500		
Channel Excavation Earth	7,000		7,000	8,750	921,250	Approx. 0.9 million cubic yards excavated in the dry (upper reservoir dewatered) and deposited in upper reservoir quarry (Spoil Area H) below elevation 2080.
Channel Excavation Rock		730,000	730,000	912,500		
Subtotal	**432,000**	**1,163,000**	**1,595,000**	**1,993,750**		
Note 1: Total cubic yards (cy) of cut between El 2,150 and 2,310 ft msl	27,000	630,000	657,000			Note: Creates approximately 15 additional ac-ft of Upper Reservoir active storage
Low Pressure Headrace Tunnels and Areas						
Isolation Gate Shafts	7,184	23,603	30,787	38,484	233,796	Assumed to be spoiled in upper northeast tiers of the existing Construction Yard (Spoil Area F) via a construction adit that extends from the lower pressure tunnel/vertical shaft interface to the construction yard.
Construction Adit (L=1,820 LR)		29,727	29,727	37,159		
Construction Adit Portal Area	5,000	5,000	10,000	12,500		
Low Pressure Headrace Tunnels		88,277	88,277	110,346		
Vertical Construction Shafts (upper bend to surface)	6,725	21,521	28,246	35,308		
Subtotal	**18,909**	**168,128**	**187,037**	**233,796**		
Power Complex Vertical Shaft - Tailrace Tunnels						
Vertical Shafts		50,776	50,776	63,470	1,030,416	Assumed to be deposited on the downstream face of the existing underwater weir (Spoil Area A) via bottom dump barges. Spoil Area B is designated as a backup upland spoil area.
Bends (2) - Allocation		5,000	5,000	6,250		
High Pressure Headrace Tunnels		194,399	194,399	242,999		
High Pressure Headrace Tunnels Construction Bypass Adit		19,829	19,829	24,786		
Penstocks		14,106	14,106	17,633		
Penstocks (at PH)		1,876	1,876	2,345		
Penstock Drainage Tunnel		7,009	7,009	8,761		
Powerhouse Main Access Tunnel		46,306	46,306	57,883		
Powerhouse Cavern		200,000	200,000	250,000		
Vertical Access Shaft (to Transformer Yard)		79,065	79,065	98,831		
Draft Tube Gate and Access Gallery Tunnel		19,700	19,700	24,625		
Draft Tube Tunnels		19,777	19,777	24,721		
Draft Tube Gate Annex		3,880	3,880	4,850		

Upper Reservoir I/O Area	**Excavation (CY)**		**Total Excavation**	**Spoil - 25% Swell (CY)**		**Assumed Spoil Location**
	Earth	**Rock**				
Draft Tube Gate Shafts		4,622	4,622	5,778		
Variable Speed Elec Equipment Gallery		11,000	11,000	13,750		
Tailrace Tunnel Construction Adit		15,017	15,017	18,771		
Tailrace Tunnels		108,341	108,341	135,426		
Tailrace Tunnels at Lower Reservoir I/O		23,630	23,630	29,538		
Subtotal	**0**	**824,333**	**824,333**	**1,030,416**		
Lower Reservoir I/O Area						
Yard Excavation - Earth	118,000		118,000	147,500	541,250	Assumed to be deposited in Upland Spoil Areas B with C and/or D as a backup.
Yard Excavation - Rock		18,000	18,000	22,500		
I/O Sinking Cut - Earth	90,000		90,000	112,500		
I/O Sinking Cut - Rock		21,000	21,000	26,250		
Cofferdam Excavation and Channel Construction - Earth	177,000		177,000	221,250		
Cofferdam Excavation and Channel Construction - Rock		9,000	9,000	11,250		
Subtotal	**385,000**	**48,000**	**433,000**	**541,250**		
Total Feasibility Study Quantities	**835,909**	**2,203,461**	**3,039,370**	**3,799,213**		

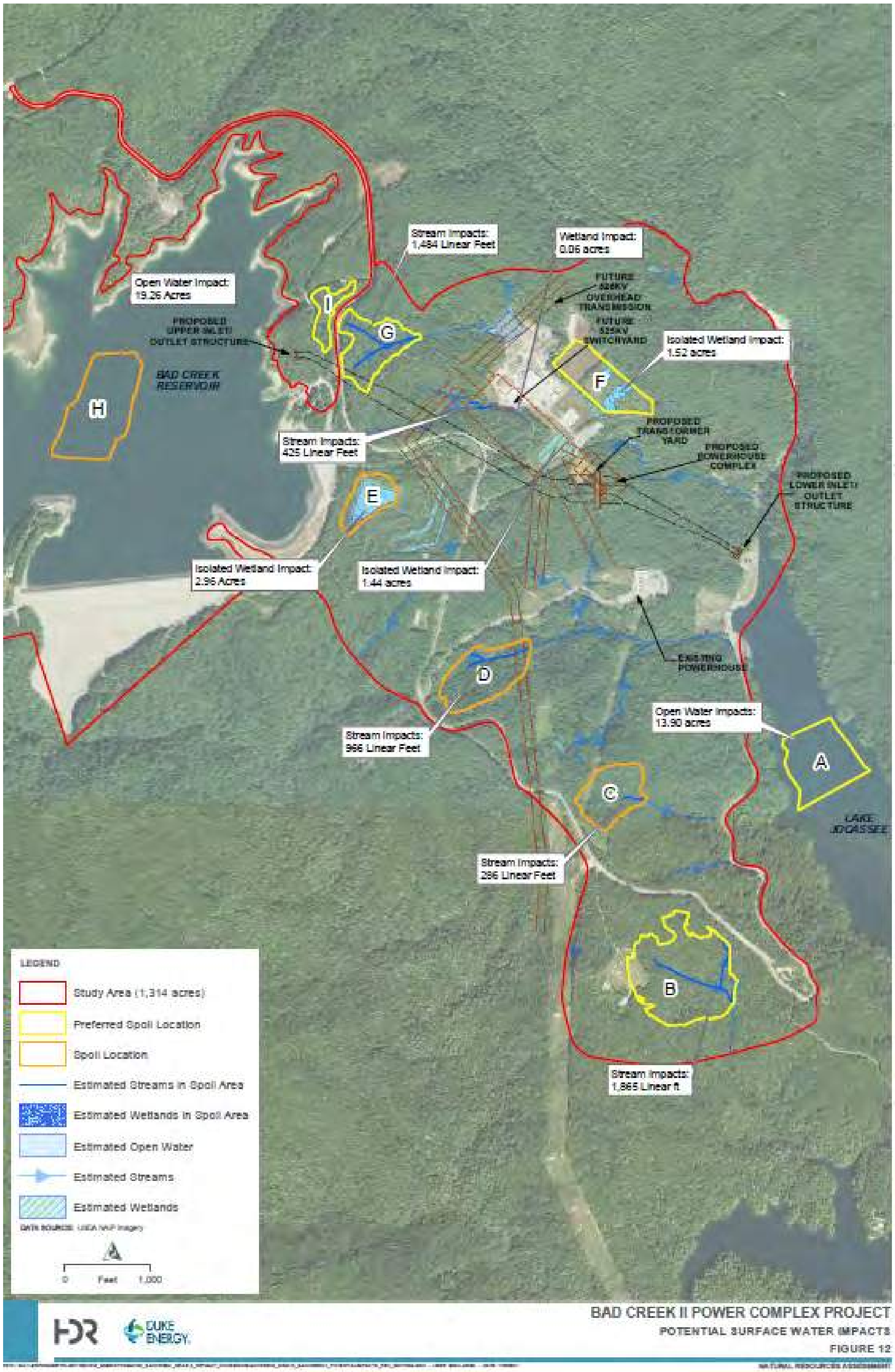

Figure 5-3. Proposed Spoil Locations

Figure 5-4. Representative Area of Outcrop Overhang at the Bad Creek Project

Appendix A

Appendix A – Stakeholder Comment Summary

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Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
1	Project Infrastructure/ Operations	**1.** Study request to address "Emergency Preparedness" during construction due to remote location of site and nearby homes. One project access road, Bad Creek Road, with no other road egress or exit to 21 home sites. If a life safety emergency , such as fire or complications due to excavation (project involves excavation and thousands of feet of underground work) occurs which prevents road usage then home owners are trapped. Suggest a temporary rough cut secondary access road with possible later usage for recreation. Project should study impact / benefit of adding an emergency services boat and dock to address fire and life safety during construction and operation due to the remote nature and potential hazards. Project should study impact / benefit of supporting the addition of another, closer,Fire House on Highway 130 / 281 coming from the Toxaway , NC side of the Bad Creek project to address response time, due to remote location and likelihood of the need for emergency, such as fire and life safety issues. Study should include issues with emergency communications plans with home owners (due to only one access road in and out).	Fishers Knob Homeowners	May 17 2022	Because this study request does not satisfy the Integrated Licensing Process (ILP) study criteria, it is considered a comment. Duke Energy expects that emergency response and preparedness and public safety measures through construction would be addressed through construction plans to be submitted to the FERC Division of Dam Safety and Inspections following issuance of the new license and prior to commencement of construction. Stakeholder comment periods and consultation throughout the ILP provide opportunities for concerns and potential protection, mitigation, and enhancement measures to be raised to Duke Energy and the Commission, and Duke Energy intends to identify and develop appropriate communication plans and measures to reduce or mitigate construction impacts in consultation with relicensing stakeholders.
2	Project Infrastructure/ Operations	**1.** Current discrepancies in project infrastructure descriptions and capacity between Scoping Document 1 (SD1), Pre-Application Document (PAD), and the Original License should be corrected or more fully explained if conditions have been modified since the approval of the Original License. Also clarify impacts from construction and new powerhouse and how mitigation will be addressed to address impacts beyond that expected in the original license. This comment includes two associated sub-parts (1a and 1b); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Duke Energy notes that it is not unusual for as-built versus originally authorized or proposed dimensions of project structures to vary for a hydropower project, particularly one the scale of Bad Creek. Duke Energy is not aware of any discrepancies that would materially affect natural resource impacts previously assessed by FERC. The relicensing process, inclusive of development of the Draft and Final License Application, provides an opportunity to provide updated Project information to the Commission. With respect to impacts of the recent and ongoing powerhouse upgrades, these upgrades were authorized by, and subject to environmental review by FERC and agencies for, FERC's August 6, 2018 Order Amending License, Revising Project Description and Annual Charges, and Approving Revised Exhibit M. Duke Energy is providing additional details and clarifications about existing Project structures in this PSP in response to comments from FERC and stakeholders, including the following: - The Bad Creek reservoir size (from the original license and as cited in Section 6.3.1.1) is correctly stated at 318 acres with storage of 33,323 acre-feet. This number is based on the original reservoir storage curves developed for the project. The 363-acre value is based on LiDAR data collected by Duke Energy in 2018, when the upper reservoir was fully drawn down. This data is of higher resolution and is used as the surface area size throughout the PAD. The 367-acre estimate is from 1992 Licensing as-built data, as described in the text on page 6-50 of the PAD and in Table 6.3-1 "Usable Storage Summary", which includes a list of all data sources and previously stated values for acres of the Bad Creek Reservoir since 1974.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
3	Aquatic Resources, Recreation	**2.** Requirements of separate FERC-licensed projects should be kept separate. Recreation provided under a separate FERC License should not count toward the recreational opportunities provided by the Bad Creek License. Several sections of the PAD include discussion about the Keowee-Toxaway (KT) Project; however, this information is not necessarily relevant as the Bad Creek Pumped Storage Project (P-2740) operates under a separate FERC License from the KT Project (P-2503). In several instances the information provided confuses the conversation as it is unclear how the KT Relicensing Agreement relates to the Bad Creek original Project construction or ongoing Project operation. This comment includes two associated sub-parts (2a and 2b); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Duke Energy agrees that mitigation for the Keowee-Toxaway Project is not intended to meet the requirements for the separate and distinct impacts from the Bad Creek Project, but that protection, mitigation, and enhancement measures in place for Lake Jocassee as required by the Keowee-Toxaway Project also benefit the Bad Creek Project. The 10-Year Work Plans, work plan summaries, and approved modifications, as well as the 2013 KT License Agreement are attached to the Aquatic Resources Study Plan for clarity on which mitigation activities are covered under each relicensing. The Recreational Resources Study includes plans to conduct a RUN study and will include the 43-mile-long Foothills Trail Corridor.
4	Recreation	**3.** Recreation requirements of the Original License should be accurately and comprehensively discussed. Due to the unusual nature of this project, with no recreational access to the Reservoir allowed, the Recreation component of the Original License was provided entirely by constructing and maintaining the 43-mile center section of the nearby Foothills Trail. A full description of the Trail (including reference to Exhibit R) should be included in discussions regarding protection, mitigation, and enhancement (PM&E) measures and comprehensive information about the Trail infrastructure, construction, and maintenance should be provided. This comment includes four associated sub-parts (3a through 3d); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	The Recreation Use and Needs Study (a task of the Recreational Resources Study) will identify facilities required by the Bad Creek Exhibit R and assess the current condition of the facilities and amenities of the Duke Energy managed access locations to the Foothills Trail. The trail and corridor conditions and potential maintenance needs will be assessed through a Foothills Trail Condition Assessment. Duke Energy acknowledges that the public uses Bad Creek Road to access public parking lot, Foothills Trail kiosk, and a spur trail providing access to the Foothills Trail and to the Lower Whitewater Falls scenic viewpoint; these components of public access will be labeled on a revised map to be included in the Recreational Resources Report and Draft License Application.
5	Recreation	**4.** Provide a summary of completed recreation-related projects. Duke should provide comprehensive information regarding fulfillment of the Original License Exhibit R; including a map and complete inventory of infrastructure and appurtenances, construction and maintenance costs, and current conditions of these features throughout the 43-mile section of Trail. This comment includes four associated sub-parts (4a through 4d); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	A comprehensive map of the Foothills Trail will be included in the Recreational Resources Study report showing trail corridor, available parcel information, and Duke Energy maintained access points. Major points of maintenance interest along the trail will be identified during the trail assessment including corridor, trail surface and structure concerns, however the report may not identify all minor constructed structures such as stairs. Duke Energy does not propose to acquire additional easements for the Foothills Trail Corridor as trail expansion is not currently proposed. As noted above, condition assessment of the trail maintained by Duke Energy will be assessed as part of this study. Duke Energy does not propose to conduct a vegetation or hemlock survey as part of the Recreational Resources Study and does not believe there to be a nexus between this resource issue and Project operations to support an ILP study.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
6	Water Resources	**5.** Federal and state protections apply to Waters of the US regardless of modification, land ownership, or use of water. As both Waters of the US (WOTUS) and Waters of the State (WoS), the Bad Creek Reservoir and streams/wetlands present within the proposed Project Boundary are subject to federal and state regulations. Wording throughout the documents should be corrected to indicate that regulations, such as water quality standards, do apply. Additionally, monitoring should be conducted to evaluate existing impacts and assess potential future impacts. This comment includes five associated sub-parts (5a through 5e); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Duke Energy is not aware of any state or federally regulated water classifications or designations assigned to the upper reservoir; however, the upper reservoir could potentially be considered Waters of the U.S. or Waters of the State according to the Pre-2015 Regulatory Definition and Practice. Duke Energy further notes that the definition of WOTUS is currently in flux. As described in the Water Resources Study, to characterize baseline conditions and assess potential water quality impacts, Duke Energy will undertake water quality monitoring (continuous temperature and bi-weekly DO) at three historic monitoring sites in the Whitewater River arm of Lake Jocassee in 2023 (two-unit powerhouse operation) and 2024 (four-unit powerhouse operation, with all ongoing upgrades complete). Monitoring is not useful in the Bad Creek upper reservoir due to significant daily water fluctuations. Upland waters and impacts to upland streams and wetlands will be considered under the future Water Quality Monitoring Plan under the Water Resources Study.
7	Multiple resources	**6.** Natural resources located within the Project Boundary continue to be protected under regulations; current conditions should be fully evaluated and discussed. This comment includes three associated sub-parts (6a through 6c); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Comments noted. Impacts to natural resources associated with construction and operation of the new powerhouse in the project area will be assessed throughout the licensing study. Duke Energy plans to provide in the license application and supporting documents information required by FERC and other regulatory entities, and relevant to the construction and operation of the expanded Project in the new license term.
8	Recreation	**7.** Current conditions should be evaluated throughout the Trail corridor. A comprehensive evaluation of existing resources and potential impacts of current and ongoing operations, including current upgrades, to Project-related recreation (i.e., the 43-mile section of Trail and appurtenances constructed and maintained by Duke) should be included. This comment includes three associated sub-parts (7a through 7c); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Foothills Trail surface and corridor conditions such as notable erosion (specific to the area within the Duke Energy easement area) will be assessed through a Foothills Trail Condition Assessment as part of the Recreational Resources Study. This study will identify any current outstanding maintenance needs. Need for additional facilities associated with trail use such as restrooms will be evaluated as part of the Recreation Use and Needs Study. Duke Energy does not propose to study vegetation or hemlock populations along the Foothills Trail Corridor as trail maintenance concerns will be addressed in assessment. The possible construction of the Bad Creek II Complex would not have direct impact on vegetation condition throughout the trail corridor. Vegetation outside of the 200-ft Duke Energy trail corridor easement will not be studied as there is not a direct nexus to the Project and lands outside the easement are not owned or controlled by Duke Energy.
9	Recreation	**8.** Proposed PM&E should be clear and consistent. Discrepancies between SD1 and the PAD create confusion on Duke's future intent regarding the Trail; these documents should be clear and consistent. With no consideration of recreation at the Reservoir and recreational access on Lake Jocassee provided by the separate KT License, the Foothills Trail should be the focus of recreational requirements of the New License. This comment includes three associated sub-parts (8a through 8c); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	The Recreation Use and Needs Study and Draft and Final License Application will provide clarifying language of the Foothills Trail nexus to the current license and subsequent renewal. Duke Energy intends to continue to ensure for the management of the 43-mile trail segment currently under its management purview. Continued operation of the existing Bad Creek Project will not increase use of the Foothills Trail or neighboring recreational resources, and no expansion of the trail corridor is currently proposed. Use and needs of the existing facilities will be evaluated and additional needs related to recreational use of the trail and associated facilities will be identified.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
10	Recreation	**9.** The RUN Study should be expanded. The proposed Recreational Use and Needs (RUN) Study should be comprehensive and specifically for recreation related to the Bad Creek Project. This comment includes five associated sub-parts (9a through 9e); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Addressed in the Recreation Use and Needs Study (task of the Recreational Resources Study). Expansion of the trail corridor is not proposed for the continued operation of the existing Bad Creek Project. All Duke Energy managed land and water access to the Foothills Trail will be addressed in the RUN Study. Duke Energy Ventures is a wholly owned subsidiary of Duke Energy Corporation that holds property that may be needed in the future to meet electric customer needs.
11	Multiple resources	**10.** Expanded information should be included in some sections to provide a more accurate, updated, and comprehensive understanding of conditions. This comment includes three associated sub-parts (10a through 9c); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Duke Energy plans to provide in the Draft and Final License Application and supporting documents information required by FERC and other regulatory entities to support their environmental review processes and required permits and approvals, and relevant to the construction and operation of the expanded Project in the New License term. Expanded information on socioeconomics, climate, and geology, and recreation will be included in relevant sections of the Study Reports and Draft and Final License Application.
12	Multiple resources	**11.** Construction of the Complex should require additional evaluation and PM&E measures. The proposed Bad Creek Complex II Expansion would double the already upgraded capacity of the Bad Creek Project. A complete analysis of permanent and temporary construction impacts and potential introduction/expansion of invasive species should be thoroughly evaluated and additional PM&E, including expanded recreational requirements, should be required. This comment includes eight associated sub-parts (11a through 11h); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Comment noted by Duke Energy. Impacts of Bad Creek II Complex construction/expansion will be assessed throughout the relicensing, and appropriate protection, mitigation, and enhancement measures will be identified and evaluated in consultation with stakeholder and proposed in the Draft and Final License Application.
13	Project Infrastructure/ Operations	**12.** The proposed Project Boundary should be expanded to include all Project related infrastructure. This comment includes three associated sub-parts (12a through 12c); the full comment is included in Appendix B.	Foothills Trail Conservancy	June 23 2022	Duke Energy intends to identify a new project boundary in the Draft and Final License application that would include all lands necessary for access to, or control of, the existing and expanded Project facilities. Duke Energy proposes that the Foothills Trail (portion of the trail presently maintained by Duke Energy) be treated as a non-Project facility in the new License, and does not expect to propose significant expansion of the Project boundary to encompass this facility. Duke Energy is committed to working with stakeholders to identify appropriate enhancements and management measures and responsibilities for this portion of the Foothills Trail in the New License term.
14	General	**13a**. The Foothills Trail Conservancy contact information should be updated in the Bad Creek Pumped Storage Project (FERC No. 2740) Distribution List (included in NOI and PAD Appendix A), to the following: Andrew Gleason Chairman, Board of Directors Foothills Trail Conservancy andrewandwilla@hotmail.com Dr. Bill Ranson Member, Board of Directors Foothills Trail Conservancy bill.ranson@retiree.furman.edu Glenn Hilliard Founder and Advisor Foothills Trail Conservancy glenn@hilliardgroup.com	Foothills Trail Conservancy		The requested contacts have been added to the Project distribution list.
15	Recreation	**13b.** SD1 Section 8.0 (page 21-23) should include the most current version of Comprehensive Plans; for example, the list includes the SC State Comprehensive Outdoor Recreation Plan (SCORP) from 2008, but the SCORP was updated in 2019 and is available online https://p.widencdn.net/bzuwqi/2019-South-Carolina-SCORP-FINAL.	Foothills Trail Conservancy		The Recreation Use and Needs Study (task of the Recreational Resources Study) will utilize the most updated SC State Comprehensive Outdoor Recreation Plan as noted.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
16	General	**13c**. PAD Section 4.4.1 (Maintenance of Public Website) – Duke commits to maintaining a public Project website during the course of the licensing process. To assist stakeholders and the general public with understanding Duke's compliance with the Licensing Agreements, we recommend maintaining this website (including compliance reports) into the future.	Foothills Trail Conservancy		Duke Energy is committed to transparent communications with stakeholders throughout Project lifecycles and anticipates using the public website or similar medium to communicate project status and updates, and resources associated with the Project, into the new license term.
17	Recreation	**13d.** PAD Section 6.8.1.1 (FERC-Approved Recreation Facilities at the Project) states that "Prior to the construction of the Project, the first portion of the Foothills Trail was built linking Table Rock State Park to Oconee State Park." This wording is confusing and could be misunderstood that the first portion of the Trail connected Table Rock State Park to Oconee State Park. In fact, Table Rock State Park and Oconee State Park represent the current end points – and the section between is the entire 77-mile Foothills Trail, including the 43-mile central section Duke constructed and continues to maintain. This section should be clarified to accurately describe the initial section built prior to construction of the Bad Creek Project.	Foothills Trail Conservancy	June 23 2022	The requested information and clarification will be provided in the Recreational Resources Study report.
18	General	**1.** At this time, we have no issues or concerns with the proposed relicensing of the Bad Creek Pumped Storage Project or with the ILP for a new license for the Bad Creek Pumped Storage Complex II. The studies identified for the environmental assessment for the Bad Creek Pumped Storage Complex II appear to cover the areas of major concern for FOLKS and our members. We look forward to working with the study groups, FERC, Duke Energy, and others throughout the process to meet our collective goals of supplying clean and green energy to the grid.	Friends of Lake Keowee	June 22 2022	Comment noted; no response required.
19	Aquatic Resources	**1.** This section describes the Project's existing lower reservoir inlet/outlet structure and references steel trash racks. The SCDNR requests information regarding the dimensions and bar spacing of the existing trash rack structure to better understand the Project's impact on aquatic species.	SCDNR	June 23 2022	The discharge structure splits the two existing discharge tunnels into two parts. The two arched tunnels have splitter walls creating four openings convey the water. Each half arch section has two steel racks (upper and lower). The lower portion is rectangular (16.25' high x 18.25' wide); the upper portion has a rectangular bottom and arched top. The bottom width is 18.25' wide. The short side is 9.25' high; the tall side is 16.25' high. The radius of the arch is 32'-4". There are 34 spaces at 6" spacing, on-center, for a flow area of 17' with this spacing (the sides are slightly smaller because of the trashrack frame).
20	Water Resources	**2.** This section describes a submerged weir located 550 meters downstream of the Project inlet/outlet structure on the lower reservoir. According to the PAD, the weir's location in the Whitewater River cove serves to dissipate the energy of the discharged water and minimize the effects of warm water from Bad Creek's upper reservoir warm water, by preventing the water from mixing with the lower cool-water layers of Lake Jocassee. The weir was constructed out of nearly half a million cubic yards of rock excavated during the construction of the Project. The SCDNR requests information regarding 1) the dimensions of the weir (feet), 2) how the Licensee inspects the weir to ensure the weir continues to function as designed, 3) the frequency of inspections, and 4) information on any maintenance that has occurred.(PAD section 5.4.5). The SCDNR requests further information regarding why the spoil should be added to the weir and how the Licensee selected the downstream slope of the weir. Additionally, since the submerged weir is located 40-50 feet below the water surface, how will the Licensee ensure the correct placement of the spoil and avoid excess turbidity and aquatic habitat degradation during deployment?	SCDNR	June 23 2022	Existing Weir: Width = 567 ft Length = 455 ft Proposed Weir: Width = 864 ft Length = 765 ft The submerged weir is located approximately 550 meters downstream of the Project discharge and was originally constructed to help minimize the effects of mixing downstream of the Whitewater River arm of Lake Jocassee; it has not been modified since the original construction. The weir is composed of rockfill (i.e., spoil from the original Project construction). The weir is not enclosed in the existing FERC Project Boundary for Bad Creek but is included in the Project Boundary for the Keowee-Toxaway Project (Lake Jocassee). If the Bad Creek II Complex is constructed, the weir may be expanded to help mitigate the effects of a second discharge in the Whitewater River arm. Duke Energy is presently evaluating if and how the underwater weir would be required to be included in the Project boundary for the Bad Creek Project in the New License term. The existing weir is not directly inspected but has been subjected to detailed bathymetric survey, and Duke Energy expects that bathymetric survey methods may also be used to verify expanded weir dimensions. Rockfill would be placed on the downstream side as there is sufficient space to accommodate the volume. The turbidity/water quality/aquatic impacts potentially associated with rockfill placement to expand the weir will be assessed as part of the Water Resources Study Plan.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
21	Project Infrastructure/ Operations	**3.** This section notes that the Licensee currently operates the Project on a "daily cycle" mode, defined as alternating between generating and pumping on a daily basis, with the reservoir typically maintained in the upper 50 to 60 ft at elevations of 2,310 and 2,250 ft msl (compared to a maximum drawdown of 160 ft). However, the PAD does not discuss how the Licensee intends to operate the Project during a subsequent license term with the addition of the proposed Complex. The SCDNR requests further information with regards to the Licensee's proposed operations at the Project including the frequency and magnitude of drawing down and refilling the Bad Creek's upper reservoir.	SCDNR	June 23 2022	With the addition of the Bad Creek II Complex, energy generation will increase but so will pumping input power requirements. The increase in generation per drawdown is estimated to be 244 MWh per cycle. The full drawdown of the reservoir will require approximately 11.5 hours with both Bad Creek I and II operating. Without the Bad Creek II Complex operating, the drawdown would require approximately 23 hours. The addition of Bad Creek II will introduce more capacity and generation into the power grid during a shorter period of time. The design of the equipment will likely be such that pumping power input may be varied which will allow better utilization of renewable energy flow into the power grid. As operation of the existing Project has evolved (within the authorized limits) over the license term to adapt to changing needs of the regional grid and energy generation sources, so too may operation of the expanded Project over the new license term. To maximize benefits of the Project for its ratepayers and shareholders, Duke Energy will be seeking to preserve flexibility to continue to operate the Bad Creek Project within the parameters to be established by the new license. To illustrate how the Bad Creek II Complex may modify existing Project operations, Duke Energy expects a variety of operating scenarios to be identified and presented to the Operations Resource Committee stakeholder team convened for this relicensing. Further, Duke Energy anticipates addressing within other respective Resource Committees (i.e. Water Quality, Recreation, etc.) how the identified operational scenarios may impact environmental resources at the Project.
22	Aquatic Resources	**4.** This section discusses the design specifications of the Licensee's proposed Complex. The details included in the upper reservoir's inlet/outlet configuration includes a coarse opening trash rack at each tunnel inlet. However, further specifications of the trash racks, including the bar spacing is not included. Additionally, no such trash rack feature was included in the proposed lower reservoir's inlet/outlet structure configuration. The SCDNR requests the additional information to better understand the Project's effects on aquatic species.	SCDNR	June 23 2022	Design of the proposed inlet/outlet structure for Bad Creek II Complex is not finalized, therefore these specifications are not available at this time. Duke Energy expects these design details will be available during the study execution phase of relicensing in 2023-2024. This information will be provided to and discussed with, including potential effects on aquatic resources, the Aquatics Resource Committee members well in advance of Draft Application filing.
23	Water Resources	**5.** Revision to Table 6.1-5 waterbodies of Lake Jocassee watershed.	SCDNR	June 23 2022	The suggested waterbodies have been added and the table is included as Table 4-1 in the Water Resources Study plan (Appendix C).
24	Water Resources	**6**. Section 6.1.5 should include Howard Creek, which includes Limber Pole and Corbin Creeks, as a contributing significant tributary draining directly to Lake Jocassee.	SCDNR	June 23 2022	Duke Energy is in agreement that Howard Creek is a significant contributing tributary to Lake Jocassee; the tributary descriptions will be revised accordingly in the future Exhibit E of the Draft and Final License Application and relevant study reports.
25	Water Resources	**7.** This section notes that previous analyses have shown that if the entire Bad Creek Reservoir active storage volume was released, then the impact on Lake Jocassee would be a 4-ft increase in water level. The SCDNR notes that the subsequent refilling of the full volume of Bad Creek Reservoir would decrease the elevation of Lake Jocassee by four feet. Additionally, this section notes that the combined capacity of Bad Creek and the Complex would allow the Licensee to reduce the drawdown time from 23 hours to 11 hours and reduce the pumping refill time from 26 hours to 13. Therefore, the additional capabilities of the Complex will allow for twice the amount of water exchange, increasing the likelihood of negative impacts to aquatic species, recreation, water quality, and shoreline erosion rate in the lower reservoir.	SCDNR	June 23 2022	While the volume of water exchanged between the upper and lower reservoirs would not change, the rate of exchange between the upper and lower reservoirs would increase with the addition of a second powerhouse. Impacts to aquatic species, recreation, water quality, shoreline erosion (Whitewater River cove), and littoral habitat will be assessed through the individual studies proposed for this relicensing.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
26	Water Resources	**8**. This section identifies the potential spoil disposal sites to be utilized during the construction of the proposed Complex. The SCDNR notes that the fill impacts appear to be in and around streams. Headwater and wetland systems provide an important link between upland watersheds and downstream aquatic environments. The SCDNR requests further information regarding the alternatives analysis associated with the selection of the areas identified as preferred and potential spoil locations. Additionally, please describe the types of environmental impacts associated with the various alternatives and any avoidance and minimization measures taken. Additionally, the SCDNR recommends that revegetation on spoil piles should be native species appropriate for the ecoregion and should exclude plant species found on the exotic pest plant council list: https://www.se-eppc.org/southcarolina/SCEPPC_LIST2014finalOct.pdf. The SCDNR prefers the use of native warm season grasses and/or other native forbs that would be beneficial for wildlife and pollinators for stabilization for the spoil areas. Native warm season grass species suggestions include switchgrass (Panicum virgatum), indiangrass (Sorghastrum nutans), big bluestem (Andropogon gerardii) and little bluestem (Schizachyrium scoparium). A list of beneficial pollinator plant species, such as milkweed (Asclepias spp.), for the southeast may be found at www.xerces.org/pollinators-southeast-region/ or by visiting http://www.pollinator.org/guides. The SCDNR strongly discourages the use of Sericea Lespedeza (*Lespedeza cuneata*) due to its invasive nature and lack of benefit to wildlife. (Section 6.3.10.3)	SCDNR	June 23 2022	As part of the Bad Creek II Power Complex Feasibility Study, an excavated materials disposal study was conducted to quantify the amount of spoil associated with the excavation and construction of the proposed Project facilities. Determining the preliminary spoil areas on Duke Energy-owned property, size of areas, amount of spoil to be placed, and feasibility and costs associated with each were an objective of the Bad Creek II Feasibility Study. Several factors were considered as part of this material disposal study including, but not limited to: (1) site safety considerations; (2) environmental considerations; (3) proximity of spoil area to construction site and haul distance; (4) volume of spoil and spoil area ability to adequately accommodate and contain; (5) previously utilized spoil areas, (6) topography, (7) logistics and costs. Offsite spoil locations were not considered during this phase of the study. Several of the areas evaluated were not selected as "preferred" by Duke Energy for several reasons including low volume area capacity, environmental and safety concerns, or access difficulties. A detailed ranking analysis of each identified sites was not performed as part of the Bad Creek II Feasibility Study. Note that Site H should be considered as a "preferred" in Table 6.6-7 Table of the PAD (Table 5-2 in Proposed Study Plan). An excavated materials disposal study was conducted to quantify the amount of spoil associated with the construction of the proposed project facilities. Table 5-3 in the Proposed Study Plan provides estimated excavation and spoil quantities for the power complex elements including the upper reservoir I/O area, water conveyance tunnels and shafts, powerhouse and access tunnels/shafts, various construction adits, and lower reservoir I/O area and the assumed spoil locations. Vegetation/native species restoration on spoil piles will be considered.
27	Aquatic Resources	**9.** SCDNR finds value in continuing to monitor and mitigate for fish entrainment impacts, especially to forage species, at the Project. The additional pumping cycles at the proposed Complex site will increase the rate of entrainment and impingement of aquatic species throughout the term of a subsequent license. (Section 6.4.2)	SCDNR	June 23 2022	The current 10-year work plan continues entrainment minimization measures, pelagic prey fish surveys, and electrofishing through 2027. During the New License term, Duke Energy proposes to continue to implement activities established by the MOU as may be modified in consultation with stakeholders through the relicensing process, and will continue to implement protection, mitigation, and enhancement activities established under the KT Project Relicensing Agreement. The updated desktop Entrainment Study suggests that fish populations in Lake Jocassee will experience minor effects from the additional operations of Bad Creek II Complex. As part of the Aquatic Resources Study, Duke Energy will consult with interested stakeholders regarding the results of the entrainment study and any necessary future protection, mitigation, or enhancement measures.
28	Wildlife & Botanical Resources	**10.** The SCDNR recommends including the federally endangered gray bat (Myotis grisescens) in the Project's list of federally listed threatened, endangered, and candidate species. Further, the SCDNR recommends the gray bat be included in the acoustic KPro analysis and results table, in addition to files being reviewed by a qualified biologist to evaluate potential presence. Though gray bat calls have little overlap with other Myotis species, they can overlap with calls of Tricolored bats – the most common species detected in the Bad Creek 2021 Bat Survey Report. Gray bat records exist in Transylvania County, North Carolina, located less than a mile north of the Project. The closest gray bat records are the SCDNR validated gray bat calls detected at a bridge approximately nine miles from the Project in 2020, and at a site approximately 15 miles northeast of the Bad Creek Reservoir (personal communication with NC bat biologist). Due to these records and the gray bat's ability to extend their range 27 km (16.8 mi) (LaVal et al. 1977) from roost sites to forage, there is a chance the gray bat could be located within the Project Area.	SCDNR	June 23 2022	Please see attached memorandum discussing the analysis of acoustic files for gray bats. No diagnostic calls for this species were identified.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
29	Wildlife & Botanical Resources	**11.** The SCDNR notes that three State Listed Species occur in the Project Area and should be included in the Natural Resources Assessment Report (eastern small-footed bat, Rafinesque's big-eared bat, bald eagle) (PAD Appendix E)	SCDNR	June 23 2022	Duke Energy acknowledges that only federally-listed and At-Risk-Species were included in the Natural Resources Assessment. Information regarding activities that may affect bat species due to construction or operation in the Project nexus will be detailed in the Draft and Final License Application and will include state-listed species listed by the SCDNR.
30	Water Resources	**12.** This section, including related Tables 8 and 10 and Figures 12 and13, identify the Licensee's preferred spoil sites. However, it is unclear to the SCDNR how the Licensee selected and prioritized the potential spoil sites, as previously mentioned. The SCDNR requests further information with regards to how the Licensee intends to select a site or sites for deposition of construction spoil, as well as what avoidance and minimization measures were considered. (PAD Section 6)	SCDNR	June 23 2022	Please see response to Comment No. 26.
31	Aquatic Resources	**13.** The SCDNR notes that the estimated percentage (12%) of entrainment of the threadfin shad population in Lake Jocassee is a high rate that should continue to be monitored. Threadfin shad are an important prey species for most sportfish in Lake Jocassee. The Project's entrainment study conducted in the first three years of Project operations (1991-1993) (Barwick et al. 1994) found that entrainment rates increased when the water elevations in Lake Jocassee were below 334 meters for a total of 30 days annually. Further, the increased rates resulted in a stable or slightly declining population of threadfin shad. The SCDNR's interests with this issue are to understand the effects of entrainment on fish populations and to evaluate methods to avoid and minimize these impacts. The SCDNR recommends the findings from Barwick et al. 1994 should be included in the Project's PAD. (Appendix F)	SCDNR	June 23 2022	Please see response to Comment No. 27. Duke Energy notes that the findings from Barwick et al. (1994) are included in Sections 6.4.2.2.3 and 6.4.3.11. of the PAD.
32	Wildlife & Botanical Resources	**14.** The SCDNR notes that caution in interpretation is also appropriate for NLEB vs. eastern small footed bat and eastern red bat vs. Seminole bat, which can share significant overlap in call type. The SCDNR disagrees with the following statement: "While no federally listed northern longeared bats were found near the Project site, the recent discovery of the summer presence of pregnant females in the South Carolina Coastal Plain may indicate a migratory presence in more upland regions of the state." The lack of captures in the middle of the state, despite SCDNR's netting efforts since 2016, suggests spatially disjunct populations in South Carolina (Blue Ridge versus Coastal Plain population) similar to the disjunct populations known to occur in North Carolina. In 2013, prior to white-nose syndrome (WNS) being detected in South Carolina, northern long-eared bats were present and breeding in Oconee, Pickens, and Greenville counties. However, extirpation from the Blue Ridge ecoregion due to WNS mortality seems likely.	SCDNR	June 23 2022	Duke Energy's consultant, ERM, acknowledges the likely extirpation of NLEB from the Project area. Duke Energy and ERM concur that there is acoustic overlap between eastern red bat and Seminole bat; the best possible determinations of likely presence were made based on the quality of recorded calls. Duke Energy and ERM concur that there is acoustic overlap in Myotis calls (NLEB and eastern small-footed bats) and between eastern red bat and Seminole bat; the best possible determinations of likely presence were made based on the quality of recorded calls.
33	Wildlife & Botanical Resources	**15.** For emergence bat call surveys, the SCDNR recommends that the Licensee should utilize the same bat detector recorder type used during other acoustic surveys (e.g., SM3BAT or Echometer Touch 2), for improved quality call collection, identification, and consistency.	SCDNR	June 23 2022	Emergence surveys used the Echometer Touch, which is an active acoustic detector. SM3BATs were used for passive acoustic surveys. The benefits of each are slightly different. However, in the future (if future surveys are necessary), bat surveys will use the same detector type for active and passive surveys, for consistency.
34	General	**16.** Minor notes and additional addresses for agency correspondence	SCDNR	June 23 2022	Comment and additional mailing addresses noted.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
35	Water Resources	**1.** This section describes the project facilities including reservoirs and dams. The final paragraph refers to stream augmentation facilities, which consisted of a "system of intakes, pipes, and sluice gates" to augment flows to Howard Creek. However, the stream augmentation system is not currently used. Howard Creek is a tributary of Lake Jocassee, classified as Outstanding Resource Waters (ORW) by the SC Department of Health and Environmental Control (SCDHEC), and receives anywhere from 40% to 80% of its flow from Bad Creek and West Bad Creek by way of seepage from the Main Dam and West Main Dam. Please elaborate the purpose and need for the stream augmentation on Howard Creek, and further explain why the system is no longer in use.	Upstate Forever	June 23 2022	Article 39 of the Original License required, in part, the Licensee to assess the desirability and feasibility of providing stormflow augmentation to facilitate sediment removal in Howard Creek following construction and providing minimum flow to Howard Creek from a flow augmentation system that had been installed to support construction. As described in a FERC order dated February 14, 1995, following the initial upper reservoir filling, Duke Energy measured flows at a control location above the area of Project impact, and in an area immediately below the west and main dams to estimate seepage from the two Project dams, and correlated these data with historic baseflow data. The results of the Licensee's study indicated that the quantity of seepage in Howard Creek was generally less than the average monthly historic flows for January-August, and equal to or greater than the monthly average for September-December. Based on this study, Duke Energy concluded that no augmentation or supplemental flows are needed, because the natural hydrology of the watershed and seepage from the dams provide a high quality baseflow to Howard Creek. The Licensee was directed, by the February 14, 1995 order, to further consult with USFWS and SCDNR regarding the need for streamflow augmentation in Howard Creek. Additional information from this study and consultation was filed with FERC on June 9, 1995. By letter order dated July 9, 1995, FERC agreed with the conclusions and recommendations of Duke Energy's transmittal, including continued monitoring of dam seepage flowrates into Howard Creek and notifying USFWS and SCDNR when combined seepage flows of Bad and West Bad Creeks drop below 2.0 cfs or exceed 3.5 cfs for two consecutive biweekly flume recordings, and no requirements for operation of the baseflow augmentation system.
36	General - Climate	**2.** This section of the PAD provides climate data for two 30-year periods from 1971-2000 and 1981-2010, and appears to be sourced from a recent (2021) SCDNR study. Although more recent and more descriptive data is probably available, it is not included here. The Upstate has seen a dramatic increase in the frequency and intensity of extreme weather events not only over the past several decades but in just the past few years, including high intensity rainfall, flash flooding, and prolonged periods of drought. If possible, please update this section to include climate data that captures recent extreme weather events. We would like to see more descriptive data through 2020 such as maximum and minimum rainfall amounts, number of days with or without rain, longest period without rainfall, number of days above average, severe weather events, and any other descriptive data.	Upstate Forever	June 23 2022	Climate data will be revised and expanded in Exhibit E of the license application to provide a more detailed treatise of recent climate trends/events in the region. This response also addresses in part Upstate Forever's comment under "General Comments" regarding climate.
37	Wildlife & Botanical Resources	**3.** Section 6.1.3 of the PAD describes major land and water uses within the Project boundary using the U.S. Geological Survey's National Land Cover Database. Both Table 6.1-3 and Figure 6.1-3 include areas categorized as "cultivated crops" (3.7% of Project boundary) or "hay/pasture" (10.1% of Project boundary), neither of which would be consistent with typical land management practices around a high priority dam, nor do they appear to agree with the images of the Main Dam in Figure 5.4-2 and the West Dam in Figure 5.4-3. Please confirm whether any cultivated crops or areas of hay or pasture do indeed exist within the project boundary, or clarify the land uses immediately adjacent to the Main Dam and West Dam.	Upstate Forever	June 23 2022	The 30-meter-resolution National Land use Cover Data (NLCD) interprets open areas as hay/pasture and/or cultivated crops. Aerial imagery confirms that 30-meter cells identified by the database as crops and/or hay/pasture are open areas associated with the West dam and East dam downstream faces (rip rap), maintained areas (mowed) around the former construction yard, maintenance areas, helicopter pad, and existing powerhouse complex. Figure 5-1 is provided in Section 5 of the Proposed Study Plan comparing the NLCD data vs. aerial imagery. The table of land uses will be updated in the license application to indicate this discrepancy.
38	Water Resources	**4.** Section 6.2.5.2 of the PAD describes the modeling framework used to evaluate the potential operational impacts of the proposed Bad Creek II Complex in the Whitewater River arm of Lake Jocassee, including potential shoreline erosion. Results of the computational flow dynamics (CFD) model indicate that the addition of the Complex is unlikely to increase the shoreline erosion potential of the Lake Keowee shoreline. Please update this section of the PAD with more information regarding the modeling results, including graphic depictions of peak velocities, discharge points, and shoreline impacts.	Upstate Forever	June 23 2022	Information regarding velocities, discharge, and shoreline impacts to the Whitewater River cove streambank opposite of the inlet/outlet structure will be developed as an objective of the Water Resources Study and will therefore be detailed in the Water Resources Study Report and Draft and Final License Application.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
39	Water Resources	**5.** This section of the PAD provides a summary of existing water quality data collected for waters within the Project Boundary and vicinity but is limited to the upper reservoir (6.3.7.1 Bad Creek Reservoir) and lower reservoir (6.3.7.2 Lake Jocassee). No water quality data is included for either Howard Creek, which receives seepage flows from the Main Dam and West Dam and is a tributary of Lake Jocassee, or Whitewater River, which is the receiving water from daily Project operations and the location of a submerged weir designed to minimize the effects of Project operations on lake stratification, protect cold-water fish habitat, and dissipate energy from discharged water. Similarly, no water quality data is provided for Bad Creek or West Bad Creek, which according to Section 6.3.1 of the PAD are only "partially to mostly submerged." In addition, neither the upper reservoir nor its tributaries have historically been monitored for water quality, which is an erroneous oversight providing no baseline water quality data for waters in the Project vicinity. Flow data is provided for Howard Creek in Table 6.1-1 but only for a brief period from 1989 to 1996. According to the current implementation of the Waters of the US (WOTUS)1, Pre-2015 Regulatory Definition and Practice, the Bad Creek Reservoir is included under WOTUS and Waters of the State (WoS) protections because it was formed by the impoundment of two free-flowing rivers or streams, Bad Creek and West Bad Creek, and as such regulatory designations do apply. More information is needed for these Project-related water resources to better understand the Project's impact on existing watershed health. Please provide a rationale for excluding these significant water resources in the Whitewater River Watershed and include measures for updating and collecting water quality data in the PAD and proposed studies for relicensing.	Upstate Forever	June 23 2022	Please see response to Comment No. 35.
40	Water Resources	**6.** Duke Energy proposes to develop a Water Quality Monitoring Plan in consultation with agencies for Project construction (pre-, during, and post-construction) and operations, including monitoring locations, methods, and reporting criteria for major parameters such as DO, temperature, pH, specific conductance, and turbidity. Duke should include nutrients (nitrogen and phosphorus) to the list of parameters they monitor as land use practices can contribute to increased nutrient levels in surface waters. The Upstate is seeing an increasing trend with rising nutrient levels in reservoirs, which can lead to harmful algal blooms, and ultimately result in lost recreation opportunities, decreased property values, and poor water quality that is expensive for water utilities to treat. Because the nearby Lake Keowee is a popular recreation destination and drinking water source for over 250,000 people in the Upstate, this should be of considerable importance. Furthermore, in continuation with our concerns regarding the absence of water quality data for Project-related waters, please include a plan for establishing and monitoring water quality data for Bad Creek, West Bad Creek, Howard Creek, and Whitewater River.	Upstate Forever	June 23 2022	Water quality in upland streams that may be impacted by construction of the Bad Creek II Complex will be monitored under the proposed Water Quality Monitoring Plan (the development of which is a Water Resources Study task). As land cover in the vicinity of the Project is predominantly forested, and common land use practices in upland areas (e.g., agriculture, livestock, industry, etc.) are not considered a major contributing factor to water quality, monitoring nutrient levels in Lake Jocassee is not proposed as part of the Water Resources Study or Water Quality Monitoring Plan. Duke Energy will undertake water quality monitoring (continuous temperature and bi-weekly DO) at three historic monitoring sites in the Whitewater River arm of Lake Jocassee in 2023 and 2024. Monitoring is not feasible in the Bad Creek upper reservoir due to significant daily water fluctuations and safety impacts.
41	Wildlife & Botanical Resources	**7.** Section 6.5.2.2 of the PAD lists numerous invasive species observed during field surveys conducted throughout the transmission line corridors in 2021. However, there is no indication of field surveys conducted in other Project areas, including access areas or on the faces of the project dams. Many of these species already are or will soon be extremely problematic for land management if left unattended. Furthermore, the PAD does not provide any other detail about current or proposed vegetation management at the project and should include information describing management activities for native and non-native invasive species in the Project boundary and vicinity.	Upstate Forever	June 23 2022	A discussion of transmission line right-of-way vegetation management protocol and status as well as facility vegetation management protocol, including herbicide application, is provided in this PSP in response to FERC Additional Information Request #9. Please refer to Table 5-1. Responses to FERC Additional Information Requests in the Proposed Study Plan.
42	Water Resources	**8.** This section appears to be mis-titled. Based on context of the section paragraph, this section should instead be titled as "Relatively Permanent Waters with Perennial Flow."	Upstate Forever	June 23 2022	Correction noted.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
43	Water Resources	**9.** The PAD estimates approximately 4 million cubic yards of spoil material will need to be disposed as a result of constructing the proposed new Complex. That is the equivalent to approximately 250,000 dump trucks. Both Section 6.6.3 and the Natural Resource Assessment in Appendix E discuss the potential for disposing spoils in wetlands and surface waters, including dredging, filling, clearing, and de-watering. However, there is no discussion in this section of transporting the spoil material off site for alternative uses or disposal. In addition, Table 6.6-7 of this section lists potential spoil locations and the estimated impacts to wetlands and surface waters, including preferred spoil locations (denoted by an asterisk *). However, the PAD does not discuss the criteria used to assess the potential spoil disposal areas, nor does it provide an explanation of why some areas are preferred over others. The Clean Water Act requires consideration for avoiding and minimizing impacts before a Section 404 permit can be obtained for placing fill in waters of the US, and before a water quality certification can be awarded by the State. Off-site transport should be included in the criteria and considered the only option unless other disposal methods can be justified. Please update this section to include a comprehensive discussion of these criteria with the addition of off-site removal, including how the potential spoil disposal areas are being identified, sized, assessed, and selected as Duke Energy's preferred locations for this purpose off-site removal. During construction of Complex II, it is anticipated that several trucks and other large equipment will be transported over roads to access the Project. This additional traffic will increase turbidity levels in stormwater runoff in both reservoirs as well as the tributary streams. Duke should include a discussion of the type and number of BMPs (e.g., vegetation, matting, silt fencing) proposed to prevent runoff from negatively impacting water quality. Furthermore, Duke should include plans for stabilizing soils at construction sites and staging areas during and after construction activities making sure to use only native vegetation in the project vicinity to stabilize and re-establish habitats.	Upstate Forever	June 23 2022	Please see response to Comment No. 26. Concerns associated with increased turbidity levels in response to runoff and selection of best management practices will be addressed under the Water Resources Study Plan and future erosion and sediment control plans to be developed to support expanded Project construction.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
44	Recreation	**10.** Section 6.8 of the PAD provides a thorough description of recreation facilities and opportunities in the Project vicinity, including the Foothills Trail and other nearby recreation resources. Notably, there is considerable emphasis on off-Project recreation areas likely due to the restricted nature of the upper reservoir. Because there is no access to the Bad Creek reservoir for recreation purposes, fulfillment of the Recreation component (Exhibit R) of the original license was provided through the creation and management of a 43-mile central section of the Foothills Trail. Exhibit R included public access and parking, trail kiosks and directional signs, additional spur trails, and stream crossings as well as continual maintenance and operational activities for limited recreation uses, primarily hiking. For this section of the PAD Duke should provide a comprehensive summary of its fulfilment of Exhibit R requirements under the original license, including a history of any modifications to Exhibit R that may have occurred during the license term. Unfortunately, language in both the PAD and Scoping Document 1 creates confusion regarding Duke's long-term plans for continued management of the Foothills Trail. Spe cifically, Section 7.1.6.1 of the PAD states, "The segment of the Foothills Trail and two undeveloped access areas on non-Project lands that were developed per the Original License will continue to be maintained by Duke Energy in the New License term as a non-Project facility and potentially under a separate agreement with regional stakeholders." Meanwhile, SD1 states that "Duke Energy does not propose to include the Foothills Trail as a project recreation facility under the new license." These two documents should be reconciled to clarify Duke's intentions and the fate of the Trail. The Foothills Trail system provides important recreational and educational opportunities to both Upstate residents and visitors from around the world. However, the Upstate is experiencing unprecedented and accelerating population growth and is expected to continue growing for decades to come. By 2040, our region's population is projected to reach nearly 1,750,000 – an increase of 64% since 1990. Already our natural resources are stretched thin, and the current pandemic has revealed how fragile and overburdened our public recreation areas have become. Continued support of the Foothills Trail is a critical component of the New License and expansion of the recreation provisions should be considered to account for the population growth, increased demand for outdoor recreational needs, and expansion of project operations from the ongoing upgrades. Ensuring that recreation opportunities centered on the Foothills Trail continue to provide quality recreation opportunities in perpetuity and that the Foothills Trail can continue to grow to meet additional demand should be paramount in this licensing. Such consideration should include all or some of the following: 1. An endowment given to the Foothills Trail Conservancy for ongoing management and maintenance of the Foothills Trail system;	Upstate Forever	June 23 2022	An inventory of recreational facilities associated with the Bad Creek Project will be provided in the Recreational Resources Study report.
45	Geology and Soils	**11.** This section of the PAD provides a brief description of soil classifications in the Project vicinity. However, it does not include an analysis of Prime Soils or Soils of Statewide Importance. Duke should consult with USDA/NRCS to provide a summary of soils that have the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, and oilseed crops, and is available for such use, and develop a plan for protecting those areas during the next licensing term. The Oconee County Conservation Bank has provided grant funding for projects that permanently protect lands with Prime or Important Soils with conservation easements held by Upstate Forever or Oconee County's Soil and Water Conservation District.	Upstate Forever	June 23 2022	Duke Energy plans to provide in the license application and supporting documents information required by FERC and other regulatory entities to support their environmental review processes, and relevant to the construction and operation of the expanded Project in the New License term. Mapping or evaluation of prime or important soils is not presently proposed by Duke Energy as part of the ongoing Geology Study or as an element of this PSP.
46	Recreation	**12.** This section should include the most recent future land use maps and comprehensive plans available for the project area in both Transylvania and Jackson counties of North Carolina, and Oconee County, South Carolina. Oconee County recently adopted its "Unified 2020 Comprehensive Plan"3 on March 3, 2020. From October 2018 through December 2019, Oconee County engaged its local citizens through numerous public meetings, newspaper inserts highlighting the elements of the plan, and a survey for public input. Because the character and density of land that abuts the Project will not be determined solely by Duke Energy, management of the Project as well as the lands in the Project vicinity should consider the vision for the future expressed by Oconee County residents and captured in their plan.	Upstate Forever	June 23 2022	The Oconee County Comprehensive Plan as well as the most recent State Comprehensive Outdoor Recreation Plans will be included in the Recreational Resources Study (Recreation Use and Needs task).

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
47	General - Climate	**13. (General Comments - Climate Change).** The PAD includes no discussion of climate change and how it may affect various aspects of the Project, including operations and management of Project resources. Climate change is an important consideration for wildlife and botanical resources, recreation, water quality and water quantity, and land planning, use, and policy. It should be included for consideration in each section of the PAD, as well as every proposed study in this licensing process, and continue to inform Project management and operation decisions throughout the life of the proposed new license. In addition, how will climate change considerations be reflected in the design and operations of Duke's current and proposed hydroelectric facilities? As previously discussed, SC has seen a dramatic increase in the frequency and intensity of extreme weather events over the past several decades, including flooding and drought. These extreme conditions will continue to have implications on the operations and management of these facilities and the natural resources. This should include, but not be limited to, discussion of increasing nighttime temperatures, changing seasonal precipitation patterns, increased frequency in extreme weather events, and increased periods of drought. Wildlife corridors, which may be necessary for species migration due to climate change, should be considered and PM&E measures identified for both relicensing of existing operations.	Upstate Forever		Climate data will be revised and expanded in Exhibit E of the license application to provide a more detailed treatise of recent climate trends in the region. Operational models (HEC-ResSim and CHEOPS) were developed with climate change scenarios in support of the 2014 New Operating Agreement (NOA) between Duke Energy, the U.S. Army Corps of Engineers, and Southeastern Power Administration. These sensitivity assessments were simulated to evaluate possible impacts of future temperature increases, basin inflow reduction, extended drought, and future water withdrawal demands; scenarios were agreed upon by the Operating Scenarios Committee. Bad Creek II Complex operations will comply with the 2014 NOA parameters, therefore no additional study is needed.
48	Recreation	**14. (General Comments - Separate Licenses with Specific Requirements).** Throughout the PAD, much consideration is given for the Keowee-Toxaway Hydroelectric Project (FERC No. 2503). However, the Keowee-Toxaway Project operates under a separate and distinct license from the Bad Creek Pumped Storage Facility. It is often confusing how one project relates to the other, and sometimes reads as if requirements under one license are used to offset obligations under the other. While both projects are indeed impacted by the other, and may influence operations at other projects (e.g., Oconee Nuclear Station), there are resources and obligations singular to each project. As already mentioned, there is an impression that some recreation opportunities lost from the exclusivity of the Bad Creek project were remedied on Lake Jocassee, which may or may not have been negotiated during the relicensing of the Keowee-Toxaway project. During the Keowee-Toxaway relicensing, stakeholders were not able to consider lost recreation opportunities of the Bad Creek project. The same is true for fishery resources and work plans conducted in coordination with SCDNR through the Keowee-Toxaway relicensing, as well as the Recreation, Use, and Needs Study (RUN Study) conducted in 2013, which failed to consider the recreation opportunities provided by the Foothills Trail. In summary, these projects are clearly complementary and inextricably linked, but do not necessarily satisfy individual license requirements.	Upstate Forever	June 23 2022	The Recreational Resources Study will include identification and assessment of recreational facilities specifically associated with the Bad Creek Project and the Foothills Trail. Attachment 1 of the Aquatic Resources Study plan (Appendix D) is being provided as additional information on mitigation required by and performed pursuant to the Original License for the Bad Creek Project.
49	Water Resources	**15. Existing Project Operation.** Throughout SD1 and the PAD, the Project is presented as an isolated pumped storage project seemingly without influence or relationship to other facilities or project operations. However, most of the volume in the upper reservoir originates from Lake Jocassee, which also plays a major role in the operations of both the Keowee-Toxaway Hydroelectric Project (FERC No. 2503) and the Oconee Nuclear Plant. All three projects depend on water levels in Jocassee to provide abundant water to safely generate power for Duke Energy customers. This section of the Scoping Document and the PAD should include a description of how the water level in Lake Jocassee affects these projects, including an extreme low inflow scenario where operations of Bad Creek may need to be curtailed or ceased to maintain operations at other projects. Furthermore, the Project presently operates within the upper 50 to 60 feet of full pond level. However, the existing license authorizes a 160-foot maximum drawdown. Currently, the Project is undergoing pump-turbine upgrades, and Duke has proposed the construction and operation of a second powerhouse as part of this relicensing. Both the upgrades and the new Complex will increase the range within which Project operations will impact water levels, creating larger and more rapid fluctuations in both the Bad Creek reservoir and Lake Jocassee. Therefore, the increased operating band may also affect a variety of environmental parameters, including but not limited to water quality, shoreline habitat, and fish entrainment.	Upstate Forever	June 23 2022	Evaluation of changing water levels (under different operation scenarios) in response to the addition of a second powerhouse (Bad Creek II Complex) is an objective of the Water Resources study, and results will be included in the study report and Draft and Final License Application. Note that the operating band for Bad Creek reservoir (or Lake Jocassee) will not be modified from present conditions.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
50	Aquatic Resources	**16. Proposed Environmental Measures).** Under the Aquatic Resources portion of this section, we believe the Fisheries MOU and 10-Year Work Plans for fishery resources that Duke has completed in partnership with SCDNR should be included. Activities included in the 10-Year Work Plans were designed to develop and enhance management strategies for fish in these areas and included fisheries surveys and inventories, water quality and aquatic habitat evaluations, fish stocking, recreation, and shoreline impacts. Duke Energy entered an MOU with SCDNR for the long-term management and maintenance of high-quality fishery resources in Lake Keowee and Lake Jocassee as well as their tributary streams. While the current MOU is in effect through 2027 and intended to mitigate for fish entrainment, we don't currently know what contribution the proposed Complex will have on entrainment. Therefore, we believe that Duke should extend the MOU and workplans through the term of the new license.	Upstate Forever	June 23 2022	During the New License term, Duke Energy proposes to continue to implement activities established by the MOU as may be modified in consultation with stakeholders through the relicensing process, and will continue to implement protection, mitigation, and enhancement activities established under the KT Project Relicensing Agreement.
51	Water Resources	**17. Resource Issues Aquatic Resource).** We support all the issues identified in this section. However, we have particular concerns that no water quality data has been collected for the Bad Creek Reservoir and associated tributaries making it impossible to determine if the current or proposed operations have or will have any negative impacts on water quality. Furthermore, we have concerns regarding the effects of construction-related erosion, sedimentation, and spoils disposal on water quality, aquatic habitat, and aquatic biota in the Bad Creek reservoir, Lake Jocassee, and surrounding tributaries. Four million cubic yards of debris is expected from the construction of Complex II, which is the equivalent of at least 250,000 dump trucks. The resulting construction activity will heavily impact roads in the watershed and create additional runoff and turbidity in nearby streams and reservoirs. In addition, Duke has proposed to dispose of spoils in several nearby locations, including wetlands, forested uplands, tributaries, and the weir. Most of the waters in the Project vicinity are characterized as extremely high-quality streams with designations including Outstanding Resource Waters, Trout Natural, and Trout Put, Grow and Take, which our State's most protective water classifications. Filling wetlands and tributaries is not an acceptable option. It is also not clear how the spoil locations were selected or why no consideration was given to transporting materials off site. Upland disposal of construction debris that results in impacts to streams or wetlands, as well as placement of rock spoils at the submerged weir, will require an Individual Permit from the USACE as well as a Water Quality Certification from SCDHEC under the authorities of Sections 404 and 401 of the Clean Water Act. Further, as part of the Mitigation Rule, it is a requirement for Duke Energy to consider all steps to avoid and minimize impacts to water resources before undertaking activities that negatively impact waters. Duke Energy expects to initiate this parallel regulatory process in conjunction with the relicensing process. However, to avoid impacts to water resources, we strongly recommend that spoils be transported off site rather than used to fill wetlands and streams. (See our previous comments regarding Section 6.6.3 of the PAD on Known or Potential Adverse Effects and Proposed PM&E Measure: Bad Creek II Complex.)	Upstate Forever	June 23 2022	Please see responses to Upstate Forever comments #5, #6, and #9 (Comment Nos. 39, 40, and 43 in this table).

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
52	Wildlife & Botanical Resources	**17. Resource Issues Terrestrial Resources).** In addition to assessing the effects of project construction, operation, and maintenance activities on ecological communities and protected terrestrial species, we believe that the effects on potential habitat should also be assessed. Furthermore, we believe this should be expanded to include the effects of non-native, invasive, and noxious species on ecological communities and potential habitat areas as well. Habitat and corridor protection is one of the most critical needs for the protection and preservation of species. Assessing the direct impact of the Project on target species is only one component to ensuring that the species have the greatest chance of survival. Rather, the assessment should explicitly examine the amount of available habitat and habitat needs for healthy, diverse, and viable populations of the target species. The assessment should examine past habitat availability, current habitat availability, and determine trends for habitat loss or creation through the term of the new license based on the identified trends. This information can then be used to identify target values for habitat protection and restoration in and near the Project. Lastly, the impacts of climate change should also be evaluated and discussed. Wildlife habitat corridors may be necessary for species migration due to climate change and should be of particular interest throughout the life of the proposed new license.	Upstate Forever	June 23 2022	Duke Energy plans to provide in the Draft and Final License Application and supporting documents information required by FERC and other regulatory entities to support their environmental review processes and required permits and approvals, and relevant to the construction and operation of the expanded Project in the New License term. Duke Energy further expects any necessary monitoring and management plans for the protection of natural resources that may be impacted by the Project to be developed in consultation with stakeholders through this relicensing process.
53	Wildlife & Botanical Resources	**18. Resource Issues Threatened and Endangered Species).** Upstate Forever has the same comments and concerns regarding the effects of project construction, operation, maintenance, and project-related recreation on RT&E species as we do on Section 4.1.3 above, including climate related impacts. In addition, both this section and Section 4.1.3 should consider Project impacts on species not included in this section of SD1. The US Fish and Wildlife Service provided a “List of Threatened, Endangered, Candidate, and Proposed Species Generated by ECOS-IPaC Website on April 11, 2022,” (List) which is available on the FERC’s eLibrary for this docket. The List includes ten (10) migratory bird species considered Birds of Conservation Concern (BCC), which warrant special attention in the project vicinity. These birds are protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act.	Upstate Forever	June 23 2022	Duke Energy plans to continue to informally consult with state and federal natural resource agencies throughout the licensing process to identify listed and sensitives species that may be present and impacted by expanded Project construction. Additional formal consultation between FERC and USFWS is expected after the filing of the license application, if Duke Energy's proposed action may affect protected species, and recommended protection, mitigation, and enhancement measures would be identified through this process.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
54	Recreation	**19. Recreation, land use, aesthetics)**. As previously mentioned, language in both the PAD and Scoping Document 1 creates confusion regarding Duke's long-term plans for continued management of the Foothills Trail. Specifically, Section 7.1.6.1 of the PAD states, "The segment of the Foothills Trail and two undeveloped access areas on non-Project lands that were developed per the Original License will continue to be maintained by Duke Energy in the New License term as a non-Project facility and potentially under a separate agreement with regional stakeholders." Meanwhile, SD1 states that "Duke Energy does not propose to include the Foothills Trail as a project recreation facility under the new license." These two documents should be reconciled to clarify Duke's intentions and the fate of the Trail. We support all the issues identified in this section. In addition, we believe that land use should be further reviewed in the context of shoreline habitat around the upper reservoir. Because there is no public access to the Bad Creek Reservoir shoreline, permitting policies addressed through a Shoreline Management Plan and Shoreline Management Guidelines are unnecessary. However, due to limited interference from human activities, much of the shoreline around the upper reservoir can and should be managed to provide prime riparian and littoral habitat. The impacts of climate change should also be evaluated and discussed. Furthermore, because there is no recreational access to the Bad Creek reservoir, the recreation component (Exhibit R) of the original license was provided through the creation and management of a 43-mile section of the Foothills Trail. Exhibit R included public access and parking, trail kiosks and directional signs, additional spur trails, and stream crossings as well as continual maintenance and operational activities for limited recreation uses, primarily hiking. However, while water-based recreation such as canoeing and swimming are understandably overlooked due to fluctuating water levels and public safety concerns, management components related to traditional recreation activities such as fly-fishing and birdwatching should have been considered and should be addressed in the current licensing. The Foothills Trail system provides important recreational and educational opportunities to both Upstate residents and visitors from around the world. Meanwhile, the Upstate is experiencing unprecedented and accelerating population growth and is expected to continue growing for decades to come. Already our natural resources are stretched thin, and the current pandemic has revealed how fragile and overburdened our public recreation areas have become. Continued support of the Foothills Trail is a critical component of the New License and expansion of the recreation provisions should be considered to account for the population growth, increased demand for outdoor recreational needs, and expansion of project operations from the ongoing upgrades. Ensuring that recreation opportunities centered on the Foothills Trail continue to provide quality recreation opportunities in perpetuity and that the Foothills Trail can continue to grow to meet additional demand should be paramount in this licensing. Such consideration should include all of the following: 1. An endowment given to the Foothills Trail Conservancy for ongoing management and maintenance of the Foothills Trail system; 2. Fee-simple donations of land to be included in the Foothills Trail system, or to State resource agencies for various purposes, including recreation, habitat management, and water quality protection;	Upstate Forever	June 23 2022	Duke Energy intends to provide for the continued management and maintenance of the portion of Foothills Trail corridor contemplated in the Exhibit R of the Bad Creek Hydroelectric License. Duke Energy currently funds the management and maintenance of the 43 miles of the trail corridor within its purview via private contractor. The mechanism for funding and maintenance of the trail in the new license term has not yet been determined but will be proposed in the Draft and Final License Application. Duke Energy does not own any notable tracks of land along the Foothills Trail Corridor that are not reserved for potential future development to meet electric customer needs. The two reserved tracks (Limberpole and Coley Creek) are encumbered by conservation easements.
55	Aquatic Resources	**20. Proposed Studies.** The proposed Fish and Aquatic Resources studies are limited in scope and should be expanded to include the Bad Creek Reservoir and associated tributaries, or Duke should include an additional study to collect water quality data for Project-related streams. Currently no water quality data exists for Bad Creek Reservoir and the surrounding streams making it impossible to assess current and future water quality conditions in these locations. (See our previous comment regarding Section 6.3.7.2.2 of the PAD on Water Quality Monitoring, and Section 4.1.2 of SD1 regarding Resource Issues – Aquatic Resources.)	Upstate Forever	June 23 2022	Water storage in the upper reservoir consists almost exclusively of pump-backed water from Lake Jocassee; the drainage area of the reservoir is limited to 1.5-square miles. Prior to impoundment, Bad Creek and West Bad Creek were tributaries of Howard Creek, however these streams are now submerged in the upper reservoir. Stream augmentation facilities were constructed at the upper reservoir to augment flows to Howard Creek following construction. As described in Duke Energy's response to Comment No. 35, the system was not subsequently operated or required to be operated for streamflow augmentation. As required by the original Bad Creek license, annual fishery assessments of Howard Creek were conducted prior to, during and following construction. Results from the recovery program suggested the Howard Creek fishery had returned to pre-construction condition by 1995. The last year of monitoring of Howard Creek occurred in 2015. No additional impacts to Howard Creek are expected from the continued operation of the Project. Potential impacts to upland waters and streams due to construction and operation of the Bad Creek II complex will be considered under the Water Resources Study Plan.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
56	Recreation	**21.** As previously mentioned in our comment on Section 8.0 of the PAD, this section should include the most recent future land use maps and comprehensive plans available for the project area in both Transylvania and Jackson counties of North Carolina, and Oconee County, South Carolina. Oconee County recently adopted its "Unified 2020 Comprehensive Plan" on March 3, 2020. From October 2018 through December 2019, Oconee County engaged its local citizens through numerous public meetings, newspaper inserts highlighting the elements of the plan, and a survey for public input. Because the character and density of land that abuts the Project will not be determined solely by Duke Energy, management of the Project as well as the lands in the Project vicinity should consider the vision for the future expressed by Oconee County residents and captured in their plan.	Upstate Forever	June 23 2022	Please see response to Upstate Forever Comment #12 (Comment No. 46).
57	Wildlife & Botanical Resources	**22.** Three new (to South Carolina) fern species have been discovered in Pickens County	Upstate Forever	June 27 2022	Duke Energy appreciates the additional new information, which will be taken into consideration as applicable during conduct of any pre-construction surveys that may be required for sensitive botanical species.
58	Env Justice	**23.** Support FERC's request for Environmental Justice study	Upstate Forever	June 23 2022	In accordance with FERC's study request and as proposed in this PSP (Appendix H), Duke Energy will conduct an Environmental Justice study for the Bad Creek relicensing.
59	Water Resources	**1.** The EPA strongly encourages Duke Energy and FERC to mitigate these impacts by reusing these materials and find other projects in the area that might need fill material, such as old mines, roads, and superfund sites. Further, we strongly recommend avoiding disposing spoil material into water bodies and wetlands. Additionally, we recommend adding all Duke's owned properties in the vicinity of the project on a map that could be considered for disposal of spoil material such as Figure 6.1-2. This information could help the public recommend sensible mitigation or further alternatives.	USEPA	June 27 2022	Please see response to Comment No. 26. Duke Energy plans to provide in the Draft and Final License Application and supporting documents information required by FERC and other regulatory entities, and relevant to the construction and operation of the expanded Project in the new license term. Clean Water Act 401/404 permits will be obtained for construction/impacts activities.
60	General - Climate	**2.** Climate - EPA recommends including more recent climate data.	USEPA	June 27 2022	Please see response to Comment No. 47.
61	Geology and Soils	**3.** The EPA understands that geological issues such as high-in-situ stresses were encountered during the construction of the existing powerhouse, and the EPA recommends including studies regarding possible secondary impacts to the existing powerhouse from proposed excavations. Additionally, if such investigations disclosed probable hazards, then please include mitigations to ensure the existing project's stability.	USEPA	June 27 2022	Studies on geology and geologic hazards were carried out for the Bad Creek II Feasibility study; results will be included in the Revised Study Plan.
62	Aquatic Resources	**4.** The EPA recommends exploring worldwide hard mitigation technologies (besides operational guidelines) that could be applied to prevent/minimize entrainments. Further, the proposed project poses an additional burden to these fisheries.	USEPA	June 27 2022	The updated desktop Entrainment Study suggests that fish populations in Lake Jocassee will experience minor effects from the additional operations of Bad Creek II Complex. As part of the Aquatic Resources Study, Duke Energy will consult with interested stakeholders regarding the results of the entrainment study and any necessary future protection, mitigation, or enhancement measures.
63	Water Resources	**5.** Figure 6.3-5. Lake Jocassee Daily Water Surface Elevation shows the elevations from May 1, 1975, to December 31, 2020. This figure is not clear, please add an additional graph showing the years instead of the "Day of Year."	USEPA	June 27 2022	An additional graphic displaying the year on the X-axis has been developed and is included following this table.
64	Water Resources	**6.** Duke Energy has sufficient time to avoid impacts or mitigate impacts. We recommend pursuing additional innovations to help mitigate water quality, and cumulative impacts.	USEPA	June 27 2022	Duke Energy plans to identify and evaluate, in consultation with stakeholders, potential avoidance and mitigation measures for the construction of the Bad Creek II Complex and propose technically and economically feasible measures in the license application. Due to the scale of the material (primarily rock) excavation for construction of the Bad Creek II Complex, Duke Energy does not presently anticipate that impacts of material disposal can be completely avoided.

Comment No.	Resource Area	Summary of Comment	Stakeholder	Date	Response
65	Water Resources	**7.** Please include information on the existing weir such as possible impacts from spoil dumping. Include how the future dumping could impact Lake Jocassee and the weir as a whole.	USEPA	June 27 2022	The submerged weir is located approximately 550 meters downstream of the Project discharge and was originally constructed to help minimize the effects of mixing downstream of the Whitewater River arm of Lake Jocassee; it has not been modified since the original construction. The weir is composed of rockfill (i.e., spoil from the original Project construction). The weir is not enclosed in the existing FERC Project Boundary for Bad Creek but is included in the Project Boundary for the Keowee-Toxaway Project (Lake Jocassee). If the Bad Creek II Complex is constructed, the weir may be expanded to help mitigate the effects of a second discharge in the Whitewater River arm. Impacts to Lake Jocassee from the potential placement of rockfill at the existing weir will be assessed as part of the Water Resources Study.
66	Water Resources	**8.** Spoil dumping would impact water quality and would impact species. We recommend developing studies in the areas Duke Energy deemed to be ideal for dumping spoil including water bodies and any wetlands.	USEPA	June 27 2022	Estimating impacts from potential spoil placement is an objective of the Water Resources Study and results will be included in the study report and Draft and Final License Application.
67	Water Resources	**9.** EPA recommends including water quality baseline data for the Bad Creek Reservoir. We believe it is important to have this data to compare future data and make accurate determinations and decisions based on data.	USEPA	June 27 2022	Duke Energy will undertake water quality monitoring (continuous temperature and bi-weekly DO) at three historic monitoring sites in the Whitewater River arm of Lake Jocassee in 2023 (two-unit powerhouse operation) and 2024 (four-unit powerhouse operation, with all ongoing upgrades complete). This data will also be used to compare against historical data. Monitoring is not feasible in the Bad Creek upper reservoir due to significant daily water fluctuations and safety issues. Bad Creek reservoir is used only for Project operations and there is no public access. Upland waters and impacts to upland streams and wetlands (as well as Lake Jocassee) will be considered under the future water quality monitoring plan under the Water Resources Study. Including a summary of baseline water quality data for waterbodies that would be impacted by the relicensing is an objective of the Water Resources Study. Baseline data will be used to compare with data collected under pre-construction and post-construction conditions.
68	General - Construction	**10.** The EPA recommends disclosing construction and operational emissions. We recommend best management practices and potentially implementing a Clean Diesel Policy to minimize mobile sources of emissions during construction.	USEPA	June 27 2022	Duke Energy expects to provide necessary information for FERC to complete its Environmental Document in the Final License Application. Best Management Practices are expected to be implemented during the construction phase, but specific measures have not yet been identified at this early stage. Such measures would the subject of construction plans to be developed prior to commencement of construction.
69	Wildlife & Botanical Resources	**1.** Duke Energy has identified several preliminary studies and environmental protection, mitigation, and enhancement measures (PM&E) in its PAD. The Service (USFWS) is in agreement with all of the PM&E measures proposed.	USFWS	June 9 2022	Comment noted; no response required.
70	Wildlife & Botanical Resources	**2.** Several at-risk-species are on the Service's National Listing Workplan to be assessed for listing during the same time frame as the ILP. If any of these species are listed or proposed for listing during that time the Service will notify Duke Energy and work with them to ensure proper protection measures are in place.	USFWS	June 9 2022	Comment noted; no response required.
71	Wildlife & Botanical Resources	**3.** On March 23, 2022, the Service published a proposal to reclassify the northern long-eared bat (NLEB) as endangered under the Endangered Species Act of 1973, as amended. The U.S. District Court for the District of Columbia has ordered the Service to complete a new final listing determination for NLEB by November 2022 (Case 1:15-cv-00477, March 1, 2021). If the final determination is to reclassify to endangered, that reclassification would go into effect 30 days later, which would be sometime during December 2022. The proposed reclassification, if finalized, would remove the current 4(d) rule for the NLEB, as these rules may be applied only to threatened species.	USFWS	June 9 2022	Comment noted. Duke Energy will monitor the status of NLEB, and will re-engage with USFWS as needed to implement conservation measures for this species.
72	Wildlife & Botanical Resources	**4.** It should be noted that the Service does not have any records of the Indiana bat within Oconee County, South Carolina and we believe this species does not need to be included in the list of T&E species to be analyzed.	USFWS	June 9 2022	Comment noted; no response required.

Gray Bat Acoustic Analysis Technical Memo

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Memo

To	Alan Stuart, Duke Energy Carolinas, LLC
From	Kathleen McDaniel, Environmental Resources Management
Date	20 July 2022
Reference	Bad Creek Pumped Storage – Gray Bat Acoustic Analysis

Dear Mr. Stuart,

On behalf of Duke Energy Carolinas, LLC (Duke Energy), ERM NC, Inc. (ERM) conducted bat surveys in the summer and fall of 2021 at the Bad Creek Pumped Storage (BCPS) Project (Project).

The pre-application document (PAD) for the Project was submitted to the Federal Energy Regulatory Commission (FERC) on 23 February 2022. As part of their review of the PAD, the South Carolina Department of Natural Resources (SCDNR) has requested a review of the acoustic files to evaluate potential presence of the gray bat (*Myotis grisescens*).

Therefore, ERM completed an additional review of acoustic files to include this species. Methods were consistent with those described in the previous report submittal (Appendix G of the PAD). Analysis of recorded bat calls was conducted using the Wildlife Acoustics 2019 software program Kaleidoscope Pro, version 5.1.8. The call library used was version 5.1.0, and files were processed on the "0 Balanced (Neutral)" setting. Other signal parameters were left at default values. The output table for the analysis including gray bats is provided in Attachment 1.

The automated results suggested potential presence of gray bats within the Project; however, with all acoustic surveys, it is important that call files be reviewed by an experienced biologist in order to assess overall quality and confidence in automated program results. Recorded files were reviewed, and calls were not identified to species unless they contained clear pulses indicative of search phase behavior. The qualitative review did not find any files that were of sufficient quality to be identified as gray bats with confidence.

Although gray bats share overlap in acoustic call parameters with other *Myotis*, this species generally produces loud, clear calls (unlike other, more difficult-to-record species) and should be readily detected if these bats are foraging in the area. The resume of the biologist conducting the analysis is provided in Attachment 2.

In short, this acoustic analysis did not find sufficiently compelling evidence of gray bat presence within the Project. If SCDNR or other studies have captured gray bats within proximity of the Project, this information should be considered by the Project. However, at this time, ERM knows of no such information, and therefore, recommends an assumption of likely absence of gray bat.

If any additional information is requested regarding this analysis, please do not hesitate to contact me at Kathleen.McDaniel@erm.com or 315-214-9174.

Sincerely,

Kathleen McDaniel

Senior Scientist, ERM

Attachment 1: Acoustic Output Table from Kaleidoscope

Attachment 2: Manual Reviewer Qualifications

Attachment 1: Acoustic Output Table from Kaleidoscope

		Nightly Detections by Species														
Site/Detector/ Night	Date	CORRAF	EPTFUS	LASBOR	LASCIN	LASINT	LASNOC	LASSEM	MYOGRI	MYOLEI	MYOLUC	MYOSEP	MYOSOD	NYCHUM	PERSUB	TADBRA
Site 1a	7/22/2021		331	13	1	6	1	20	18		9		1	7	47	1
	7/23/2021		146	6	2	3	1	36	7		3	1		5	39	1
	7/24/2021		14	20	1	1	2	42	2		12		1	20	22	1
	7/25/2021		25	16	6	3	1	35	1		6	1	6	11	36	1
Site 1b	7/22/2021		19	23		3		21	2	2	11		1	17	23	
	7/23/2021		12	21	1	2		20	2	1	6	4		25	37	
	7/24/2021		17	25	3	2	1	30	5		11	1		18	34	2
	7/25/2021		22	26	8	3	2	23	9	1	16	5	3	18	59	4
Site 2a	7/22/2021		336	2		6		13	18		2		1	2	45	1
	7/23/2021		146	6	2	3	1	36	7		3	1		5	39	1
	7/24/2021		277	8	2	5	1	18	6		5			7	37	10
	7/25/2021		30	6	2	6	1	7	4		4	1	2	2	43	3
Site 2b	7/22/2021		49		1	1			1						3	5
	7/23/2021		40		2	3	1	11	2	1	2		1	4	28	10
	7/24/2021	1	12	1	1	1	1				1		1		5	6
	7/25/2021		22		4	5	2	23	1	1	6		2	4	24	13
Site 3a	7/22/2021		3				2	3							3	
	7/23/2021		16		2	2		3					3	4	2	
	7/24/2021		2	2	9	1	1	4							1	
	7/25/2021		4	1		3		8	2		1	1		1	3	1
Site 3b	7/22/2021		3	2				3	1		2			1	3	
	7/23/2021		10	3					2		4	1	1	2	4	
	7/24/2021		14	1		2	3	1			1					
	7/25/2021		7	5				6	10	1	9	1	1	4	10	
Site 4a	7/22/2021		3	21	20	2	3	51	5		3		3	16	78	3
	7/23/2021		21	45	4	2	1	151	2		14	1	3	81	108	4
	7/24/2021			11	1			16	8		6			4	47	
	7/25/2021		3	20	1	3		36	10		5	1	4	29	136	1
Site 4b	7/22/2021			4	2	2	1	18	2		4		1	2	685	
	7/23/2021		6	33	1	2		84	1		2	1		28	340	
	7/24/2021			1				5			1			7	65	
	7/25/2021			9		1		12	3		4	3	5	20	305	

[a] Species codes: CORRAF (*Corynorhinus rafinesquii*, Rafinesque's big-eared bat), EPTFUS (*Eptesicus fuscus*, big brown bat), LASBOR (*Lasiurus borealis*, eastern red bat), LASCIN (*Lasiurus cinereus*, hoary bat), LASINT, (*Lasiurus intermedius*, northern yellow bat), LASNOC (*Lasionycteris noctivagans*, silver-haired bat), LASSEM (*Lasiurus seminolus*, Seminole bat), MYOGRI (*Myotis grisescens*, gray bat), MYOLEI (*Myotis leibii*, eastern small-footed bat), MYOLUC (*Myotis lucifugus*, little brown bat), MYOSEP (*Myotis septentrionalis*, northern long-eared bat), MYOSOD (*Myotis sodalis*, Indiana bat), NYCHUM (*Nyticeius humeralis*, evening bat), PERSUB (*Perimyotis subflavus*, tri-colored bat), TADBRA (*Tadarida brasiliensis,* Brazilian (Mexican) free-tailed bat).

		Presence P-Values (low numbers indicate confidence in presence													
Site/Detector	Date	CORRAF	EPTFUS	LASBOR	LASCIN	LASINT	LASNOC	LASSEM	MYOGRI	MYOLEI	MYOLUC	MYOSEP	MYOSOD	NYCHUM	PERSUB	TADBRA
Site 1a	7/22/2021	1	0	0.00242	1	1	1	1.01E-05	0	1	0.138785	1	0.945774	1	0	1
	7/23/2021	1	0	0.962581	1	1	1	0	0	1	0.880019	0.131901	1	1	0	1
	7/24/2021	1	0	0.000552	0.967706	1	1	0	0.035939	1	0.006168	1	0.917264	1	1E-07	0.992669
	7/25/2021	1	0	0.002698	0.02166	1	1	0	0.257307	1	0.574049	0.64771	0.000223	1	0	1
Site 1b	7/22/2021	1	0	0	1	0.980101	1	0.000341	0.066074	0	0.069897	1	0.89618	1	0	1
	7/23/2021	1	0	1E-07	0.979673	0.994397	1	0.000494	0.058313	0	0.971663	0.000682	1	0.367809	0	1
	7/24/2021	1	0	0	0.309303	1	1	6E-07	2.45E-05	1	0.146531	0.694879	1	1	0	0.858903
	7/25/2021	1	0	0	0.001288	1	1	0.000362	0	0	0.025496	0.001595	0.465877	1	0	0.577173
Site 2a	7/22/2021	1	0	1	1	1	1	5E-07	0	1	1	1	0.742711	1	0	1
	7/23/2021	1	0	0.962581	1	1	1	0	0	1	0.880019	0.131901	1	1	0	1
	7/24/2021	1	0	0.09672	1	1	1	0.000002	0	1	0.591776	1	1	1	0	1
	7/25/2021	1	0	0.015997	0.986807	0.659013	1	0.044249	4.4E-06	1	0.885661	0.303916	0.298055	1	0	0.522087
Site 2b	7/22/2021	1	0	1	1	1	1	1	0.005237	1	1	1	1	1	0.000262	0.220967
	7/23/2021	1	0	1	1	1	1	2E-07	8.68E-05	0	0.968519	1	0.581425	1	0	0.000169
	7/24/2021	0	0	0.257452	0.993581	1	1	1	1	1	0.739122	1	0.227054	1	2.1E-06	0.000933
	7/25/2021	1	0	1	0.435656	1	1	0	0.019442	0	0.022914	1	0.226284	1	0	7E-07
Site 3a	7/22/2021	1	0.039517	1	1	1	0.433682	0.011905	1	1	1	1	1	1	0.013619	1
	7/23/2021	1	0	1	0.649007	0.99785	1	0.015112	1	1	1	1	0.000235	0.352699	0.165358	1
	7/24/2021	1	0.311361	0.499411	0	0.651176	1	0.040695	1	1	1	1	1	1	0.682907	1
	7/25/2021	1	0.009554	1	1	0.215819	1	0.000094	0.000564	1	0.437912	0.092554	1	1	0.131669	0.60742
Site 3b	7/22/2021	1	0.003328	0.357434	1	1	1	0.176591	0.050303	1	0.285945	1	1	1	0.025381	1
	7/23/2021	1	0	0.014936	1	1	1	1	0.001704	1	0.035839	0.34024	0.556008	0.901696	0.000204	1
	7/24/2021	1	0	0.53084	1	0.992757	0.997572	0.697728	1	1	0.386	1	1	1	1	1
	7/25/2021	1	1.8E-06	0.06462	1	1	1	0.050497	0	0	0.000374	0.553693	0.832451	1	5E-07	1
Site 4a	7/22/2021	1	0.41291	0.002095	0	0.886183	1	0	2.2E-06	1	1	1	0.151562	1	0	1
	7/23/2021	1	0	7.99E-05	0.184993	1	1	0	0.080222	1	0.307889	0.935869	0.393728	1	0	0.405279
	7/24/2021	1	1	0.00155	0.135504	1	1	0.000139	0	1	0.665946	1	1	1	0	1
	7/25/2021	1	0.07566	0.000176	0.645505	0.502607	1	0	0	1	1	0.484422	0.192038	1	0	0.843478
Site 4b	7/22/2021	1	1	0.994463	0.006623	0.220381	1	0	0.000812	1	1	1	1	1	0	1
	7/23/2021	1	5.74E-05	7.39E-05	0.755991	1	1	0	0.374449	1	1	0.391831	1	1	0	1
	7/24/2021	1	1	0.992348	1	1	1	0.002958	1	1	1	1	1	0.98813	0	1
	7/25/2021	1	1	0.007595	1	0.660248	1	0.000467	0.000286	1	1	0.002959	0.574826	1	0	1

[a] Species codes: CORRAF (*Corynorhinus rafinesquii*, Rafinesque's big-eared bat), EPTFUS (*Eptesicus fuscus*, big brown bat), LASBOR (*Lasiurus borealis*, eastern red bat), LASCIN (*Lasiurus cinereus*, hoary bat), LASINT, (*Lasiurus intermedius*, northern yellow bat), LASNOC (*Lasionycteris noctivagans*, silver-haired bat), LASSEM (*Lasiurus seminolus*, Seminole bat), MYOGRI (*Myotis grisescens*, gray bat), MYOLEI (*Myotis leibii*, eastern small-footed bat), MYOLUC (*Myotis lucifugus*, little brown bat), MYOSEP (*Myotis septentrionalis*, northern long-eared bat), MYOSOD (*Myotis sodalis*, Indiana bat), NYCHUM (*Nyticeius humeralis*, evening bat), PERSUB (*Perimyotis subflavus*, tri-colored bat), TADBRA (*Tadarida brasiliensis,* Brazilian (Mexican) free-tailed bat).

Attachment 2: Manual Reviewer Qualifications

Kathleen McDaniel

Senior Scientist, Biological Field Services

Kathleen (O'Connor) McDaniel is a Senior Biologist based in Syracuse, New York. She has over a decade of experience working in impact assessments for endangered species. She is a subject matter expert in bats, particularly the federally listed Indiana bat and northern long-eared bat. She has conducted both active and passive acoustic surveys, has worked with multiple hardware units, and is proficient in all the candidate and approved acoustic analysis software programs. She has experience with Section 7 Consultation, including coordination with USFWS and USFS and assisting with the preparation and review of documents including Biological Assessments, Biological Evaluations, Resource Reports, Critical Impact Assessments, and survey reports. In New York, she has experience with State Environmental Quality Review (SEQR), Incidental Take Permits, and development of mitigation plans for protected species.

Experience: 12 years' experience in IAP

Email: kathleen.mcdaniel@erm.com

Education

- BS. Biology, Union College, United States, 2010

Languages

- English, native speaker

Fields of Competence

- Threatened and endangered species surveys.
- Biological Assessments, Biological Evaluations, Environmental Impact Statements, and Resource Reports.
- Presence/likely absence surveys (mist net and acoustic surveys) for bats, including Indiana bat and northern long-eared bat.
- Federal permit holder (TE83013B-0) for Indiana bats and northern long-eared bats; Qualified Bat Surveyor in Pennsylvania.
- Acoustic analysis, including manual vetting of call files and training others in manual vetting.
- GPS data collection and troubleshooting, including experience with Trimble units and GPS Pathfinder Office.
- Field coordination, data management, and reporting of field surveys.

Key Industry Sectors

- Section 7 consultation
- FERC projects

Key Projects

Confidential Hydroelectric Project

As Project Manager, develop a survey plan and oversee surveys within an approximately 350-acre hydroelectric facility in South Carolina. Led conversations with the client to assess impacts and plan Project activities in real-time. Following capture of state-listed species, expanded scope to including additional habitat assessments and emergence surveys.

Confidential Oil and Gas Project

As a field coordinator, oversaw multiple crews conducting bat acoustic surveys along an approximately 170-mile pipeline through West Virginia. Responsible for the final analysis of all acoustic data. Assisted with agency communication (federal and state) before and after surveys. Provided oversight and communication between field crews and client.

Confidential Solar Development Client

Assisted with the development of multiple Indiana bat conservation plans in Virginia for solar projects in that state. Included review of known records, discussions with agency representatives, and development of the final plans.

Confidential Mining Project

As a biologist, conducted all acoustic analysis for an acoustic survey completed at a mine site in British Columbia. Completed training for internal staff on deployment of bat detectors, and an introduction to manual vetting of acoustic files. Assisted in the preparation of the report, and participated in planning discussions for future baseline surveys within the mine property boundary.

Confidential Oil and Gas Project

As a biologist and team lead, participated in project organization, preparation of study plans and survey reports, professional correspondence with land agents, client and agency contacts on a project involving over 500 miles of proposed pipeline route in West Virginia, Virginia, and North Carolina. Led field teams in bat habitat assessments including roost tree mapping and potential hibernacula surveys. Performed presence/absence surveys according to federal guidance, included acoustic and mist netting surveys. Served as lead acoustic vetter responsible for acoustic analysis of over 500 sites.

Assisted with coordination and consultation efforts, including drafting sections of a Biological Evaluation and Biological Assessment. Participated in calls with USFWS and client to assess impacts to species; review agency-issued documents including Biological Opinion and Final Environmental Impact Statement.

Confidential Solar Project

Conducted Indiana bat and northern long-eared bat acoustic surveys for a project site in southeastern NY. Completed survey effort and agency coordination to determine presence or likely absence of bats within the Project footprint.

Confidential Oil and Gas Project

As a field lead, implemented a bat mitigation effort for a 30-mile pipeline in West Virginia. Effort included the placement of bat boxes (rocket boxes and maternity boxes) to replace potential roosts that had been removed during construction of the Project.

Confidential Wind Project

As bat team lead and Qualified Bat Surveyor, managed field crews on a proposed project approximately 23 miles through Pennsylvania. Key tasks included communication with all bat teams (four teams on site), as well as logistics of field protocols, land access, data management, and crew safety. As a crew lead, conduct mist net surveys and assist with foraging radio-tracking efforts.

Confidential Real Estate Development Project

Prepared permit documents for a proposed 190-acre property in Dutchess County, New York. This included review of wetland survey reports and previous correspondence with USACE, as well as coordination with NYSDEC on protected species known to occur on the property. The Incidental Take Permit to NYSDEC included the development of mitigation plans for Blanding's turtle and bat species.

Confidential Solar Project

Prepared the draft EAF for a 160-acre solar site in Bennington, New York. Drafted and submitted a protected species report and prepared various materials for planning meetings with the town.

Bat Acoustic Workshops

As an instructor, developed and implemented a bat acoustics workshop to provide training in bat acoustics, including equipment management, site selection and setup, and acoustic analysis. Have trained groups from the New York State Department of Environmental Conservation, Vermont Fish & Wildlife Department, New York State Department of Transportation, and the State University of New York College of Environmental Science and Forestry.

Key Projects Prior to Joining ERM

Wildlife Technician at New York State Department of Environmental Conservation

Performed duties for the Endangered Species Unit, focused on bats; executed winter hibernacula surveys; carried out acoustic and mist net surveys; other bat research included attaching radio-transmitters, radio-tracking to roost trees, taking wing tissue samples from live animals.

Acoustic experience included coordination of the state-wide acoustic program summers of 2011-2014. Ensured over 50 routes were run throughout the state in just over six weeks during the summer.

Seasonal Technician at Cary Institute of Ecosystem Studies

Used Sherman traps and Havahart traps to trap small and meso-mammals (mice, chipmunks, squirrels, opossums and raccoons). Extracted mammals from traps and examine in hand to determine sex, age, weight and tick burden. Fed and cared for small mammals and birds, ensuring their health and general well-being.

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Lake Jocassee Surface Water Elevations

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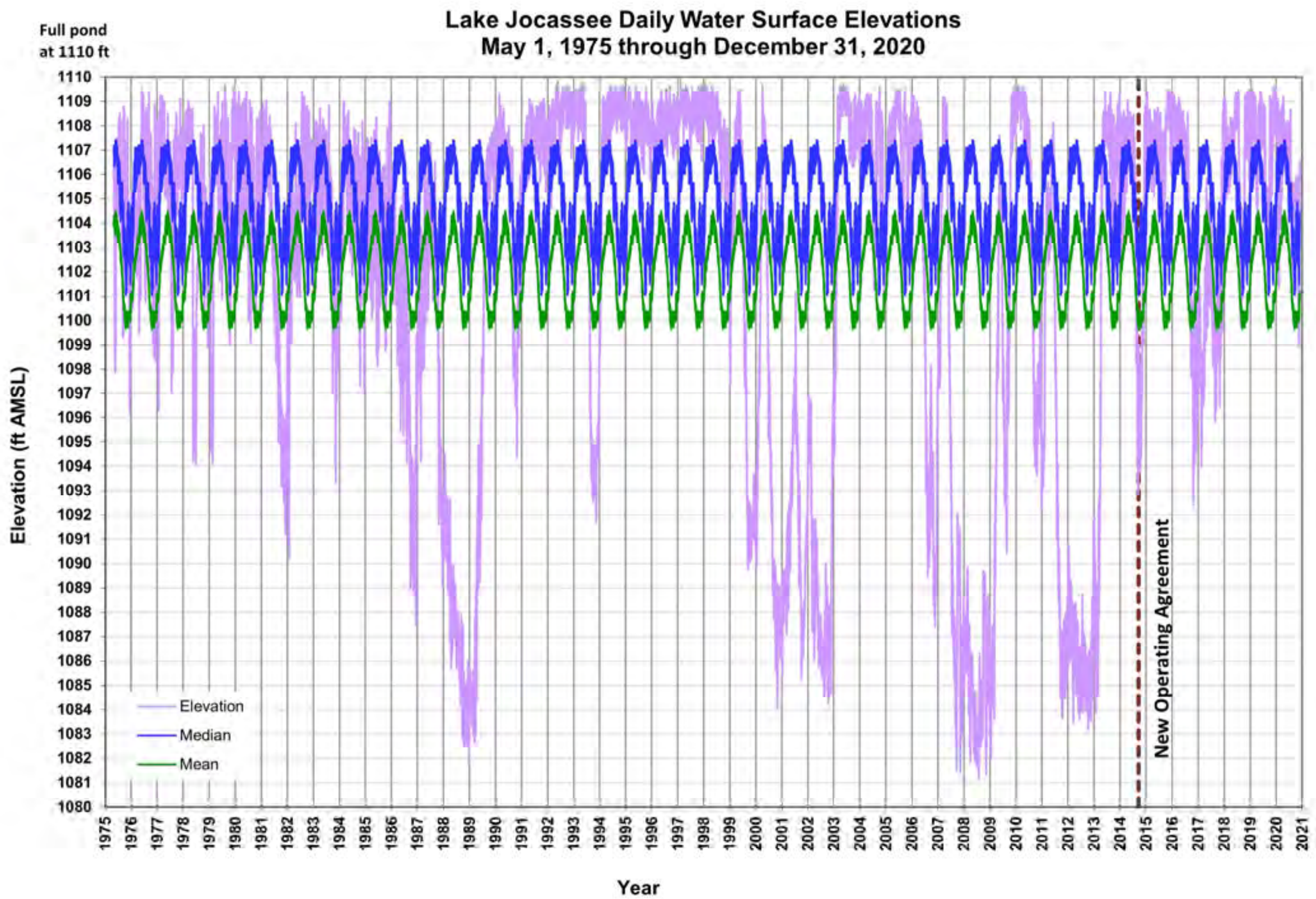
Full pond
at 1110 ft
Lake Jocassee Daily Water Surface Elevations
May 1, 1975 through December 31, 2020
Elevation (ft AMSL)
Year
Elevation
Median
Mean
New Operating Agreement

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Appendix B

Appendix B –
Correspondence

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Bad Creek Stakeholder Kick-off Meeting Summary and Presentation

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Meeting Summary

Project:	Bad Creek Pumped Storage Project (FERC No. 2740)
Subject:	Bad Creek Relicensing Stakeholder Team Kick-off Meeting
Date:	Tuesday, May 31, 2022
Location:	Duke Energy - Greenville Office 425 Fairforest Way Room 100 Greenville, SC 29607

Attendees: Elizabeth Miller (SC DNR)
Rowdy Harris (SCPRT)
Sue Williams (Advocates for Quality Development)
Gerry Yantis (Advocates for Quality Development)
Phil Mitchell (Fisher Knob HOA)
Andrew Gleason (Foothills Trail Conservancy)
Bill Ranson (Foothills Trail Conservancy)
Glen Hilliard (Foothills Trail Conservancy - Advisor)
Dale Wilde (Friends of Lake Keowee Society)
Wes Cooler (Naturaland Trust)
Andy Douglas (SC Wildlife Federation)
Chris Starker (Upstate Forever)
Erika Hollis (Upstate Forever)
Michael Abney (Duke Energy)
Jennifer Bennett (Duke Energy)
Ed Bruce (Duke Energy)
Jeff Lineberger (Duke Energy)
Christy Churchill (Duke Energy)
John Crutchfield (Duke Energy)
Lynne Dunn (Duke Energy)
Paul Keener (Duke Energy)
Maverick Raber (Duke Energy)
Alan Stuart (Duke Energy)
Nick Wahl (Duke Energy)
Ben Williamson (Duke Energy)
Sarah Kulpa (HDR)
Maggie Salazar (HDR)

Overview

This meeting summary provides documentation of the Duke Energy Carolinas, LLC Bad Creek Pumped Storage Project (Project) stakeholder meeting in support of the Project relicensing. The meeting was held in person at Duke's office in Greenville, SC. A copy of the presentation and a copy of the sign-in sheets are attached to this meeting summary (Attachments 1 and 2).

Welcome and Introductions

Alan Stuart welcomed participants, reviewed the agenda, and introduced the purpose of the meeting. Individuals provided an introduction and signed in. A. Stuart noted that the U.S. Fish and Wildlife Service and the S.C. Department of Health and Environmental Control will participate in the core stakeholder group, but could not attend this meeting. Chris Starker asked if the cultural resource agencies and Tribes will participate. A. Stuart confirmed the tribal entities to which Duke and FERC have reached out (Eastern Band of Cherokee Indians, Catawba Indian Nation, United Keetowah Band of Cherokee Indians, Cherokee Nation of Oklahoma, and also noted that Dr. Wenonah Haire (Catawba Indian Nation Tribal Historic Preservation Officer) asked for a copy for the Pre-Application Document (PAD) which was sent. A. Stuart thanked participants who had returned and completed the stakeholder “application” he recently distributed.

Participants introduced themselves and described their role/interest in the relicensing, including:

- Fisher Knob HOA – 21 homeowners, shared access road off Highway 130, concerned about access during construction and interest in developing a secondary access road
- Upstate Forever – multiple issues, including focus on clean water
- Naturaland Trust – ownership of 500 acres in the vicinity of Lake Jocassee and in the vicinity of the Bad Creek-Jocassee transmission corridor
- Advocates for Quality Development – focus on sustainable and quality development in Pickens and Oconee Counties
- Friends of Lake Keowee Society – natural resource education, environmental monitoring
- SC Wildlife Federation – preservation and habitat protection and enhancement, adopt-a-stream programs

Safety Moment

A. Stuart presented a safety moment on distracted driving.

Project Overview

A. Stuart familiarized participants with the Project location. As a follow-up to a question raised during the Scoping Meeting about alternate pumped storage sites previously studied by Duke Energy, A. Stuart presented the approximate locations of the Coley Creek and Limber Pole project tracts. Duke Energy retains ownership and development rights of these parcels for future pumped storage development. A. Stuart explained that Duke expects to retain these rights, because future generation and storage needs are uncertain, but does not have any active plans for their development. A. Stuart noted that the Foothills Trail goes through the Coley Creek tract. Wes Cooler asked what the boundaries shown on the presentation slide represent, and A. Stuart noted that it is just the parcel boundary, not a particular project or reservoir boundary and pointed out the conceptual dam locations on the figure. A. Stuart noted that Coley Creek Project Tract is likely the Long Spur Ridge site brought up by Chris Starker in the Scoping Meeting. A. Stuart noted that Duke had put together a pre-filing application for Coley Creek 20-30 years ago but it was never filed with FERC. Jeff Lineberger clarified that the size of the project boundary scaling is not to scale on the figure shown but is generally accurate depicting the potential locations, however Lake Jocassee is a prime location for pumped storage due to the elevation and rainfall.

A. Stuart updated the group on the ongoing Bad Creek powerhouse upgrades.

A. Stuart provided examples of Relicensing (or Settlement) Agreements including both “off-license” (i.e., outside of FERC jurisdiction and project boundary) and “in-license” agreements. A. Stuart noted that a settlement agreement with the stakeholders is a desirable outcome for this relicensing.

A. Stuart reviewed the Integrated Licensing Process (ILP process and reasoning for choosing this regulatory process instead of the Traditional Licensing Process (TLP).

A. Stuart noted that Duke Energy is anticipating making a decision in 2024 (prior to the license application filing) on whether to advance the development proposal for the Bad Creek II Complex, but that Duke Energy could change direction before or after that time. In the event that the license issued by FERC (expected 2027) includes provisions for construction and protection, mitigation and enhancement measures (PME) for Bad Creek II, and the project is then cancelled by Duke, Duke would pursue an amendment of the license to remove these conditions. A. Stuart noted that a cost benefit analysis will be internally reviewed for the Bad Creek II Complex at multiple points over the next few years, and cost could inhibit the viability of the project expansion. However, A. Stuart clarified that at this point, construction of the Bad Creek II Complex is a good path forward for storing more energy needed to meet Duke’s generation needs for current and future renewable generation.

A. Stuart reinforced that this group will be the core stakeholders and reviewed expectations, including time commitments, agreement (not signing) with the terms of a charter, and process efficiency. Specific Resource Committee meetings will be set up by Duke Energy resource specialists. Meeting summaries will be taken and shared with the larger stakeholder group. A. Stuart reviewed the Resource Committee Duke leads:

- Lead Technical Manager – John Crutchfield
- Aquatics – Mike Abney and Nick Wahl
- Cultural Resources – Christy Churchill
- Recreation & Aesthetics – Jennifer Bennett
- Water Quality – Maverick Raber
- Operations – Lynne Dunn and Ed Bruce
- Wildlife & Botanical – Mike Abney and Scott Fletcher

A. Stuart clarified that the Proposed Study Plans will be worked on this year. Sarah Kulpa noted that baseline terrestrial surveys had been performed in support of the PAD, and detailed species surveys are not proposed for the ILP, because project construction isn’t scheduled to begin until 2027. Where detailed species (or wetlands) surveys are required by regulatory agencies, Duke would expect to perform those at an appropriately close interval prior to disturbance.

A. Stuart told the group that a secure SharePoint site will be used for sharing files, reviews, and document control. S. Kulpa reminded the group of the public website and noted the SharePoint site would be internal to the core stakeholder group. HDR will provide technical support/troubleshooting for SharePoint access. Access is easier if individuals have a Microsoft online/365 account. A. Stuart suggested a virtual tutorial for using SharePoint. A. Stuart noted that correspondence logs will be maintained through the relicensing. A. Stuart hopes to do quarterly newsletters so that stakeholders can share with their constituents.

A. Stuart noted that site visits to (tours) the Bad Creek facility are starting to being held again now that the COVID pandemic is subsiding. Availability of Duke Energy's group bus is necessary for scheduling. Interested individuals and organizations should contact Duke.

A. Stuart reviewed the overall relicensing schedule and provided milestones and important comment periods for the stakeholders, FERC staff, and Duke Energy.

Dale Wilde noted that FOLKS support the Bad Creek II Complex, however recommended Duke Energy to increase their public engagement and information sharing, so misinformation is not spread. A. Stuart agreed and noted that the public website is a means to disseminate information to anyone who wants it. A. Stuart will look into public meetings or an additional education campaign further internally.

A. Stuart added that later in the process, Duke Energy would likely engage a professional facilitator for stakeholder meetings (similar to role of Ken Kearns – now retired – in the Keowee-Toxaway relicensing). Duke has not yet identified a facilitator and welcomes suggestions from the group.

J. Lineberger noted that the relicensing process is much different than when the Bad Creek Project was originally constructed.

A. Stuart noted that the next stakeholder meeting would be in near the near future, but date is TBD. Greenville will likely be the meeting point since there are people coming from Charlotte, NC and Charleston, SC. Resource Committee group leads will schedule the meetings and provide next steps. Virtual (Teams) meetings will also be utilized to increase stakeholder team meeting efficiencies and reduce travel.

A. Stuart asked the group for identification of representative and alternative/or agency contacts by June 14, 2022 and sign up for Resource Committees by June 23, 2022.

Attachment 1

Attachment 1 – Meeting Presentation

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Bad Creek Hydroelectric Project (FERC No. 2740)

Relicensing Stakeholder Kick-off Meeting

May 31, 2022

MEETING AGENDA

- Welcome
- Safety Moment
- Introductions
  - Duke Energy
  - Consultants
  - State and Federal Agencies
  - Local and County Governments
  - Non-Governmental Organizations
- Bad Creek Project and Relicensing Process Presentation
- Lunch (provided)
- Relicensing Process Next Steps/2022 Detail Schedule Review
- Open Discussion
- Action Items
- Adjourn

Safety Moment – Distracted Driving

Every day about 8 people in the U.S. are killed in crashes reported to involve a distracted driver.

Stay focused and avoid phone calls and text messages

If you need to read directions, pull over

Don't reach for items while driving

Make all adjustments before driving (mirrors, phone holder, seat position, etc.)

Keep your emotions in check

Introductions

- Duke Energy
- Consultants
- State and Federal Agencies
- Local and County Governments
- Non-Governmental Organizations

Today’s Objectives

Introduce Relicensing in Detail

Background Information

Integrated Licensing Process

Duke’s Relicensing Process

Request Participation

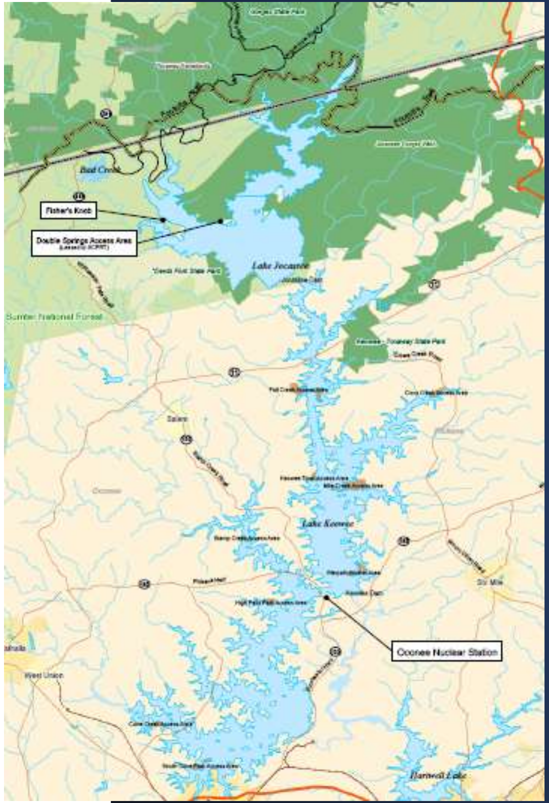
Process Input/Feedback

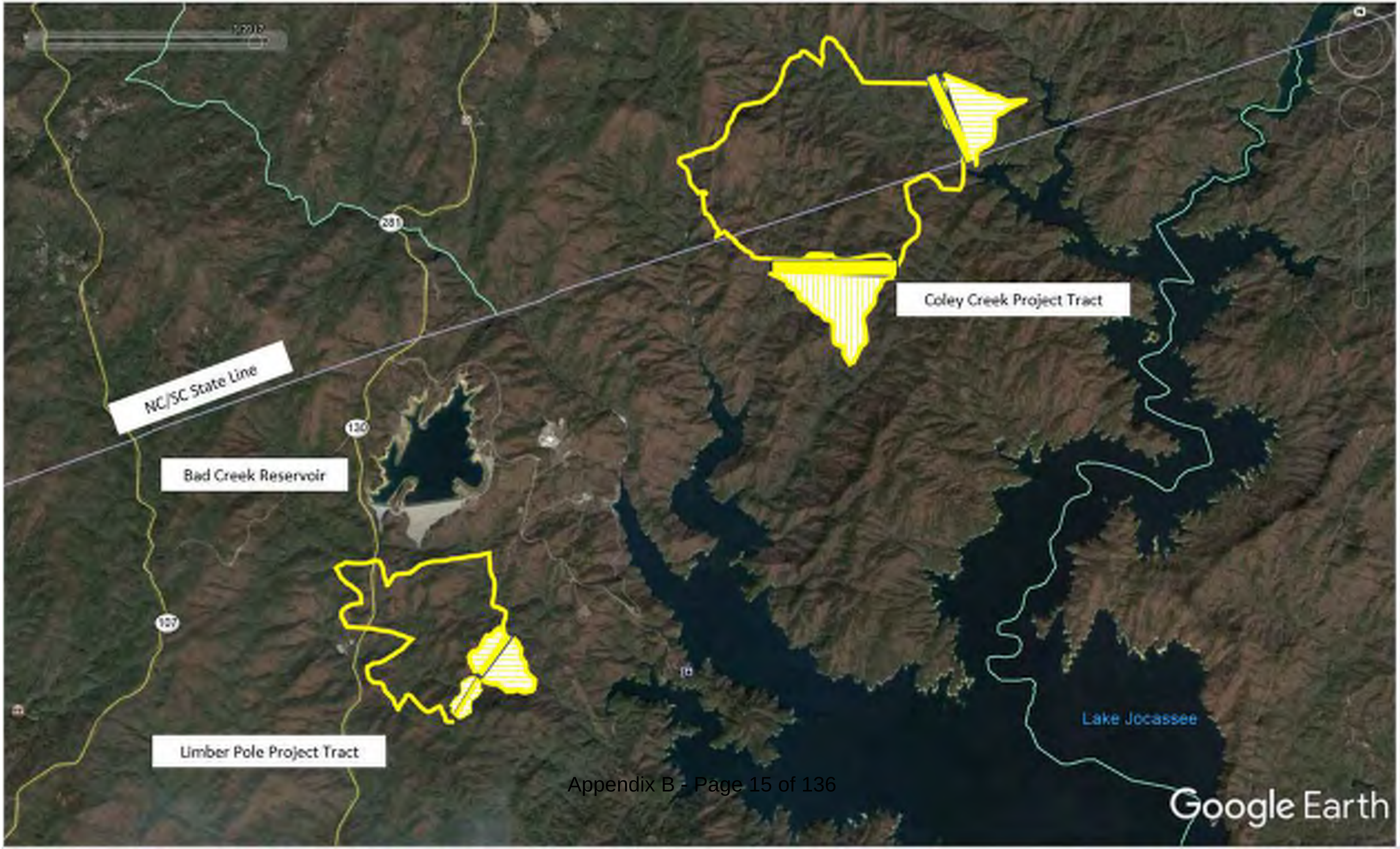
Stakeholder Team

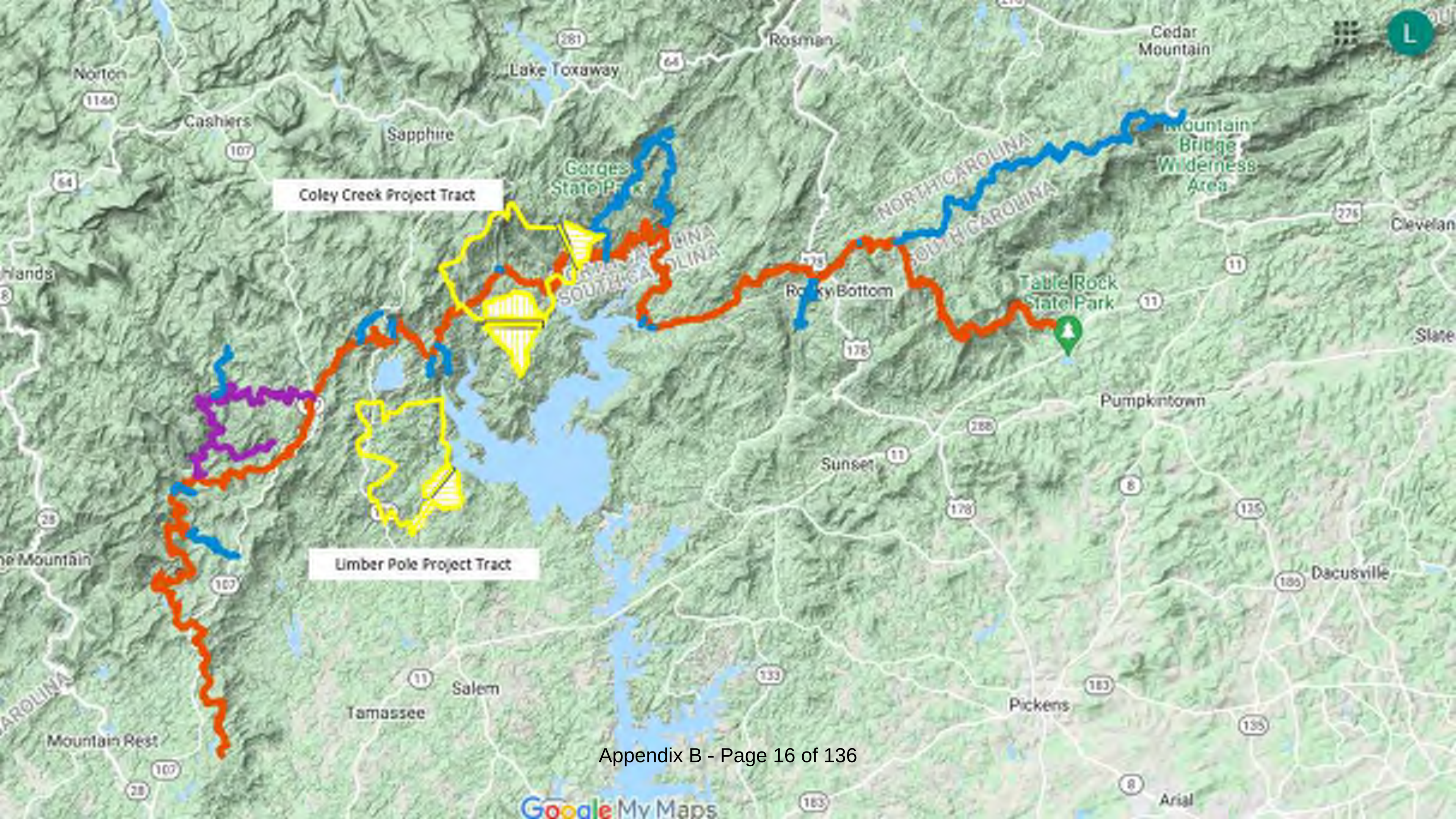
- Resource Committees

BC Project - Overview

- Single Development
    - Oconee County, SC
- Original License Issued 1977
- License Application Due July 31, 2025

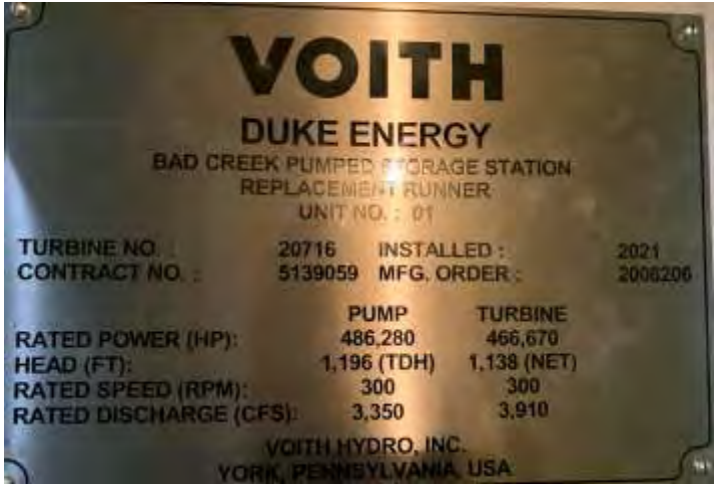



Coley Creek Project Tract
NC/SC State Line
Bad Creek Reservoir
Limber Pole Project Tract
Lake Jocassee
Google Earth


Coley Creek Project Tract
Limber Pole Project Tract
Cedar Mountain
Rosman
Lake Toxaway
Norton
Cashiers
Sapphire
Gorges State Park
Mountain Bridge Wilderness Area
NORTH CAROLINA
SOUTH CAROLINA
Rocky Bottom
Table Rock State Park
Pumpkintown
Sunset
Cleveland
Dacusville
Salem
Tamassee
Mountain Rest
Pickens
Arial
Google My Maps

BC Powerhouse

- 1,400 MW Authorized Installed Capacity
- 4 - Pumped/Generator Turbines
    - Francis Style
    - Maximum Hydraulic Capacity = 19,760 cfs (Gen Mode)
    - Unit rotation speed = 300 rpms (Gen mode)

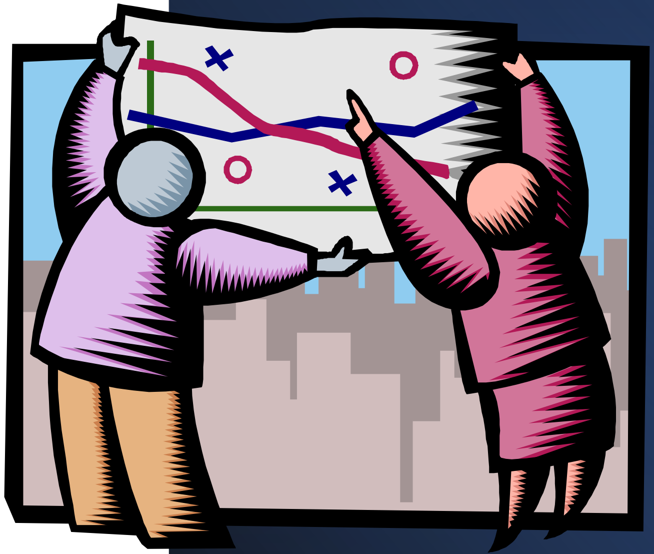


Existing Uprated Bad Creek – Maximum Flow		
Item	Turbine Mode	Pump Mode
Duration (hours)	20	26
MWh	30,379	38,803
Maximum Power (MW)	1,695	1,595

Existing Uprated Bad Creek – Best Efficiency		
Item	Turbine Mode	Pump Mode
Duration (hours)	23	26
MWh	31,440	38,803
Maximum Power (MW)	1,426	1,595

Duke Energy's Relicensing Roles

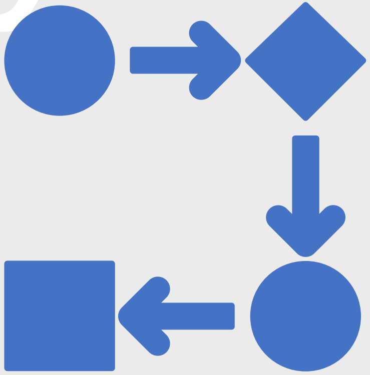
- File a timely & complete application
  - Conduct studies
  - Maintains schedules
  - Prepares documents
- Convener
  - Sponsors Stakeholder Team
  - Coordinates Resource Committees



Stakeholder Interests

- Sustainable, cost-effective solutions
- Cooperation
- Mutual-gain negotiations
- Relicensing Agreement

The Relicensing Process



Integrated Licensing Process (ILP)

ILP	TLP/ALP
Rigid timeline	Process can linger
PAD	First Stage Consultation Document
Scoping early in process	Scoping after license application is filed
Study Plan approval by FERC	No study approval

ILP Lessons Learned

Stay ahead of the process

Understand the process and schedule

Study criteria

Objective of study

Resource management goals OR Public interest considerations

Existing data and reason more is needed

Project nexus

Methodology

Cost considerations

Be efficient with communications & meetings

Bad Creek ILP Relicensing Timeline Overview

RELICENSING STAKEHOLDER TEAM

FEDERAL AGENCIES

- ❑ U.S. Fish and Wildlife Service
- ❑ U.S. Forest Service – Sumter National Forest

SOUTH CAROLINA STATE AGENCIES

- ❑ South Carolina Department of Archives and History
- ❑ South Carolina Department of Health and Environmental Control
- ❑ South Carolina Department of Natural Resources
- ❑ South Carolina Department of Parks, Recreation & Tourism

TRIBES

- ❑ Catawba Indian Nation
- ❑ Eastern Band of Cherokee Indians

LOCAL GOVERNMENT

- ❑ Oconee County

NON-GOVERNMENTAL ORGANIZATIONS

- ❑ Advocates for Quality Development
- ❑ Fishers Knob Homeowners Association
- ❑ Foothills Trail Conservancy
- ❑ Friends of Lake Keowee Society
- ❑ Naturaland Trust
- ❑ South Carolina Wildlife Federation
- ❑ Upstate Forever

Expectations for Stakeholders

5-year time commitment

Quarterly meetings transition to monthly

Resource Committee Meetings more frequent and as needed

Charter

Attendance requirements

Conduct in and out of meetings

Process Efficiency

Electronic communications & tools

Efficient use of meeting time

Virtual Meetings ok so long as they are productive and useful in keeping deadlines.

Relicensing Agreements (RA)

- Optional
- Resolve all substantial issues
- Legally binding contracts
- Duke RAs
  - Keowee-Toxaway
  - Nantahala
  - Tuckasegee
  - Catawba-Wateree

Electronic Communications

Communications Protocol

Objectives

- Efficient dissemination of information
- Limit paper consumption
- Maintain consultation record

Primary Communications Channels will be Electronic

Electronic Communications

- Meeting notices, agenda, summaries, study plans, study reports – Email & Website
- Quarterly Newsletters- Email
- Information Requests will be funneled through respective Resource Committee
- Study reports – Email & Website*
- Preliminary Licensing Proposal, License Application – Website and DVD*

** Hard copies available to agencies and tribes upon written request*

BC Relicensing: Resource Committees

- Lead Technical Manager (John Crutchfield)

- Aquatics (Mike Abney and Nick Wahl)
- Cultural Resources (Christy Churchill)
- Recreation & Aesthetics (Jennifer Bennett)
- Water Quality (Maverick Raber)
- Operations (Lynne Dunn and Ed Bruce)
- Wildlife & Botanical (Mike Abney and Scott Fletcher)

Study Request Criteria

Describe	Describe the goals and objectives of each study proposal and the information to be obtained.
Explain	If applicable, explain the relevant resource management goals of the agencies or Indian tribes with jurisdiction over the resource to be studied.
Explain	If the requester is not a resource agency, explain any relevant public interest considerations in regard to the proposed study.

Study Request Criteria (cont.)

Describe	Describe existing information concerning the subject of the study proposal, and the need for additional information.
Explain	Explain the nexus between project operations and effects on the resource to be studies, and how the study results would inform the development of license requirements.
Explain	Explain how any proposed study methodology is consistent with generally accepted practice in the scientific community or, as appropriate, considers relevant tribal values and knowledge.

Study Request Criteria (cont.)

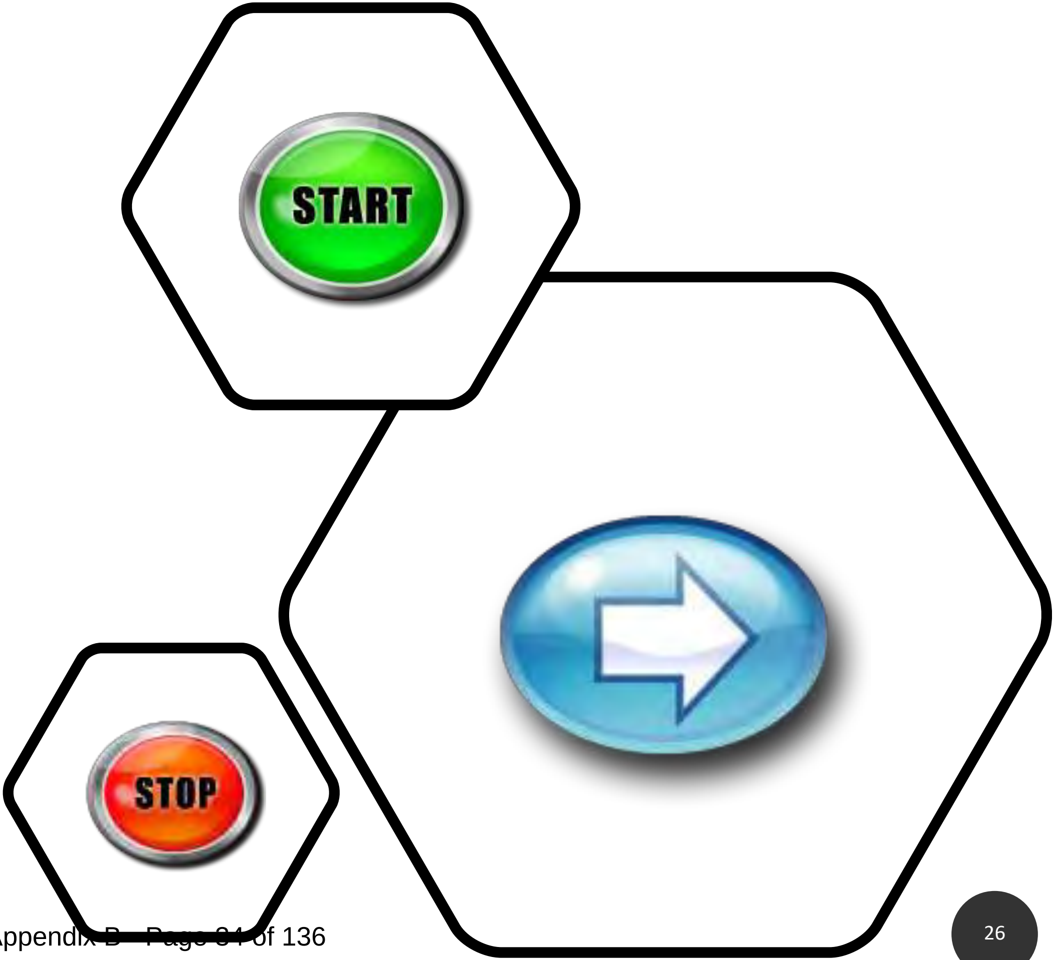
Describe	Describe considerations of level of effort and cost, as applicable, and why any proposed alternative studies would not be sufficient to meet the stated information needs.

Study Plan Criteria

The potential applicant's proposed plan must include with respect to each study:

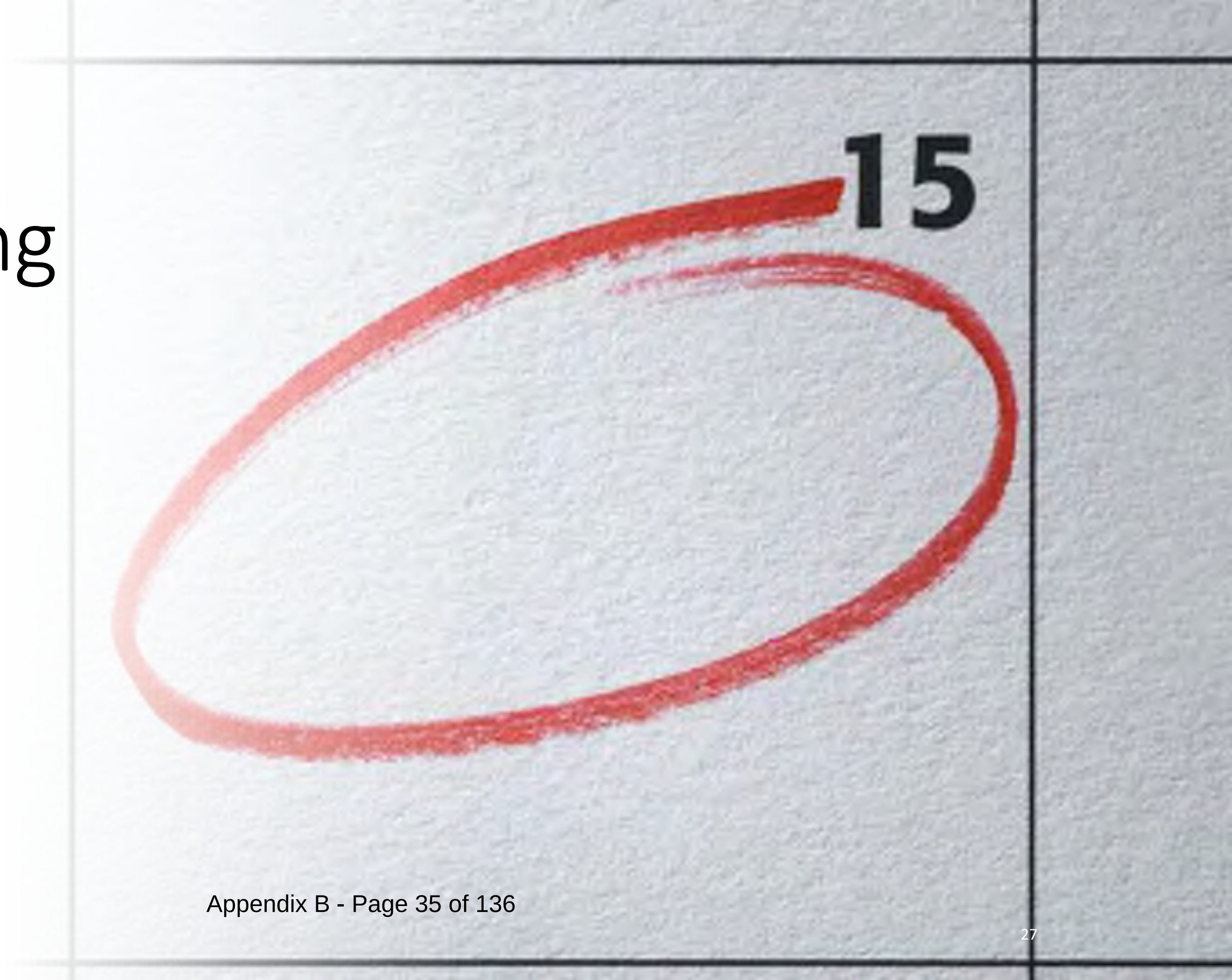
1. A detailed description of the study and methodology used
2. A schedule for conducting the study
3. Provisions for periodic progress reports
4. If the potential applicant does not adopt a proposed study, an explanation of why the study was not adopted.

Process Improvements

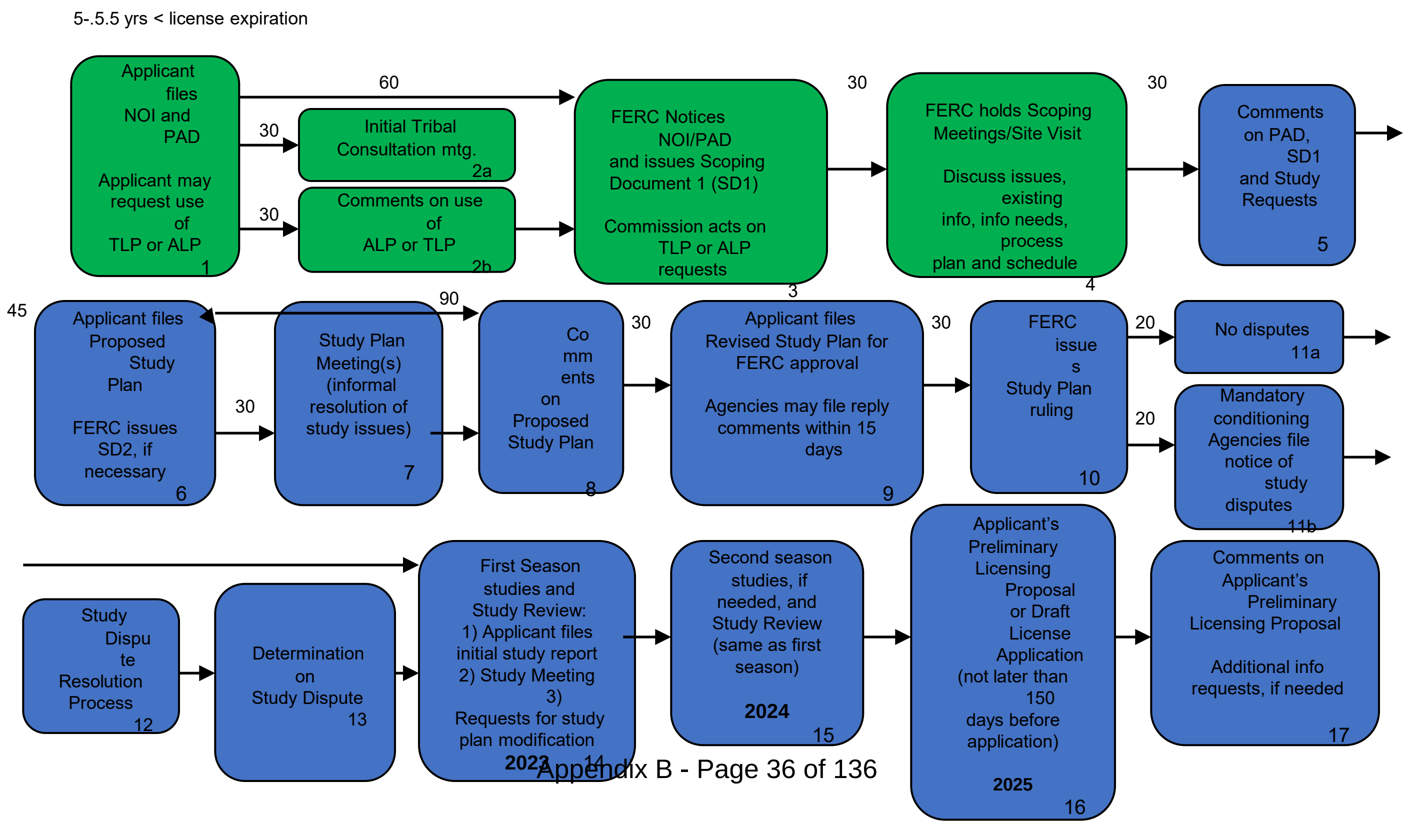


Relicensing Process

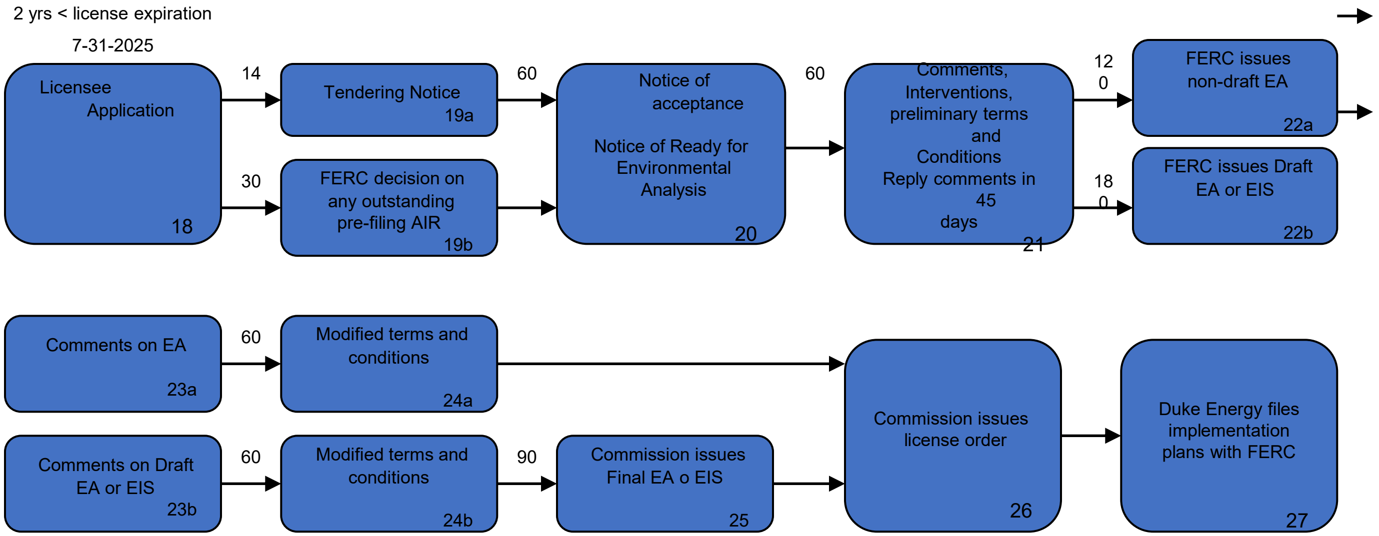
Detail Schedule



Bad Creek ILP: Pre-Application Activities



Bad Creek ILP: Post-Application Activities



Bad Creek Relicensing Dates
2023: Filing of PAD
2025: Filing of License Application
2027: Existing License Expires

Activity	Responsible Parties	Timeframe	Estimated Filing Date or Deadline
File Notice of Intent (NOI) and Pre-application Document (PAD) (18 CFR §5.5(d))	Licensee	Within 5 years to 5.5 years prior to license expiration	Feb 23, 2022
Initial Tribal Consultation Meeting (18 CFR §5.7)	FERC	No later than 30 days following filing of NOI/PAD	Mar 25, 2022
Issue Notice of NOI/PAD and Scoping Document 1 (SD1) (18 CFR §5.8(a))	FERC	Within 60 days following filing of NOI/PAD	Apr 24, 2022
Conduct Scoping Meetings and site visit (18 CFR §5.8(b)(viii))	FERC	Within 30 days following Notice of NOI/PAD and SD1	May 16-17, 2022
Comments on PAD, SD1, and Study Requests (18 CFR §5.9(a))	Licensee Stakeholders	Within 60 days following Notice of NOI/PAD and SD1	June 23, 2022
Issue Scoping Document 2 (SD2), if necessary (18 CFR §5.10)	FERC	Within 45 days following deadline for filing comments on PAD/SD1	Aug 7, 2022
File Proposed Study Plan (PSP) (18 CFR §5.11)	Licensee	Within 45 days following deadline for filing comments on PAD/SD1	Aug 7, 2022
PSP Meeting (18 CFR §5.11(e))	Licensee	Within 30 days following filing of PSP	Sep 6, 2022
Comments on PSP (18 CFR §5.12)	Stakeholders	Within 90 days following filing of PSP	Nov 5, 2022
File Revised Study Plan (RSP) (18 CFR §5.13(a))	Licensee	Within 30 days following deadline for comments on PSP	Dec 5, 2022
Comments on RSP (18 CFR §5.13(b))	Stakeholders	Within 15 days following filing of RSP	Dec 20, 2022
Issue Study Plan Determination (18 CFR §5.13(c))	FERC	Within 30 days following filing of RSP	Jan 4, 2023
Conduct First Season of Studies (18 CFR §5.15)	Licensee	-	Spring-Fall 2023
File Study Progress Reports (18 CFR §5.15(b))	Licensee	Quarterly	Spring 2023 -Fall 2024
File Initial Study Report (ISR) (18 CFR §5.15(c))	Licensee	Pursuant to the Commission-approved study plan or no later than 1 year after Commission approval of the study plan, whichever comes first	Jan 4, 2024

Action Items

- Formal Request
    - Stakeholder Team Representative & Alternate OR Agency contact(s) (June 14, 2022)
- Resource Committees Formed (June 23, 2022)

Questions

Contact

BC Relicensing Project Manager

Alan Stuart

Alan.Stuart@duke-energy.com

980.373.2079

Attachment 2

Attachment 2 – Sign-In Sheet

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NAME	AFFILIATION	PRIMARY PHONE NUMBER
Bill Ranson	Foothills Trail Conservancy	864.325.1702
Andrew Gleason	Foothills Trail Conservancy	864-546-1589
Elizabeth Miller	SCDNR	843-953-3881
WES COOLER	NATURALAND TRUST	864.918.3826
Dale wilde	Friends of lake keowee	207-604-6539
John Crutchfield	Duke Energy	919-757-1095
Chris Starker	Upstate Forever	864-250-0500 x115
Erika Hollis	Upstate Forever	864-250-0500 x117
PHIL MITCHELL	FISHER KNOB HOMEOWNERS ASSOC AT BAD CREEK	864-614-9481
Nick Wahl	Duke Energy	980-875-4705
Maggie Salazar	HDR	610-299-0959
Sarah Kulpa	HDR	315-415-8703
Michael Abney	Duke Energy	704-975-4358
Ed Bruce	Duke Energy	704-607-3734
Jennifer Bennett	Duke Energy	828-546-3168.

Bad Creek Relicensing (FERC No. 2740)
Stakeholder Team Kick-off Meeting
May 31, 2022

NAME	AFFILIATION	PRIMARY PHONE NUMBER
Lynne Dunn	Duke Energy	910-417-1338
Paul Keener	Duke Energy	704.215.0559
Christy Churchill	Duke Energy	704 975 2008
Glenn Hilliard	Foothills Trail Conservancy	(678) 938-6258
Gerry Yantis	AQD · Advocates for Quality Development	571-205-3256
Sue Williams	AQD	619-892-8660
Andy Douglas	SC Wildlife Fed	864 380 6983
Jeff Lineberger	Duke Energy	704-564-5613
MAVERICK RABER	DUKE ENERGY	919-698-2522
BEN WILLIAMSON	DUKE ENERGY	770-362-4857
Randy Harris	SCPRT	864-992-2328

FERC and Stakeholder Study Requests and Comments

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FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, D.C. 20426
June 16, 2022

OFFICE OF ENERGY PROJECTS

Project No. 2740-053 – South Carolina
Bad Creek Pumped Storage Project
Duke Energy Carolinas, LLC

Via FERC Service

Alan Stuart
Duke Energy Carolinas, LLC
Mail Code EC-12Q
526 S. Church Street
Charlotte, NC 28202

Reference: Staff Comments on the Pre-Application Document and Study Request for the Bad Creek Pumped Storage Project

Dear Mr. Stuart:

We have reviewed the Pre-Application Document (PAD) for the relicensing of Duke Energy Carolinas, LLC's (Duke Energy) Bad Creek Pumped Storage Project No. 2740-053 (Bad Creek Project), filed on February 23, 2022, and participated in the scoping meetings for the project during the week of May 16, 2002.

Based on our review of the PAD and the scoping meetings, we need additional information and clarification on the material presented in the PAD. The additional information (see the attached Schedule A) should be filed with the proposed study plan on or before August 7, 2022. If the requested information is not readily available, the proposed study plan should discuss Duke Energy's plans for gathering the information prior to filing the final license application. We are also requesting a study related to environmental justice (Schedule B).

If you have any questions, please contact Navreet Deo at (202) 502-6304, or navreet.deo@ferc.gov.

Sincerely,

Stephen Bowler, Chief
South Branch
Division of Hydropower Licensing

Attachments: Schedule A
Schedule B

SCHEDULE A
ADDITIONAL INFORMATION REQUESTS

General

1. The PAD includes several maps of the existing project facilities, proposed facilities, and areas of potential affect if Duke Energy Carolinas, LLC (Duke Energy) decides to pursue the Bad Creek II Complex (Complex) as part of its relicensing proposal. To facilitate review of the existing project facilities and resources, as well as the facilities and resources that could be affected by the construction, operation, and maintenance of the Complex, please file the following geographic information system (GIS) data layers shown in the PAD, if available: (1) existing project features layout with callout labels (figure 5.4-12; and figure 2 in Appendix E); (2) proposed Complex features layout with callout labels (figure 5.4-13; and figure 2 in Appendix E); (3) potential spoil locations relative to surface waters with spoil area labels and surface water impact callout labels (figure 6.3-7); (4) the estimated riparian and littoral zones from the desktop analysis, and wetlands from the field assessment with callout labels (figure 6.6-2); (5) protected species habitat polygons and photo location points (figure 6.6-4); and (6) Foothills Trail layer, parking area and connector trail to the Foothills Trail in the Bad Creek Project boundary, other recreational facilities in the project vicinity, and the state and federal land layers (figure 6.8-1).

Project Facilities and Operation

2. Section 5.4 of the PAD provides a description of existing project facilities. However, for some project features we need additional detail (i.e., composition, dimension, etc.) to gain a more complete understanding of project facilities and operation. To assist us in our analysis, please provide: (1) the composition, method of repair, and frequency of repair, of the Bad Creek Project dam (main dam) flashboards; (2) the length (feet) of the Bad Creek Upper Reservoir (upper reservoir) intake channel; (3) the length and composition of the upper reservoir dewatering dam; (4) the width (feet) of each of the two, sluice gates located in the upper reservoir dewatering dam, as well as a description of the gates' operation, uses, and frequency of use; (5) the total number, dimensions (i.e., length and height)), and clear bar spacing (inches) of the trash rack structure(s) attached to the steel lift gates in the lower reservoir (Lake Jocassee)[1] inlet/outlet structure; (6) the dimensions (i.e., length and diameter) and composition of the manifold tunnel as part of the larger water conveyance system; (7) the number, length, composition, and uses of, the secondary penstocks; (8) the dimensions (i.e., height

[1] The Keowee-Toxaway Relicensing Agreement includes operating provisions and protection, mitigation, and enhancement measures associated with the Keowee-Toxaway Hydroelectric Project No. 2503 (Keowee-Toxaway Project). Lake Jocassee, the Bad Creek Project's lower reservoir, is part of the Keowee-Toxaway Project.

and width) of each of the four draft tube gates; and (9) the number, length, and voltage (V) of the project generator lead(s).

3. Section 5.4.5 of the PAD describes an existing, submerged weir that is not part of the licensed project facilities. However, the PAD states that the weir helps minimize the effects of project operation on the natural stratification of Lake Jocassee and cold-water fish habitats by preventing warm water discharged by the project from mixing with cool water in the lower layers of the lake. So that we have a full understanding of project facilities and operation, please clarify: (1) the composition and dimensions (feet) of the weir; (2) if the weir is used for normal project operation; and (3) if the weir is enclosed by the existing project boundary, or will be enclosed within the project boundary, as part of Duke Energy's relicensing proposal.

4. Section 5.4.12 of the PAD states that the total maximum hydraulic capacity of the four, reversible pump-turbine units is 19,760 cubic feet per second (cfs), when the project operates in generation mode. So that we can have a full understanding of any differences between pumping and generating, please clarify: (1) the total maximum hydraulic capacity of the units when operating in pumping mode; and (2) provide the minimum and maximum hydraulic capacity of each of the pump-turbine units in both generation and pumping modes.

5. Section 5.6 of the PAD describes potential changes to project facilities and operation that would result from the current proposal to construct and operate a second powerhouse as part of the new Complex. The proposal includes four new, variable-speed pump-turbine units, which would increase both the generating and pumping capacity of the project. The Complex would also include a new water conveyance system consisting of additional inlet/outlet structures for both the upper and lower reservoirs.

The PAD also states that while the existing license authorizes operation of the upper reservoir within a 160-foot fluctuation band (between 2,310 feet mean sea level (msl) and 2,150 feet msl), as of January 1995 the upper reservoir surface elevation is maintained within a 60-foot band (between 2,310 feet msl and 2,250 feet msl).

Please clarify whether operation of the proposed Complex features, specifically use of the additional pump-turbine units, would result in any changes to the upper reservoir water surface fluctuation band.

Fisheries and Aquatic Resources

6. Section 6.3.7 of the PAD provides information about existing water quality monitoring data associated with the project. However, the PAD does not indicate whether any water quality monitoring has been conducted in Howard Creek or at the

project discharge structure. So that we have a full understanding of all aquatic resource monitoring conducted at the project, please describe any water quality monitoring that has occurred in Howard Creek or at the project discharge structure during the current license term, and if so, please file the data in Microsoft Excel, or a similar format.

7. Section 7.1.2.2 of the PAD indicates that operation of the proposed Complex would not result in additional water level rise in Lake Jocassee compared to existing operation. However, the same section does not indicate whether the Complex would result in additional lowering of the water level in Lake Jocassee. So that we have a full understanding of proposed project operation, please describe whether the Complex would result in lower water levels in Lake Jocassee compared to existing operation, and if so, please estimate the magnitude of any additional changes in water level.

Terrestrial Resources and Threatened and Endangered Species

8. Section 6.1.3 of the PAD describes the land uses within the Bad Creek Project boundary based on the U.S. Geological Survey's National Land Cover Database. Table 6.1-3 and figure 6.1-3 show land uses at the upper reservoir (excluding the full transmission line corridor), including 3.7 percent of land categorized as "cultivated crops" which appear to be located immediately adjacent to the main dam. However, in other project figures, such as 5.4-1 and 5.4-2, this same area appears to be rock and/or barren land that is part of the dam, surrounded by forested land. In addition, table 6.1-3 and figure 6.1-3 show 2.0 percent of land within the project boundary (excluding the full transmission line corridor) categorized as "hay/pasture" in various pockets surrounding the shoreline of the reservoir and the transformer yard and switchyard. However, in other figures in the PAD, these areas appear to be maintained as lawn areas or part of earthen dams. Please clarify the land uses immediately adjacent to the main dam and confirm whether any cultivated crops or hay/pasture areas occur within the project boundary.

9. Section 6.5.3 of the PAD indicates that Duke Energy maintains vegetation: (1) in project access areas on an as needed basis; (2) in the existing transmission line corridor on a regular basis; and (3) on the faces of the project dams in accordance with the FERC-approved Dam Safety Surveillance and Monitoring Plan. The PAD does not provide any other detail about vegetation management at the project. To facilitate review of existing project operation and maintenance activities that affect terrestrial resources, please provide a detailed description of the management of native and non-native invasive[2]

[2] Section 6.5.2.2 of the PAD lists invasive species of concern in South Carolina and specifies that non-native invasive plants, such as Japanese honeysuckle, Japanese knotweed, Japanese stiltgrass, multiflora rose, princess tree/royal paulownia, and tree-of-heaven, were observed during Duke Energy's 2021 field surveys of the existing project transmission line corridor.

vegetation (i.e., any manual, mechanical, chemical, and/or biological) that occurs along project access roads, within the transmission line corridor right-of-way, the area surrounding upper reservoir, and adjacent to other project facilities. If herbicides are used to control vegetation within the project boundary, please provide the location(s), schedule(s), and method(s) of application (e.g., foliar and stump/stem/vine).

10. Section 6.7.1.3.4 of the PAD discusses the potential for monarch butterflies and their habitats to occur within the project boundary. The PAD indicates that during Duke Energy's reconnaissance field surveys, suitable habitat for the monarch butterfly, including milkweeds (Asclepias spp.) and a variety of other flowering plants for nectar, as well as nighttime roosting trees such as willows and pines were observed within the forested areas in the maintained right-of-way. This section of the PAD also includes general statements about vegetation management practices, such as mowing only from November 1st through April 1st (i.e., outside the monarch's breeding and migration period), that could alleviate potential effects to this species from proposed actions at the project. In addition, it states that Duke Energy is an active partner in the "Monarch Candidate Conservation Agreement with Assurances program" (Monarch Program). However, there is no description of any current vegetation management and other practices that Duke Energy implements to benefit monarchs. Please provide a detailed description of the Monarch Program, Duke Energy's role in this program as it relates to management and operation of the Bad Creek Project, and any measures that are currently implemented to protect monarchs at the project.

11. Section 6.5.2 of the PAD provides information about wildlife, including a reference to observations of over 170 species of birds (i.e., eBird volunteer birding database, 2021), in the project vicinity. However, the PAD does not include information about any avian interactions that may have been observed with the project transmission line or switchyard (e.g., nest building, perching, electrocutions, collisions, and any outages related to such interactions). Please provide any available data regarding observed/documented avian interactions with the existing project transmission lines and switchyard.

In addition, so that we may understand the potential for avian interactions with the transmission lines and the switchyard, please include information about the configuration and maintenance of the project transmission lines and switchyard as they relate to avian protection. Please indicate whether the existing project transmission line poles and conductors are consistent with the Avian Power Line Interaction Committee (APLIC) and the U.S. Fish and Wildlife Service (FWS) guidelines to minimize adverse interactions (i.e., potential avian electrocutions and collisions) (APLIC, 2006 and 2012; and APLIC and FWS, 2005). Please provide detailed descriptions, figures, and/or diagrams of the design of the project transmission lines and any existing avian protection devices installed on them. If any avian protection measures are currently proposed for the existing or new transmission lines associated with the Complex, please provide the specifications and location(s) of these measures and a description of their consistency with APLIC guidelines, if applicable. If Duke Energy has an Avian Protection Plan for the Bad Creek Project, or for all of its hydropower projects that include transmission lines, please file a copy of the current plan.

12. Section 6.6.3 and the Natural Resource Assessment in Appendix E of the PAD discuss the potential effects of constructing the proposed Complex infrastructure and of disposing spoils in wetlands and surface waterbodies in the project area (e.g., dredging, filling, clearing, and de-watering). The PAD indicates that approximately 4 million cubic yards of spoil material for the Complex infrastructure would need to be deposited at on-site spoil locations and at the existing submerged weir in Lake Jocassee. Table 6.6-7 provides a preliminary assessment of potential spoil locations and the estimated impacts to wetlands and surface waters. This table indicates that there are five locations that Duke Energy prefers for spoil disposal (i.e., areas A, B, F, G, and I) and four other locations with the potential for spoil disposal (i.e., C, D, E, and H). However, the PAD does not describe the criteria used to assess the potential spoil disposal areas or provide an explanation of why areas A, B, F, G, and I were selected as preferred locations as opposed to areas C, D, E, H, or other, off-site potential spoil disposal areas. Please file a detailed description of how the potential spoil disposal areas are being identified, sized, assessed, and selected as Duke Energy's preferred locations for this purpose. Please update table 6.6-7 to include a comparison of the estimated acreage of forested uplands and wetlands that would be removed, filled, or otherwise affected at each potential spoil disposal area.

13. Sections 6.7.1.1.1 and 6.7.1.1.2 of the PAD describe the potential for the Indiana bat and northern long-eared bat and their winter and summer habitats to occur within the project boundary. The PAD indicates that one small cave/den was identified in the project boundary that could be used as winter hibernacula for these species. We are unable to find any other information about this cave/den in the PAD, including in the 2021 Bat Survey Report in Appendix G of the PAD. To facilitate review of the existing information about bats and their habitats in the project boundary, please: (1) provide a written description of the cave/den including a general location within the project boundary,[3] size, and the estimated proximity to the existing and proposed project facilities, as well as current project operation and maintenance activities; (2) clarify whether the cave/den was surveyed during Duke Energy's 2021 field surveys; and (3) describe any bats or signs of bats that were observed, if applicable.

This section of the PAD also indicates that large trees with peeling bark and snags with cavities or crevices suitable for summer roosting habitat and potential foraging

[3] In the interest of protecting potential habitat in the cave/den, please do not file the precise location.

habitat for Indiana and northern long-eared bats were abundant within the project boundary. There are general statements about the benefits of limiting tree removal to the period when these species are inactive (i.e., November 15th through March 31st), and a general proposal to coordinate with FWS prior to any tree clearing activities. However, it is not clear what, if any, practices Duke Energy currently implements to benefit Indiana and northern long-eared bats. It also is not clear if Duke Energy currently consults FWS prior to tree clearing activities, or if that is strictly a proposal for relicensing with or without the Complex. Please provide a description of any measures that are currently implemented to protect Indiana and northern long-eared bats and/or other bat species at the project, if any. In addition, please note that if the Complex is ultimately proposed as part of the relicensing process, additional information will be needed in the license application regarding the number of trees that would be removed or disturbed during project construction, operation, and maintenance.

Recreation, Land Use, and Aesthetics

14. Section 6.8 of the PAD describes the non-project Foothills Trail, which is managed through off-license agreements with the Foothills Trail Conservancy. During scoping meetings for the project, several individuals commented on the need to maintain or improve access to the Foothills Trail as part of the relicensing of the Bad Creek Project. Please clarify whether or not Duke Energy intends to evaluate improvements to the Foothills Trail (including additional parking areas or trailheads) as part of the project's relicensing.

15. During scoping meetings, several individuals commented about potential effects of construction of the Bad Creek II Complex on access to the Foothills Trail. Please describe how construction of the Complex would affect access to or use of access roads, parking areas, or trailheads associated with the Foothills Trail. Please also discuss construction-relate effects to the trail itself and trail users, including changes in quality of the recreation experience during construction. Provide a discussion of the timing and duration of any effects in relation to the recreation season and the trail's peak use periods.

Noise, Air Quality, and Traffic

16. Section 5.6 of the PAD describes Duke Energy's preliminary proposal for construction of the Complex and the PAD provides some description of anticipated effects of construction of the Complex on environmental resources. So that we have a full understanding of the potential effects of construction of the Complex on environmental and other resources, please provide a description of the anticipated effects of construction on noise (including frequency, duration, and level in decibels), air quality (including airborne debris and dust, as well as heavy vehicle emissions), and traffic (including proposed routes for heavy equipment used for construction or spoil disposal,

temporary or permanent road closures, and parking or laydown areas for vehicles or equipment).

Literature Cited

APLIC (Avian Power Line Interaction Committee). 2012. Reducing Avian Collisions with Power Lines: The State of the Art in 2012. Edison Electric Institute and APLIC. Washington, D.C.

APLIC. 2006. Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006. Edison Electric Institute and APLIC. Washington, D.C.

APLIC and FWS (U.S. Fish and Wildlife Service). 2005. Avian Protection Plan Guidelines. Available at: https://www.aplic.org/uploads/files/2634/APPguidelines_final-draft_Aprl2005.pdf. Accessed January 24, 2022.

SCHEDULE B
ADDITIONAL STUDY REQUEST

To assist Commission staff with its analysis under the National Environmental Policy Act (NEPA), we recommend that the Duke Energy Carolinas, LLC conduct an Environmental Justice Study (EJ Study) for the Bad Creek Pumped Storage Project (Bad Creek Project). Pursuant to section 5.9 of the Commission's regulations we address the seven study request criteria below.

Environmental Justice Study

Goals and Objectives

§5.9(b)(1) Describe the goals and objectives of each study proposal and the information to be obtained.

The proposed EJ Study has five objectives: (1) to identify presence of environmental justice communities that may be affected by the relicensing of the Bad Creek Project, including the construction of the Complex, and identify outreach strategies to engage the identified environmental justice communities in the relicensing process, if present; (2) to identify the presence of non-English speaking populations that may be affected by the project and identify outreach strategies to engage non-English speaking populations in the relicensing process, if present; (3) to discuss effects of relicensing the project on any identified environmental justice communities and identify any effects that are disproportionately high and adverse; (4) to identify mitigation measures to avoid or minimize project effects on environmental-justice communities; and (5) to identify sensitive receptor locations within the project area and identify potential effects and measures taken to avoid or minimize the effects to such locations, if they are present.

Relevant Resource Management Goals and Public Interest Considerations

§5.9(b)(2) — If applicable, explain the relevant resource management goals of the agencies or Indian tribes with jurisdiction over the resource to be studied.

Not applicable.

§5.9(b)(3) — If the requester is not a resource agency, explain any relevant public interest considerations in regard to the proposed study.

Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad,*[1] and Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations*,[2] as amended, require federal agencies to consider if impacts on human health or the environment would be disproportionately high and adverse for environmental justice communities in the surrounding community resulting from the programs, policies, or activities of federal agencies.

Further, Sections 4(e) and 10(a) of the Federal Power Act require the Commission to give equal consideration to all uses of the waterway on which a project is located, and what conditions should be placed on any license that may be issued. In making its license decision, the Commission must equally consider the environmental, recreational, fish and wildlife, and other non-developmental values of the project, as well as power and developmental values.

Existing Information and Need for Additional Information

§5.9(b)(4) Describe existing information concerning the subject of the study proposal, and the need for additional information.

The information necessary to conduct an identification of environmental justice communities near the project is available through the U.S. Census Bureau's American Community Survey; however, such information must be aggregated and compared in order to make determinations about the presence of environmental justice communities within the project area. The nature of effects of the project on any communities present would need to be determined through consultation with the communities, and are dependent on the applicant's relicensing proposal.

Project Nexus

§5.9(b)(5) Explain any nexus between project operations and effects (direct, indirect, and/or cumulative) on the resource to be studied, and how the study results would inform the development of license requirements.

Project construction, operation, and maintenance has the potential to affect human health or the environment in environmental justice communities. Examples of resource impacts may include, but are not necessarily limited to, project-related effects on: erosion

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[1] 86 Fed. Reg. 7,619-7,633 (January 27, 2021).

[2] 59 Fed Reg. 7,629-7,633 (February 16, 1994).

or sedimentation of private properties; groundwater or other drinking water sources; subsistence fishing, hunting, or plant gathering; access for recreation; housing or industries of importance to environmental justice communities; and construction-or operation-related air quality, noise, and traffic.

Proposed Methodology

§5.9(b)(6) Explain how any proposed study methodology (including any preferred data collection and analysis techniques, or objectively quantified information, and a schedule including appropriate field season(s) and the duration) is consistent with generally accepted practice in the scientific community or, as appropriate, considers relevant tribal values and knowledge.

Below, we provide the methodology that Commission staff has adopted for collecting environmental justice data for hydroelectric projects. This methodology has been successfully employed on a number of projects in the licensing process and is consistent with guidance from the Environmental Protection Agency's *Promising Practices for EJ Methodologies in NEPA Reviews* (2016).[3] Please prepare an Environmental Justice Study Report that provides the following:

a) A table of racial, ethnic, and poverty statistics for each state, county, and census block group within the geographic scope of analysis. For the project, the geographic scope of analysis is all areas within 1 mile of the project boundary, and within 5 miles around the proposed construction of the Complex. The table should include the following information from the U.S. Census Bureau's most recently available *American Community Survey* 5-Year Estimates for each state, county, and block group (wholly or partially) within the geographic scope of analysis:

    i. Total population;

    ii. Total population of each racial and ethnic group (i.e., White Alone Not Hispanic, Black or African American, American Indian and Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, some other race, two or more races, Hispanic or Latino origin [of any race]) (count for each group);

[3] Available online at https://www.epa.gov/sites/default/files/2016-08/documents/nepa_promising_practices_document_2016.pdf.

iii. Minority population including individuals of Hispanic or Latino origin as a percentage of total population;[4] and

iv. Total population below poverty level as a percentage.[5]

The data should be collected from the most recent *American Community Survey* files available, using table #B03002 for race and ethnicity data and table #B17017 for low-income households. A template table is provided below.

b) Identification of environmental justice populations by block group, using the data obtained in response to part a above, by applying the following methods included in EPA's *Promising Practices for EJ Methodologies in NEPA Reviews* (2016).

i. To identify environmental justice communities based on the presence of minority populations, use the "50-percent" and the "meaningfully greater" analysis methods. To use the "50-percent" analysis method, determine whether the total percent minority population of any block group in the affected area exceeds 50-percent. To use the "meaningfully greater" analysis, determine whether any affected block group affected is 10-percent greater than the minority population percent in the county using the following process:

1. Calculate the percent minority in the reference population (county);

2. To the reference population's percent minority, add 10-percent (i.e., multiply the percent minority in the reference population by 1.1); and

3. This new percentage is the threshold that a block group's percent minority would need to exceed to qualify as an environmental justice community under the meaningfully greater analysis method.

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[4] To calculate the percent total minority population, subtract the percentage of "White Alone Not Hispanic" from 100 percent for any given area.

[5] To calculate percentage of total population below poverty level, divide the total households below the poverty level by the total number of households and multiply by 100.

ii. To identify environmental justice communities based on the presence of low-income populations, use the "low-income threshold criteria" method. To use the "low-income threshold criteria," the percent of the population below the poverty level in the identified block group must be equal to or greater than that of the reference population (county).

c) A map showing the project boundary and location(s) of any proposed project-related construction in relation to any identified environmental justice communities within the geographic scope. Denote on the map if the block group is identified as an environmental justice community based on the presence of minority population, low-income population, or both.

d) A discussion of anticipated project-related effects on any environmental justice communities for all resources where there is a potential nexus between the effect and the environmental justice community. For any identified effects, please also describe whether or not any of the effects would be disproportionately high and adverse.

e) If environmental justice communities are present, please provide a description of your public outreach efforts regarding your project, including:

i. a summary of any outreach to environmental justice communities conducted prior to filing the application (include the date, time, and location of any public meetings beyond those required by the regulations);

ii. a summary of comments received from members of environmental justice communities or organizations representing the communities;

iii. a description of information provided to environmental justice communities; and

iv. planned future outreach activities and methods specific to working with the identified communities.

f) A description of any mitigation measures proposed to avoid and/or minimize project effects on environmental justice communities.

g) Identification of any non-English speaking groups, within the geographic scope of analysis, that would be affected by the project (regardless of whether the group is part of an identified environmental justice community). Please describe your previous or planned efforts to identify and communicate with these non-English speaking groups, and identify and describe any measures that you propose to avoid and minimize any project-related effects non-English speaking groups.

h) If new construction is proposed, identification of sensitive receptor locations (e.g., schools, day care centers, hospitals, etc.) within the geographic scope of analysis. Show these locations on the map generated in step c. Provide a table that includes their distances from project facilities and any project-related effects on these locations, including measures taken to avoid or minimize project-related effects.

This study should be conducted in consultation with other relicensing stakeholders who express interest. When you file your final study report with the Commission, please include documentation of any consultation you conducted with entities that expressed interest in environmental justice, copies of their comments, and an explanation of how you have addressed their comments in your final response.

Environmental Justice Data Table Template

	RACE AND ETHNICITY DATA										LOW-INCOME DATA
Geography	**Total Population (count)**	**White Alone Not Hispanic (count)**	**African American (count)**	**Native American/ Alaska Native (count)**	**Asian (count)**	**Native Hawaiian & Other Pacific Islander (count)**	**Some Other Race (count)**	**Two or More Races (count)**	**Hispanic or Latino (count)**	**Total Minority (%)**	**Below Poverty Level (%)**
State											
County or Parish											
Census Tract X, Block Group X											

<u>Level of Effort and Cost</u>

§5.9(b)(7) Describe considerations of level of effort and cost, as applicable, and why any proposed alternative studies would not be sufficient to meet the stated information needs.

The estimated cost of all efforts to complete this study is $50,000.

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E., Room 1A
Washington, D.C. 20426

Re: EPA comments on Notice of Intent to File License Application; Filing of Pre-Application Document (PAD), Commencement of Pre-filing Process, Request for Comments on the PAD and Scoping Document, and Identification of Issues and Associated Study Requests for Bad Creek Pumped Storage Project (FERC P-2740), Oconee County, South Carolina.

Dear Secretary Bose:

The U.S. Environmental Protection Agency (EPA) has reviewed the referenced Scoping Document, Pre-Application Document (PAD), and Notice of Intent (NOI) consistent with our responsibilities under Section 102(2)(C) of the National Environmental Policy Act (NEPA), the Council on Environmental Quality regulations (40 CFR Parts 1500-1508), and the EPA's authority under Section 309 of the Clean Air Act. The Federal Energy Regulatory Commission (FERC) proposes to issue a new license for the Bad Creek Pumped Storage Project (P-2740). The existing FERC license expires on July 31. 2027. The proposed project is located at Lake Jocassee, Oconee County, South Carolina. The Bad Creek Pumped Storage is operated by Duke Energy, and Duke Energy is proposing to construct a new power complex that includes a new four-unit underground powerhouse adjacent to the existing Bad Creek Powerhouse. he addition of the proposed Bad Creek II Complex would add 1,400-MW to the current capacity of 1,400-MW for a total of 2,800-MW.

We appreciate the opportunity to comment. If you have any questions regarding our comments, please contact Maria R. Clark at clark.maria@epa.gov or 404-562-9513.

Technical Issues and Recommendations:

5.6.3.3 Rock and Soil Disposal Areas: the PAD states that Duke Energy is presently evaluating areas within the project boundary and property owned by Duke Energy to dispose excavated earth and additional rock.

Recommendation: The EPA strongly encourages Duke Energy and FERC to mitigate these impacts by reusing these materials and find other projects in the area that might need fill material, such as old mines, roads, and superfund sites. Further, we strongly recommend avoiding disposing spoil material into water bodies and wetlands.

Additionally, we recommend adding all Duke's owned properties in the vicinity of the project on a map that could be considered for disposal of spoil material such as Figure 6.1-2. This information could help the public recommend sensible mitigation or further alternatives.

6.1.2 Climate: the PAD includes 30-year climate data for the Oconee County, South Carolina, for the years of 1971-2000 and 1981-2010.

Recommendation: we recommend including more recent data.

6.2.5 Known or Potential Adverse Effects: the PAD states that a geotechnical investigation was conducted for the proposed project, and the final report is expected by early 2023.

Recommendation: The EPA understands that geological issues such as high-in-situ stresses were encountered during the construction of the existing powerhouse, and the EPA recommends including studies regarding possible secondary impacts to the existing powerhouse from proposed excavations. Additionally, if such investigations disclosed probable hazards, then please include mitigations to ensure the existing project's stability.

6.4.2.2.4 Summary of Entrainment Study: the PAD includes results of studies regarding fish entrainment. While the PAD noted that consultations were also conducted with resource agencies and Duke Energy received no objections, we noticed that the PAD's observations described that major die-offs occurred when drawdown was extended.

Recommendation: The EPA recommends exploring worldwide hard mitigation technologies (besides operational guidelines) that could be applied to prevent/minimize entrainments. Further, the proposed project poses an additional burden to these fisheries.

Additional recommendations to include in the proposed studies:

- Figure 6.3-5. Lake Jocassee Daily Water Surface Elevation shows the elevations from May 1, 1975, to December 31, 2020. This figure is not clear, please add an additional graph showing the years instead of the "Day of Year."

- Duke Energy has sufficient time to avoid impacts or mitigate impacts. We recommend pursuing additional innovations to help mitigate water quality, and cumulative impacts.

- Please include information on the existing weir such as possible impacts from spoil dumping. Include how the future dumping could impact Lake Jocassee and the weir as a whole.

- Spoil dumping would impact water quality and would impact species. We recommend developing studies in the areas Duke Energy deemed to be ideal for dumping spoil including water bodies and any wetlands.

- We recommend including water quality baseline data for the Bad Creek Reservoir. We believe is important to have this data to compare future data and make accurate determinations and decisions based on data.

- The EPA recommends disclosing construction and operational emissions. We recommend best management practices and potentially implementing a Clean Diesel Policy to minimize mobile sources of emissions during construction. See the following suitable resources:
    - https://www.epa.gov/dera/reducing-diesel-emissions-construction-and-agriculture
    - https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-air-pollution-nonroad-diesel

United States Department of the Interior

FISH AND WILDLIFE SERVICE
176 Croghan Spur Road, Suite 200
Charleston, South Carolina 29407

June 8, 2022

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE, Room 1A,
Washington, DC 20426

Re: COMMENTS on Notice of Intent to File License Application; Filing of Pre-Application Document (PAD), Commencement of Pre-filing Process, Request for Comments on the PAD and Scoping Document, and Identification of Issues and Associated Study Requests for Bad Creek Pumped Storage Project (FERC No. 2740), Oconee County, South Carolina. FWS Log No. 2022-0030610

Dear Ms. Bose:

The U.S. Fish and Wildlife Service (Service) has reviewed the Federal Energy Regulatory Commission's (Commission) April 22, 2022, Notice of Intent (NOI) to File License Application, Filing of Pre-Application Document (PAD), Commencement of Pre-filing Process, Request for Comments on the PAD and Scoping Document, and Identification of Issues and Associated Study Requests for the above-referenced hydroelectric project. The following comments are submitted in accordance with the provisions of the Fish and Wildlife Coordination Act, as amended (16 U.S.C. 661-667e) and the Federal Power Act (16 U.S.C. 803(a) and (j)).

The Bad Creek Pumped Storage (Project) is located in Oconee County, South Carolina, about eight miles north of the Town of Salem. The project facilities consist of an upper reservoir, a main dam, a west dam, an east saddle dike, a water conveyance system, an underground powerhouse, access roads, and voltage transformation facilities. The project has a total installed capacity of 1,400 megawatts (MW). The total average annual generation of the project is about 1,884,685 megawatt-hours (MWh). The project does not occupy Federal lands.

By letter dated February 23, 2022, Duke Energy Carolinas (Duke Energy) filed a NOI and PAD for a new license for the Project. The current Project license was issued August 1, 1977, and is set to expire on July 31, 2027. In its PAD filed with the Commission, Duke Energy declared its intent to apply for a New License for the Project using the Integrated Licensing Process (ILP) as defined under FERC Regulations (18 CFR Part 5).

During the relicensing process Duke Energy proposes to analyze the potential to develop a Bad Creek II Complex (Complex). The Complex would consist of a new: (a) upper reservoir inlet/outlet structure, (b) water conveyance system, (c) underground powerhouse, (d) powerhouse access tunnels, (e) lower reservoir inlet/outlet structure, (f) switchyard, (g) transformer yard, and (h) transmission line. The Complex powerhouse would include four new, reversible pump-turbine units with an installed generating capacity between 106 MW and 425

MW, and a starting capacity between 308 MW and 372 MW for pumping. Average annual generation for the project would increase by up to 25,856 MWh.

COMMENTS ON SCOPING DOCUMENT 1

3.2.2 Proposed Environmental Measures

Duke Energy has identified several preliminary studies and environmental protection, mitigation, and enhancement measures (PM&E) in its PAD. We are in agreement with all of the PM&E measures proposed.

Terrestrial Resources and Threatened and Endangered Species

Regarding the second bullet, the Service looks forward to working with Duke Energy to determine the need for pre-construction surveys, and/or conservation measures to protect threatened and endangered (T&E) species and at-risk species (ARS). Several of the ARS are on the Service's National Listing Workplan (https://www.fws.gov/project/national-listing-workplan) to be assessed for listing during the same time frame as the ILP. If any of these species are listed or proposed for listing during that time the Service will notify Duke Energy and work with them to ensure proper protection measures are in place.

Regarding the third bullet and the northern long-eared bat (NLEB), on March 23, 2022, the Service published a proposal to reclassify the NLEB as endangered under the Endangered Species Act of 1973, as amended. The U.S. District Court for the District of Columbia has ordered the Service to complete a new final listing determination for the NLEB by November 2022 (Case 1:15-cv-00477, March 1, 2021). If the final determination is to reclassify to endangered, that reclassification would go into effect 30 days later, which would be sometime during December 2022. The bat, currently listed as threatened, faces extinction due to the range-wide impacts of white-nose syndrome (WNS), a deadly fungal disease affecting cave-dwelling bats across the continent. The proposed reclassification, if finalized, would remove the current 4(d) rule for the NLEB, as these rules may be applied only to threatened species.

The Service does not yet know what impact this proposed up-listing will have on tree clearing and similar activities, but we look forward to working with Duke Energy to minimize impacts. Similarly, there is potential for additional bat species to be listed during the ILP.

4.1. Resource Issues.

The Service agrees with the outline of issues that you propose to include in the Environmental Assessment.

4.1.4 Threatened and Endangered Species

It should be noted that the Service does not have any records of the Indiana bat within Oconee County, South Carolina and we believe this species does not need to be included in the list of T&E species to be analyzed.

5.0 Proposed Studies

The Service agrees with the Duke Energy's proposed studies and have no additional study requests.

COMMENTS ON THE PAD

The Service has reviewed the PAD, with a focus on sections with relevance to our interests and authority. In general, it is a comprehensive document that meets purposes and content requirements set forth in §5.6 of FERC's Regulations (18 C.F.R. §5.6).

The Service appreciates the effort put into the development of the PAD and of Scoping Document 1. We look forward to working with the Commission and its staff, Duke Energy, and others throughout the process to meet our collective goals. If you have any questions, please contact Ms. Melanie Olds at (843) 300-0413 or at melanie_olds@fws.gov, and reference FWS No. 2022-0030610.

Sincerely,

Thomas D. McCoy

Thomas D. McCoy
Field Supervisor

ec: eFile
Alan Stuart, Duke Energy
Elizabeth Miller, SCDNR
John Faustini, USFWS Regional Hydrologist and FERC Hydropower Coordinator

South Carolina Department of
Natural Resources

1000 Assembly Street
PO Box 167
Columbia, SC 29202
843-953-3881 Office
millere@dnr.sc.gov

Robert H. Boyles, Jr.
Director

Lorianne Riggin
Director, Office of
Environmental Programs

June 23, 2022

Electronic Transmission

Hon. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

REFERENCE: Comments on the Pre-Application Document, Scoping Document 1, and Study Requests for Bad Creek Pumped Storage Project (P-2740-053).

Dear Secretary Bose:

The South Carolina Department of Natural Resources (SCDNR) has reviewed the Pre-Application Document (PAD) prepared by Duke Energy Carolinas, LLC (Licensee) and Scoping Document 1 (SD1) prepared by the Federal Energy Regulatory Commission (Commission or FERC) for the proposed relicensing of the Bad Creek Pumped Storage Project, FERC Project No. 2740 (Project). The Licensee has chosen to utilize the Commission's Integrated Licensing Process (ILP) to relicense the Project.

This letter is provided in response to the Commission's notice of April 22, 2022, solicitation for public comments on the PAD, SD1, and identification of issues and study requests related to the proposed relicensing of the Project. The SCDNR submits these comments, opinions, and recommendations in accordance with provisions of the Fish and Wildlife Coordination Act, as amended (16 U.S.C. Sec. 661-667); the Federal Power Act (16 U.S.C. Sec. 791 et seq.); the National Environmental Policy Act (42 U.S.C. Sec. 4321 et seq.); and the Electric Consumers Protection Act of 1986 (Pub. L. No. 99-495, 100 Stat. 1243).

Project Description

The Project is located in Oconee County, South Carolina, approximately eight miles north of the Town of Salem. The Bad Creek Reservoir (or upper reservoir) was formed from the damming of Bad Creek and West Bad Creek and serves as the Project's upper reservoir. Lake Jocassee, licensed as part of the Licensee's Keowee-Toxaway Hydroelectric Project (FERC Project No. 2503), serves as the lower reservoir. The Project is located on a headwater tributary of the

Savannah River. The Project facilities consist of an upper reservoir, a main dam, a west dam, an east saddle dike, a water conveyance system, an underground powerhouse, access roads, and voltage transformation facilities. The Project has a total installed capacity of 1,400 megawatts (MW). The total average annual generation of the Project is about 1,884,685 megawatt-hours (MWh). The Project is operated under the terms of the Project's original license, set to expire on July 31, 2027.

The Licensee has proposed to assess the feasibility to develop a Bad Creek II Complex (Complex) during the pre-filing period of the ILP's relicensing process. The Complex would consist of the following new facilities or structures: (a) upper reservoir inlet/outlet structure, (b) water conveyance system, (c) underground powerhouse, (d) powerhouse access tunnels, (e) lower reservoir inlet/outlet structure, (f) switchyard, (g) transformer yard, and (h) transmission line. The Complex powerhouse would include four, new reversible pump-turbine units with an installed generating capacity between 106 MW and 425 MW, and a starting capacity between 308 MW and 372 MW for pumping. Average annual generation for the Project would increase by up to 25,856 MWh. With the new pump-turbine units, generating and pumping capacity would increase due to a combination of an increase in flow and improvement in the hydraulic design of the generation runners. The overall cycle capacity would increase by an estimated 80 percent when all four units are in operation.

SCDNR Responsibilities and Objectives

The SCDNR is the state agency charged by state law with the management, protection, and enhancement of wildlife, fisheries, and marine resources in South Carolina. The SCDNR is responsible for formulating comprehensive policies for water resources through a State Water Plan to address issues affecting water supply, water quality, navigation, hydroelectric power, outdoor recreation, fish and wildlife needs, and other water resource interests. The SCDNR is also charged with the statewide responsibilities for regulating watercraft operation and associated recreation on state waters, conducting geological surveys and mapping, promoting soil and water conservation, management of invasive aquatic plants, flood mitigation, drought response planning and coordination, and the state scenic rivers program. The SCDNR's mission is to serve as the principal advocate for and steward of South Carolina's natural resources. The SCDNR authorities and responsibilities are described in Titles 48, 49, and 50, South Carolina Code of Laws (1976), as amended.

The SCDNR's interests and management objective for the Bad Creek Pumped Storage Project include the protection, enhancement, and restoration of natural resources and their associated values. Specific objectives are to:

- Ensure the FERC license recognizes that the waters and land surrounding the Bad Creek Reservoir, Lake Jocassee, and Savannah River are important public trust resources, and that the Project is managed to achieve public benefits.

- Maintain and/or enhance the water quality conditions to meet state standards and current use classifications that protect and provide for fish and wildlife habitat, contact recreation, and public water supply.

- Ensure the implementation of appropriate water management and downstream flows to be consistent with the South Carolina Water Plan to protect water quality, provide for reasonable navigation, protect fish and wildlife resources, and meet present and future water supply demands (municipal, industrial, agricultural).

- Protect and enhance fish and wildlife populations and their habitat by:
    1. Minimizing entrainment mortality for fish;
    2. Developing shoreline management plans to protect and enhance shoreline and littoral habitats for aquatic species, as well as environmentally sensitive areas and natural communities of concern from future development and shoreline erosion;
    3. Implementing long-term monitoring strategies to ensure protection of key aquatic species and to appraise restoration and enhancement efforts;
    4. Reducing negative effects to stream fish populations caused by habitat fragmentation resulting from the dams and lakes and monitoring the viability of key conservation species potentially impacted by fragmentation, such as rare, threatened, and endangered (RTE) species and species of conservation concern identified in the State Wildlife Action Plan; and
    5. Minimizing the spread of exotic, invasive species; and increasing the acreage of protected natural areas.
- Protect and enhance public opportunities for fishing, hunting, wildlife viewing, boating, and other outdoor recreation by:
    1. Expanding and improving existing areas and facilities to meet user needs;
    2. Developing, based on user needs and capacity, new locations for recreation areas/facilities;
    3. Increasing land areas designated for outdoor recreation and wildlife conservation;
    4. Designing and implementing management plans for facilities to minimize crowding and safety problems.
    5. Ensuring facilities comply with the Americans with Disabilities Act Standards for Accessible Design;
    6. Improving safety and law enforcement among recreational users; and
    7. Protecting aesthetic values within the Project area.

- Protect any significant historic, cultural, or archaeological resources from human and natural impacts.

Comments on PAD

The SCDNR understands the purpose of the PAD is to provide the Commission, federal and state agencies, and other interested stakeholders with background information related to Project facilities and other aspects of the Project, such as engineering, operational, economic, and environmental considerations. The PAD is also intended to define pertinent Project issues and potential study needs. Under FERC regulations, the Licensee is required to complete the PAD using existing, relevant, and reasonably available information that is pertinent to the Project. The SCDNR provides the following comments in response to solicitation for public comment.

Section 5.4.4 Lower Reservoir Inlet/Outlet Structure

This section describes the Project's existing lower reservoir inlet/outlet structure and references steel trash racks. The SCDNR requests information regarding the dimensions and bar spacing of the existing trash rack structure to better understand the Project's impact on aquatic species.

Section 5.4.5 Submerged Weir in Lower Reservoir

This section describes a submerged weir located 550 meters downstream of the Project inlet/outlet structure on the lower reservoir. According to the PAD, the weir's location in the Whitewater River cove serves to dissipate the energy of the discharged water and minimize the effects of warm water from Bad Creek's upper reservoir warm water, by preventing the water from mixing with the lower cool-water layers of Lake Jocassee. The weir was constructed out of nearly half a million cubic yards of rock excavated during the construction of the Project. The SCDNR requests further information regarding 1) the dimensions of the weir (feet), 2) how the Licensee inspects the weir to ensure the weir continues to function as designed, 3) the frequency of inspections, and 4) information on any maintenance that has occurred. Section 6.3.10.2 states that spoil from the proposed construction of the Complex will be added to the downstream slope of the weir. The SCDNR requests further information regarding why the spoil should be added to the weir and how the Licensee selected the downstream slope of the weir. Additionally, since the submerged weir is located 40-50 feet below the water surface, how will the Licensee ensure the correct placement of the spoil and avoid excess turbidity and aquatic habitat degradation during deployment?

Section 5.5.1 Current and Proposed Operations

This section notes that the Licensee currently operates the Project on a "daily cycle" mode, defined as alternating between generating and pumping on a daily basis, with the reservoir typically maintained in the upper 50 to 60 ft at elevations of 2,310 and 2,250 ft msl (compared to a maximum drawdown of 160 ft). However, the PAD does not discuss how the Licensee intends to operate the Project during a subsequent license term with the addition of the proposed Complex. The SCDNR requests further information with regards to the Licensee's proposed operations at the Project including the frequency and magnitude of drawing down and refilling the Bad Creek's upper reservoir.

Section 5.6.2 Proposed Project Facilities

This section discusses the design specifications of the Licensee's proposed Complex. The details included in the upper reservoir's inlet/outlet configuration includes a coarse opening trash rack at each tunnel inlet. However, further specifications of the trash racks, including the bar spacing is not included. Additionally, no such trash rack feature was included in the proposed lower reservoir's inlet/outlet structure configuration. The SCDNR requests the additional information to better understand the Project's effects on aquatic species.

Section 6.1.3.2 Water Use & Table 6.1-5

Table 6.1-5 should include the following waterbodies within the Lake Jocassee Watershed:

Name	**State**	**Description**	**Surface Water Classification**
Coley Creek	SC	The portion of the creek in SC	TPGT
Devils Hole Creek	SC	The entire creek tributary to Lake Jocassee	TPGT
Howard Creek	SC	The portion below Bad Creek to Lake Jocassee	TN
Jackie's Branch	SC	The entire creek tributary to Lake Jocassee	TN
Mill Creek	SC	The entire creek tributary to Lake Jocassee	TPGT

Section 6.1.5 Tributary Rivers and Streams

This section should include Howard Creek, which includes Limber Pole and Corbin Creeks, as a contributing significant tributary draining directly to Lake Jocassee.

Section 6.3.10.1 Impact on Water Exchange Between the Upper and Lower Reservoirs

This section notes that previous analyses have shown that if the entire Bad Creek Reservoir active storage volume was released, then the impact on Lake Jocassee would be a 4-ft increase in water level. The SCDNR notes that the subsequent refilling of the full volume of Bad Creek Reservoir would decrease the elevation of Lake Jocassee by four feet. Additionally, this section notes that the combined capacity of Bad Creek and the Complex would allow the Licensee to reduce the drawdown time from 23 hours to 11 hours and reduce the pumping refill time from 26 hours to 13. Therefore, the additional capabilities of the Complex will allow for twice the amount of water exchange, increasing the likelihood of negative impacts to aquatic species, recreation, water quality, and shoreline erosion rate in the lower reservoir.

Section 6.3.10.3 Spoil Locations & Figure 6.3-7

This section identifies the potential spoil disposal sites to be utilized during the construction of the proposed Complex. The SCDNR notes that the fill impacts appear to be in and around streams. Headwater and wetland systems provide an important link between upland watersheds and downstream aquatic environments. The SCDNR requests further information regarding the alternatives analysis associated with the selection of the areas identified as preferred and potential spoil locations. Additionally, please describe the types of environmental impacts associated with the various alternatives and any avoidance and minimization measures taken. Additionally, the SCDNR recommends that revegetation on spoil piles should be native species appropriate for the ecoregion and should exclude plant species found on the exotic pest plant council list: https://www.se-eppc.org/southcarolina/SCEPPC_LIST2014finalOct.pdf. The SCDNR prefers the use of native warm season grasses and/or other native forbs that would be beneficial for wildlife and pollinators for stabilization for the spoil areas. Native warm season grass species suggestions include switchgrass (*Panicum virgatum*), indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*) and little bluestem (*Schizachyrium scoparium*). A list of beneficial pollinator plant species, such as milkweed (Asclepias spp.), for the southeast may be found at www.xerces.org/pollinators-southeast-region/ or by visiting http://www.pollinator.org/guides. The SCDNR strongly discourages the use of Sericea Lespedeza (*Lespedeza cuneata*) due to its invasive nature and lack of benefit to wildlife[1].

Section 6.4.2 Environmental Studies and Agreements under the Work Plans

The SCDNR finds value in continuing to monitor and mitigate for fish entrainment impacts, especially to forage species, at the Project. The additional pumping cycles at the proposed Complex site will increase the rate of entrainment and impingement of aquatic species throughout the term of a subsequent license.

Section 6.7.1 Federally Listed Threatened, Endangered, and Candidate Species

The SCDNR recommends including the federally endangered gray bat (*Myotis grisescens*) in the Project's list of federally listed threatened, endangered, and candidate species. Further, the SCDNR recommends the gray bat be included in the acoustic KPro analysis and results table, in addition to files being reviewed by a qualified biologist to evaluate potential presence. Though gray bat calls have little overlap with other *Myotis* species, they can overlap with calls of Tri-colored bats – the most common species detected in the Bad Creek 2021 Bat Survey Report. Gray bat records exist in Transylvania County, North Carolina, located less than a mile north of the Project. The closest gray bat records are the SCDNR validated gray bat calls detected at a bridge approximately nine miles from the Project in 2020, and at a site approximately 15 miles northeast of the Bad Creek Reservoir (personal communication with NC bat biologist). Due to these records and the gray bat's ability to extend their range 27 km (16.8 mi) (LaVal et al. 1977) from roost sites to forage, there is a chance the gray bat could be located within the Project Area.

[1] Native to eastern Asia, Sericea Lespedeza is considered a noxious, invasive plant pest, earning a "severe threat" designation by the South Carolina Exotic Pest Plant Council. A study of a reclaimed mine in Virginia found that northern bobwhite (*Colinus virginianus*) populations were limited due to poor habitat quality resulting from the monoculture plantings of Sericea Lespedeza and Tall Fescue (*Festuca arundinacea*) (Stauffer 2011). At a former surface mine site in Kentucky (now Peabody Wildlife Management Area), a 2015 study demonstrated that areas dominated by Sericea Lespedeza were not preferred habitat for bobwhite (Unger et al.), as it is not a preferred food for bobwhite (Ellis 1961), nor does it contain enough nutritional value to support a bobwhite population (Newlon et al. 1964).

Appendix E Natural Resources Assessments

The SCDNR notes that three State Listed Species occur in the Project Area and should be included in the Natural Resources Assessment Report. Please note take of state listed species is prohibited under S.C. Code of Laws §50-15-30.

Species name	**State Status**
Eastern Small-footed Bat (*Myotis leibii*)	State Threatened
Rafinesque's Big-eared Bat (*Corynorhinus rafinesquii*)	State Endangered
Bald Eagle (*Haliaeetus leucocephalus*)	State Threatened

Section 6.0 Summary of Potential Environmental Impacts and Agency Coordination

This section, including related Tables 8 and 10 and Figures 12 and13, identify the Licensee's preferred spoil sites. However, it is unclear to the SCDNR how the Licensee selected and prioritized the potential spoil sites, as previously mentioned. The SCDNR requests further information with regards to how the Licensee intends to select a site or sites for deposition of construction spoil, as well as what avoidance and minimization measures were considered.

Appendix F Desktop Entrainment Analysis

The SCDNR notes that the estimated percentage (12%) of entrainment of the threadfin shad population in Lake Jocassee is a high rate that should continue to be monitored. Threadfin shad are an important prey species for most sportfish in Lake Jocassee. The Project's entrainment study conducted in the first three years of Project operations (1991-1993) (Barwick et al. 1994) found that entrainment rates increased when the water elevations in Lake Jocassee were below 334 meters for a total of 30 days annually. Further, the increased rates resulted in a stable or slightly declining population of threadfin shad. The SCDNR's interests with this issue are to understand the effects of entrainment on fish populations and to evaluate methods to avoid and minimize these impacts. The SCDNR recommends the findings from Barwick et al. 1994 should be included in the Project's PAD.

Appendix G 2021 Bat Survey Report

Section 4.1 Records Review

The SCDNR notes that caution in interpretation is also appropriate for the following species that can share significant overlap in call type:

- Northern long-eared bat versus Eastern small-footed bat
- Eastern red bat versus Seminole bat

The SCDNR disagrees with the following statement: "While no federally listed northern long-eared bats were found near the Project site, the recent discovery of the summer presence of pregnant females in the South Carolina Coastal Plain may indicate a migratory presence in more upland regions of the state." The lack of captures in the middle of the state, despite SCDNR's netting efforts since 2016, suggests spatially disjunct populations in South Carolina (Blue Ridge versus Coastal Plain population) similar to the disjunct populations known to occur in North Carolina. In 2013, prior to white-nose syndrome (WNS) being detected in South Carolina, northern long-eared bats were present and breeding in Oconee, Pickens, and Greenville counties. However, extirpation from the Blue Ridge ecoregion due to WNS mortality seems likely.

Section 4.2 Habitat Surveys

For emergence bat call surveys, the SCDNR recommends that the Licensee should utilize the same bat detector recorder type used during other acoustic surveys (e.g., SM3BAT or Echometer Touch 2), for improved quality call collection, identification, and consistency.

Comments on Scoping Document 1

Section 1.0 Introduction

This section should note that the Project is located on a headwater tributary to the Savannah River.

Section 5.0 Proposed Studies

The SCDNR accepts all twelve initial study proposals by the Licensee.

Section 9.0 Mailing Lists

The SCDNR requests the following individuals be added to FERC's official mailing list for the Bad Creek Pumped Storage Project:

Ms. Lorianne Riggin
South Carolina Department of Natural Resources
PO Box 167
1000 Assembly Street
Columbia, South Carolina 29202

Ms. Elizabeth Miller
South Carolina Department of Natural Resources
PO Box 12559
217 Fort Johnson Road
Charleston, South Carolina 29422-2559

Study Requests

The SCDNR finds the initial list of study proposals from the Licensee to be thorough and adequate to assess the potential impacts to natural resources affected by Project operations. The

SCDNR plans to continue to be an active participant in study plan review for each of the proposals.

The SCDNR appreciates the opportunity to review and provide comments and recommendations regarding the PAD and SD1 for the Bad Creek Pumped Storage Project. If you have any questions or need additional information, please do not hesitate to contact me by phone at 843-953-3881 or email at millere@dnr.sc.gov.

Sincerely,

Elizabeth C. Miller
FERC Coordinator, SCDNR

cc: Alan Stuart, Duke Energy
Melanie Olds, USFWS
Chuck Hightower, SCDHEC
Derrick Miller, USFS

Reference:

Barwick, D.H., T.C. Folsom, L.E. Miller, and S.S. Howie. 1994. Assessment of Fish Entrainment at the Bad Creek Pumped Storage Station. Duke Power Company. Huntersville, NC.

LaVal, R. K., R. L. Clawson, M. L. LaVal, and W. Caire. 1977. Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. Journal of Mammalogy 58:592–599.

Foothills Trail Conservancy
PO Box 3041
Greenville, SC 29602
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June 23, 2022

Electronically Filed

The Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street N.E.
Washington, DC 20426

Subject: Foothills Trail Conservancy's Comments on Duke Energy's Bad Creek Pumped Storage Project (P-2740-053) Submittals (SD1, NOI, and PAD)

The Honorable Ms. Bose,

Since 1974, the Foothills Trail Conservancy (FTC) nonprofit organization has been at the forefront of collaborative efforts to create, maintain, protect, and expand the Foothills Trail – a preeminent long-distance hiking trail in the Carolinas. With a part-time Executive Director and all-volunteer Board of Directors, FTC continues to lead efforts to construct and maintain the walking path and related appurtenances on many sections of the Trail.

The Foothills Trail is a 77-mile hiking-only National Recreation Trail that showcases the beauty and diversity of the Blue Ridge Region in North and South Carolina. In addition to the 77-miles that form the mainstem or "spine", over 30 miles of existing spur trails connect to and expand access to and from the Foothills Trail (the Trail). The Trail leads hikers through the Blue Ridge Escarpment, one of the most ecologically diverse places in the world; past numerous waterfalls, incredible vistas, rare plants, abundant wildlife, through multiple state parks, across Sassafras Mountain (the highest mountain in SC) -- and includes unparalleled access to the Chattooga River, a nationally-designated Wild & Scenic River, and the Jocassee Gorges Management Area, which was included in National Geographic magazine's "50 of the Last Great Places – Destinations of a Lifetime".

Located within a region experiencing incredible population growth (mid-way between Atlanta and Charlotte, and about an hour drive from Greenville, SC and Asheville, NC), the Trail system provides important recreational and educational opportunities to tens of thousands of nearby residents and draws visitors from around the world. Many people are relocating to North Carolina and South Carolina, making them some of the fastest growing states in the nation.[1] As people continue to discover this spectacular corner of the world, we're also seeing the demand for outdoor recreation skyrocket. NC and SC State Parks within this region have experienced significant surges in visitor use,[2] pushing some to implement a parking reservation system and to turn users away during busy weekends.[3]

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[1] https://www.census.gov/library/visualizations/2021/comm/how-does-your-state-compare.html

[2] North Carolina State Parks Report Record 22.8 Million Visitors in 2021. https://www.ncdcr.gov/news/press-releases/2022/01/25/north-carolina-state-parks-report-record-228-million-visitors-2021

[3] https://southcarolinaparks.com/jones-gap

Creation of the existing Trail was a tremendous accomplishment that involved decades of collaborative efforts among federal and state governments, utilities, nonprofit organizations, private landowners, and numerous dedicated individuals. In addition to FTC and Duke Energy, numerous partner organizations assisted in making the Trail a reality. Due to the unusual nature of the Bad Creek Pumped Storage Project - with no recreational access to the Reservoir allowed - the Recreation component of the Original License was provided entirely by construction and maintenance of the 43-mile center section of the nearby Foothills Trail. Duke Energy (Duke) continues to be a critical partner in the sustained existence of this important regional and national recreational resource.

Examples of additional partners include the SC Department of Parks, Recreation & Tourism, SC Department of Natural Resources, NC Division of Parks and Recreation, NC Wildlife Resources Commission, and USDA Forest Service (Andrew Pickens and Nantahala Districts), Oconee and Pickens Counties, Naturaland Trust, Conserving Carolina, and many others. Additionally, FTC has coordinated countless volunteer efforts to assist in construction and maintenance activities – for example, over 2,200 volunteer hours in 2021 alone!

Continued support, enhancement, and expansion of the Trail should be the priority solution for meeting recreational needs for the proposed New License - and more recreation should be added if the proposed Complex construction occurs. A variety of factors must be considered to ensure the continuation of this unmatched resource, from permanent protection of an expanded Trail corridor to maintain Trail experience and allow flexibility as needed; to comprehensive assessment of future needs, current conditions, and both previous and anticipated costs. Future conditions include impacts from potential changing land use, impacts of climate change on recreational needs in the Trail area, needs for expanded/improved access, parking, camping sites, and/or appurtenances (e.g., pit toilets, bear proof lockers). Current conditions include an inventory of and map showing land ownership of all parcels the Trail traverses, legal agreements related to trail infrastructure (e.g., lease agreements), and a detailed inventory of trail-related infrastructure that is Duke's responsibility to maintain. Additional information needs include construction costs, maintenance costs, current condition, and projected maintenance schedule. Our community has provided a significant match to Duke's investment in recreational resources through thousands of volunteer hours each year and through assistance with Trail improvements. FTC values the ongoing cooperative partnership with Duke and looks forward to our continued shared dedication to the Foothills Trail.

We appreciate the opportunity to participate as a stakeholder in the relicensing process for the Bad Creek Pumped Storage Project (the Project), including the proposed construction of the 1,400-MW Bad Creek II Power Complex (the Complex) that would double capacity of this facility. We look forward to continued collaboration with Duke, as well as additional stakeholders and the Federal Energy Regulatory Commission (FERC) to ensure that the new license adequately provides for the recreational and natural resource protection needs of the region.

To broadly summarize, FTC's priority interests are repairing, enhancing, expanding, and permanently protecting Duke's 43-mile section of the Trail, to ensure the exceptional experience provided by the entire Foothills Trail continues for current and future generations.

Although the Trail provides opportunities to recreate within an exceptional landscape, its future is at risk from potential land development, loss of legal access to the corridor, degraded quality due to improper maintenance or overuse, and climate change.

We applaud Duke's interest in continued support of the Trail and respectfully request inclusion of expanded assessments and additional measures as part of the Relicensing, as well as for the construction of the proposed Complex.

Foothills Trail Conservancy is pleased to offer the following detailed comments and recommendations on Duke's Scoping Document 1 (SD1) and the Pre-Application Document (PAD).

Sincerely,

Andrew Gleason
Foothills Trail Conservancy Board Chairman

COMMENT 1: <u>Project infrastructure and capacity seems to have changed over time.</u> Clear and consistent information regarding infrastructure size and Project capacity changes over time should be provided. The current discrepancies between Scoping Document 1 (SD1), Pre-Application Document (PAD), and the Original License should be corrected or more fully explained if conditions have been modified since the approval of the Original License.

1a) This information, including completed and ongoing modifications, could be summarized in a table to provide FERC and stakeholders a clear understanding of infrastructure details. Specific examples of inconsistent information or confusing presentation are provided below.

Bad Creek Reservoir Size is listed as:

- 318-acre with storage capacity of 33,323 acre-feet (Original License),
- 367-acre with storage capacity of 33,900 acre-feet (NOI),
- 363-acre with storage capacity of 35,513 acre-feet (PAD 1.1 and 5.4.1),
- 318-acre with storage capacity of 33,323 acre-feet (PAD 6.3.1.1).

Bad Creek installed capacity is listed as:

- 1,000 MW at Bad Creek (Original License),
- 1,400 MW at Bad Creek plus 1,400 MW from proposed new Complex for authorized installed capacity of 2,800 MW (NOI),
- 2,200 MW combined capacity of Bad Creek and Jocassee, with another 280 MW planned to come online by 2023 with completion of ongoing upgrades to the pump-turbine units at Bad Creek (PAD 1.2),
- 1,400 MW proposed new Complex adjacent to existing Bad Creek Powerhouse (PAD).

1b) In cases where impacts are larger than approved in the Original License, an explanation should be provided including additional mitigation measures that have been implemented. For example, stakeholders can deduce that the current ongoing upgrades to the pump-turbine units at Bad Creek will increase installed capacity by 400MW - or 40 percent - beyond that authorized by the Original License. However, it is unclear if potential increased impacts from this construction and upgrades have been evaluated. The documents should be revised to fully discuss impacts from the increased capacity provided by the upgrades currently being installed, including any expanded erosion prevention and recreational mitigation measures being taken to address impacts that are beyond that expected in the Original License.

Comment 1 requests revisions/clarifications to: NOI, PAD: 1.1, 1.2, 5.4.1, 6.3.1.1, 7.1.1.1.

COMMENT 2: <u>Requirements of separate FERC-licenced projects should be kept separate.</u> Recreation provided under a separate FERC License should not count toward the recreational opportunities provided by the Bad Creek License.

Several sections of the PAD include discussion about the Keowee-Toxaway (KT) Project; however, this information is not necessarily relevant as the Bad Creek Pumped Storage Project (P-2740) operates under a separate FERC License from the KT Project (P-2503). In several instances the information provided confuses the conversation as it is unclear how the KT Relicensing Agreement relates to the Bad Creek original Project construction or ongoing Project operation.

While the KT Relicensing Agreement includes critical information related to the KT Project, it should not be relevant to meeting the requirements for the separate and distinct impacts from the Bad Creek Project. Discussions during the KT Relicensing did not consider inclusion of mitigation measures for the Bad Creek Project; hence, requirements of the KT License should not be considered mitigation for Bad Creek. Specific examples are included below.

2a) PAD Section 1.6 (Licensing Background) states both that the Bad Creek Fishery Resources Work Plan was formerly the Keowee-Toxaway Fishery Resources Work Plan and that several activities included in Bad Creek studies were later transferred to the KT Project. Clarification should be provided on related requirements of each Original License and specific activities that were transferred between Licenses.

This section also indicates that Duke and SCDNR collaborated on the development of MOUs (each decade) to establish a framework to help maintain the high quality of fisheries of Lakes Jocassee and Keowee, and that these plans include focus on recreation. Specific recreational benefits provided from these MOUs – that are in addition to those required by the Keowee Toxaway License - should be clearly explained and Duke should provide a copy of each MOU and a summary list of activities successfully completed.

2b) PAD Section 6.8.3.1 (2013 Recreation Use and Needs Study) discusses a study completed in 2013. However, this study did not consider usage of nor the recreational needs provided by the Foothills Trail or the 43-mile section of the Trail that Duke was required to construct and maintain in order to fulfill the Recreation requirements of the Bad Creek Original License. Rather, the 2013 RUN Study evaluated lake access and boating facilities as part of the separate KT Relicensing Project.

Comment 2 suggests revisions/clarifications to PAD 1.2, 1.6, 6.8.3.1, 7.1.6.1.

COMMENT 3: <u>Recreation requirements of the Original License should be accurately and comprehensively discussed.</u> Due to the unusual nature of this project, with no recreational access to the Reservoir allowed, the Recreation component of the Original License was provided entirely by constructing and maintaining the 43-mile center section of the nearby Foothills Trail. A full description of the Trail (including reference to Exhibit R) should be included in discussions regarding protection, mitigation, and enhancement (PM&E) measures and comprehensive information about the Trail infrastructure, construction, and maintenance should be provided.

3a) SD1 3.1.1 and PAD Section 6.8.1 incorrectly state that the Foothills Trail is managed or maintained by the Foothills Trail Conservancy. While FTC maintains and assists with some portions of the Trail, these document sections should be revised to accurately reflect that Duke continues to be responsible for Trail operations and maintenance within the 43-mile section of Trail built to satisfy recreational requirements of the Original License.

In May 1980, Duke submitted "A Plan for Development and Management of the Foothills Trail and A Supplement to the Bad Creek Pumped Storage Project Exhibit R" (Exhibit R) that described ongoing operational, educational, and maintenance needs that would be provided by Duke. These include, but are not limited to:

- Maintaining stream crossing structures, signs, latrines, gates and footpaths within Duke's section of the trail,
- Employing a full-time professional with responsibilities for maintenance and supervision of the Trail and associated facilities,
- Removing trash from access points on a regular basis
- Cleaning up litter along the trail,
- Coordinating with law enforcement,
- Assisting with development of a trail guidebook and offering them at the Visitor Center,
- Educating people on trail-use guidelines by offering a slide show at Keowee-Toxaway Visitor Center and other locations,
- Displaying trail information at the Visitor Center (Including the Trail on the topographic model of the Keowee-Toxaway Project area).

3b) Numerous document sections inaccurately indicate that there is no recreation provided within the Project Boundary. Although most of the Trail is outside of the proposed Project Boundary, public access is currently provided within and adjoining the proposed Project Boundary. The public utilizes Bad Creek Road to access a public parking lot, Foothills Trail kiosk, and a spur trail providing access to the Foothills Trail and to the Lower Whitewater Falls scenic viewpoint. Each of these infrastructure components are shown on the Project Boundary map and should be labeled appropriately.

3c) Wording throughout some sections indicates that recreation was not met "in" the Project Boundary and could be misunderstood to mean that there was no recreation required "for" the Project. Wording should be clarified and additional explanation of the Trail should be added where appropriate.

3d) Several sections mention major PM&E measures required for the original Project construction and list Exhibit S (Environmental Study Plans), Duke and SC Department of Natural Resources (SCDNR) MOU and 10-Year Work Plans, and the Keowee-Toxaway Project Relicensing Agreement FERC No 2503 (KT Project). These sections should include reference to the Bad Creek Project license Exhibit R ("A Plan for Development and Management of the Foothills Trail and A Supplement to the Bad Creek Pumped Storage Project"), which specifies Duke's recreational requirements under the Original License. (SD1; PAD 1.1, 1.6, 6, 6.4.6)

Comment 3 requests revisions/clarifications to SD1, NOI, and PAD 1.1, 1.6, 5.2, 6, 6.4.6, 6.8.1, 6.8.3, 6.8.5, 7.

COMMENT 4: <u>Provide a summary of completed recreation-related projects.</u> Duke should provide comprehensive information regarding fulfillment of the Original License Exhibit R; including a map and complete inventory of infrastructure and appurtenances, construction and maintenance costs, and current conditions of these features throughout the 43-mile section of Trail.

4a) Requested information regarding Duke's 43-mile section includes, but is not limited to:

- Summary of recreation-related requirements from the Original License and actions taken to meet those requirements, including specific measurables.
- Status and durability of trail-related agreements with landowners.

- Copies of all trail-related legal agreements (lease agreements, etc.).
- Comprehensive inventory for all structures (e.g., parking lots, bridges, stairs, campsites), including, but not limited to structure name, structure material, year constructed, cost of installation, expected lifespan, assessment of current condition, and maintenance records (including costs).
- Associated costs, including past land/easement procurement, trail and infrastructure construction, and trail and infrastructure repairs and maintenance.
- Schedule of anticipated maintenance needs and costs.
- Potential need for acquisition of land and/or easements to ensure existence of Trail corridor in perpetuity for future generations, including projected costs.
- Detailed map(s) of Duke's 43-mile Trail section should be added that includes, at a minimum, the following information: parcel boundaries, current property owner(s), access locations (from water and land), spur trails, land use, structures (e.g., parking lots, bridges, stairs, campsites), streams/wetlands, areas of concern (e.g., erosion, overused parking/campsites), and points of interest.

4b) The history of compliance, including inspection reports should be included. For example, in 2000, FERC conducted an Environmental and Public Use Inspection (EPUI), which covered twenty-four miles of trail and identified a range of maintenance deficiencies that included trees across the trail, footbridges in need of repair, smaller bridges that had been washed out, loose handrails, missing footing steps, soil erosion, etc.

4c) Erosion throughout the trail corridor is a serious concern. Within the last six years, the Trail has experienced several landslides that required rebuilding portions of the Trail. Records of erosion-related problems, best management practices (BMPs), maintenance, and repairs should be included.

4d) Decline of native vegetation would significantly degrade the Trail. An evaluation should be conducted throughout the Trail corridor documenting the health of native vegetation, distribution of invasive species, and impact of diseases. For example, the current condition of Hemlock trees should be assessed, trees with a chance of surviving the Hemlock wooly adelgid should be treated, and non-surviving trees should be replaced. An inventory and map of hemlock trees should be included, noting current condition and anticipated actions.

Comment 4 requests revisions/clarifications to SD1, NOI, and PAD 1.1, 1.6, 5.2, 6, 6.4.6, 6.8.1, 6.8.3, 6.8.5, 7, 7.1.6.

COMMENT 5: <u>Federal and state protections apply to Waters of the US regardless of modification, land ownership, or use of water</u>. As both Waters of the US (WOTUS) and Waters of the State (WoS), the Bad Creek Reservoir and streams/wetlands present within the proposed Project Boundary are subject to federal and state regulations. Wording throughout the documents should be corrected to indicate that regulations, such as water quality standards, do apply. Additionally, monitoring should be conducted to evaluate existing impacts and assess potential future impacts.

The Bad Creek Reservoir was formed by damming Bad Creek and West Bad Creek, which were previously identified as Outstanding Resource Waters (figure 1). Converting streams to open water (e.g., ponds, lakes, reservoirs) does not remove their qualifications as waters of the U.S. or waters of S.C and regulatory designations continue to apply.

5a) Section 1.5 (Other Major Regulatory Approvals) discusses various regulations related to impacts to waterways and states that new construction will require permits and authorizations from the U.S. Army Corps of Engineers (USACE). This wording could be revised to provide a clearer explanation that activities below the Ordinary High Water Mark (OHWM) are regulated by the USACE and the SC Department of Health and Environmental Control (SCDHEC).

5b) Sections 6.1.3.2 (Water Use) and 6.3.7.1 (Bad Creek Reservoir) incorrectly state that the waters within the Project area are not included in state water quality standards nor water classifications. Waterbodies within Duke's proposed Project Boundary are considered jurisdictional WOTUS and WoS and, as such, are assigned water classifications, must meet applicable water quality standards, and are protected by anti-degradation rules. SCDHEC Regulation 61-68 Water Classifications and Standards clearly states that the regulations "establish the State's official classified water uses for all waters of the State…"[4]

Furthermore, the SCDHEC Watershed Atlas (https://gis.dhec.sc.gov/watersheds/) identifies waters within the proposed Project Boundary with the following classifications (figure 1): streams flooded by Bad Creek Reservoir as Outstanding Resource Waters (ORW), the headwaters of Howard Creek as ORW becoming Trout Natural (TN) below the confluence with flow from Bad Creek Reservoir, unnamed stream 1 and impoundment as ORW, and unnamed stream 2 as Trout, Put, Grow, and Take (TPGT).[5]

Section 6.1.3.2 is titled "Water Use"; however, it does not include any discussion of actual water uses, but rather discusses Water Classifications. As such, the section heading should be revised to "Water Classifications and Standards".[6]

Sections 6.3.6 and 6.3.7.1 should be revised to recognize that Bed Creek Reservoir *is* subject to state classification designation and associated standards. As such, water quality monitoring should be conducted to ensure compliance with applicable water quality standards. Modifications or mitigation measures should be implemented, if needed, to address any potential degradation of water quality conditions from ongoing or proposed Project operations.

5c) Section 6.3.4 (Existing and Proposed Uses of Project Waters) and 7.1.2 (Water Resources) state that Bad Creek Reservoir waters are used only for Project operations and that there are no other existing or proposed uses for these waters. However, Section 6.1.1 of the PAD indicates that the Bad Creek Reservoir provides seepage flows from the Main Dam and the West Dam of approximately 5.0 cfs combined. According to the flow data provided by Duke in this section, the flow of Howard's Creek at USGS gauge 02184475 – downstream from Bad Creek Reservoir – ranges from 7.4 cfs (1996) to 12.9 cfs (1990). Further evaluating these data indicates that the Bad Creek Reservoir seepage provides 39 to 80 percent of the flow in Howard Creek. These seepage flows are critical to the continued health of Howard Creek, which is

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[4] SCDHEC Regulation 61-68 Water Classifications and Standards https://live-sc-dhec.pantheonsite.io/sites/default/files/media/document/R.61-68.pdf

[5] SC Watershed Atlas [accessed 03 Jun 2022] https://gis.dhec.sc.gov/watersheds/

[6] SCDHEC Regulation 61-68 Water Classifications and Standards https://live-sc-dhec.pantheonsite.io/sites/default/files/media/document/R.61-68.pdf

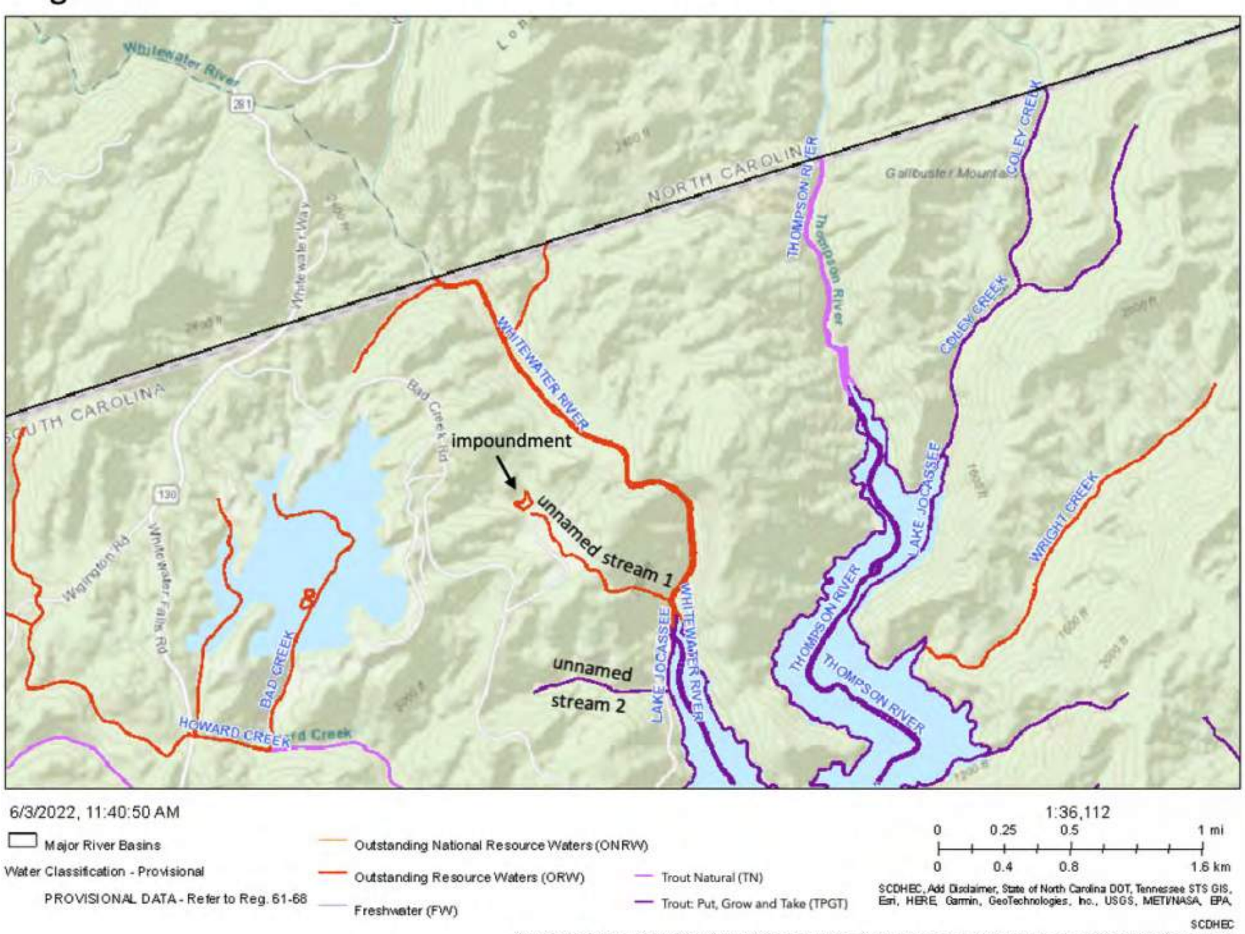
currently designated as an ORW (upstream and along Reservoir) and TN (downstream from Reservoir).

5d) Sections 6.3.8 (Gradient for Downstream Reaches Directly Affected by the Project) and 6.3.9 (Known or Potential Adverse Effects and Proposed PM&E Measures: Existing Operations) should be expanded to include Howard Creek, as it receives a substantial portion of flow from Bad Creek Reservoir and the additional unnamed tributaries to Lake Jocassee located within the Project Boundary. Additional discussion should be included regarding potential impact of continued and modified operations as well as PM&E.

5e) Section 7.1.2.1 (Potential Issues – Existing Project) notes that there are "no known potential adverse effects"; however, PAD Section 6.3.7.1 indicates that there is currently no monitoring, making it impossible to evaluate if there are any existing adverse effects. Additionally, conditions could be further impacted by the completion of the currently ongoing upgrades that will increase capacity from the 1,000 MW, that was mitigated under the Original License, to 1,400 MW. Duke should initiate a water quality monitoring program at the Bad Creek Reservoir to evaluate current impacts and, if needed, propose PM&E.

Comment 5 requests revisions/clarifications to PAD 1.5, 6.1.3.2, 6.3.4, 6.3.6, 6.3.7.1, 6.3.8, 6.3.9, 7.1.2, 7.1.2.1.

Figure 1 SCDHEC Watershed Atlas



COMMENT 6: Natural resources located within the Project Boundary continue to be protected under regulations; current conditions should be fully evaluated and discussed.

6a) PAD Section 7.1.3 (Fish and Aquatic Resources) should provide information regarding current status of fish and aquatic resources in waterways within the Project Boundary. Damming a stream does not remove all potential for fish or aquatic species to exist. In fact, the "world's most prestigious professional bass tournament" – the Bassmaster Classic – has been held multiple years on Lake Hartwell,[7] which is located in the chain of lakes downstream from the Bad Creek Reservoir. Fish and other aquatic resources should be evaluated, and potential impacts and PM&E should be determined.

6b) PAD Section 7.1.4.1 ([Wildlife and Botanical Resources] Potential Issues – Existing Project) outlines protection of upland habitat and shoreline management around Lake Jocassee and on the faces of the dams; however, it should be expanded to include a discussion of vegetation and shoreline management around the Bad Creek Reservoir as well. Additional discussion should also be included regarding vegetation management techniques along the transmission line corridor, with emphasis on strategies for reducing impacts to water resources and preventing the introduction and spread of invasive species.

Additionally, the condition of vegetation throughout the corridor of Duke's 43-mile section of Trail is a serious concern. The evaluation should be expanded throughout the Trail corridor documenting the health of native vegetation, distribution of invasive species, and impact of diseases. For example, the current condition of Hemlock trees should be assessed, trees with a chance of surviving the Hemlock wooly adelgid should be treated, and non-surviving trees should be replaced. An inventory and map of hemlock trees should be included, noting current condition and anticipated actions.

6c) PAD Sections 7.1.5 (Wetlands and Riparian Habitat) and 7.1.5.1 (Potential Issues – Existing Project) – a map indicating location, size, and condition of all jurisdictional waters within the Project Boundary should be included. This section notes that continued operations are not expected to impact wetland, riparian, or littoral habitat, yet the ongoing vegetation maintenance along the transmission line likely involves mowing and/or application of pesticides. These activities can impact these sensitive ecosystems by removing or destabilizing habitat or plant communities; activities can also degrade water quality and increase erosion if appropriate vegetation is not maintained.

Comment 6 requests revisions/clarifications to PAD 7.1.3, 7.1.4, 7.1.4.1, 7.1.5, 7.1.5.1.

COMMENT 7: Current conditions should be evaluated throughout the Trail corridor. A comprehensive evaluation of existing resources and potential impacts of current and ongoing operations, including of current upgrades, to Project-related recreation (i.e., the 43-mile section of Trail and appurtenances constructed and maintained by Duke) should be included. Specific sections are noted below.

7a) SD1 Section 3.2.2 (page 9) should include a discussion of potential threats to Aquatic Resources throughout the Trail corridor. These could include upland soil erosion (potentially caused as a result of a storm, wildfire, or by trail use). Current conditions within the Trail

[7] https://andersonscliving.com/good-to-know/2022-bassmaster-classic-coming-to-lake-hartwell/

corridor should be included in PAD Section 6.2.3 (Reservoir Shoreline and Stream Banks) regarding stream banks and PAD Section 7.1.1.1 (Geology and Soils Potential Issues – Existing Project) regarding any slope instability or erosion.

Without proper controls, stormwater runoff can accelerate erosion, contribute to streambank instability, increase pollutant loading, and degrade the quality of receiving water bodies. Erosion throughout the Trail corridor is a serious concern. Within the last six years, the Trail has experienced several landslides that required rebuilding portions of the Trail. Increased intensity of storm events and our changing climate will continue to amplify these problems. Best management practices (BMPs) that have been installed, such as water bars, may need repair or additional measures may be needed to address these problems throughout the Trail corridor.

Additionally, erosion and vehicle-related spills can occur in parking lots and at access points. For example, recent vandalism at a Trail access parking lot included drilling a hole in a vehicle's gas tank - and resulted in gasoline draining directly to a nearby stream. (See WYFF: Thieves, vandals strike Foothills Trail parking lot, leaving hikers stranded, woman says 5/30/22). Ensuring BMPs are appropriately constructed and maintained is especially important as we see increasing Trail usage and heightened intensity of storm events.

Also, regarding water quality impacts, there are limited restroom facilities currently available to Trail users - with all located at Trail access parking lots. None of the backcountry, designated campsites have restroom facilities. As noted by the US Department of Agriculture Forest Service (USFS), heavy usage of backcountry trails can result in environmental degradation associated with human waste disposal.[8] The increasing popularity of the Trail may support the need for pit toilets to reduce potential for human waste to contaminate aquatic resources.

7b) SD1 Section 3.2.2 (page 10) Terrestrial Resources and Threatened and Endangered Species and PAD 6.5.4 ([Wildlife/Botanical] Known or Potential Adverse Effects and Proposed PM&E Measures: Existing Operations). Throughout the Trail corridor, these resources are at an increased threat from spread of invasive species and introduction of diseases, which are associated with both land disturbance and climate change. Invasive species can cause economic and ecological harm and their spread would significantly degrade the ecological integrity and recreational experience of the Trail corridor. Invasive species spread rapidly, outcompete valuable native species, and once established they can be difficult and costly to control. Regular assessments of invasive species throughout the Trail corridor would allow prevention and quick response, helping protect the long-term integrity of the Trail.

Additionally, decline of native vegetation due to diseases or insects would significantly degrade the Trail. An evaluation should be conducted throughout the Trail corridor documenting the health of native vegetation, distribution of problematic insects, and impact of diseases. For example, the current condition of Hemlock trees should be assessed, significant trees with a strong chance of surviving the Hemlock wooly adelgid should be treated, and consideration should be given to preventing erosion and accelerating forest recovery in areas with significant hemlock losses. An inventory and map of hemlock groves should be included, noting current condition and anticipated actions. Climate change is an important consideration for wildlife and botanical resources and should be considered throughout the life of the proposed new license.

[8] https://www.fs.fed.us/t-d/pubs/html/95231202/95231202.html

PAD Section 6.5.2.2 (Invasive Species) should also include a map indicating locations of invasive species throughout the Project-related areas, especially in relation to sensitive species, pristine ecosystems, and the Foothills Trail. Additional information should be provided outlining Duke's efforts and plans to control, eradicate, and prevent movement of invasive species throughout these areas.

7c) The following PAD sections should include a thorough discussion of and maps identifying resources within the Trail corridor: 5.2 (Project Location and Maps), 6.1.5 (Tributary Rivers and Streams), 6.2.1 (Geologic Features), 6.2.4 (Known or Potential Adverse Effects and Proposed PM&E Measures: Existing Operations), 6.3.1 (Drainage Area), 6.3.7 (Existing Water Quality Data), 6.3.8 (Gradient for Downstream Reaches Directly Affected by the Project), 6.3.10.2 (Impacts to Project Streams), 6.5 (Wildlife and Botanical Resources), 6.5.1 (Terrestrial Habitats), 6.5.3 (Known or Potential Adverse Effects and Proposed PM&E Measures: Existing Operations), 6.6 (Wetlands Riparian, and Littoral Habitat), 6.7 (Rare, Threatened, and Endangered Species), 6.7.1.2 (Migratory Bird Treaty Act of 1918), 6.7.1.3 (At Risk Species), 6.7.2 (State-listed Threatened, Endangered, and Candidate Species), 6.7.3 (Known or Potential Adverse Effects and Proposed PM&E Measures: Existing Operations), 6.9 (Aesthetic Resources), and 7.1.1.1 (Geology and Soils Potential Issues – Existing Project).

Climate change is an important consideration for natural resources within the Trail corridor and should be considered throughout the life of the proposed new license. Of particular note is the consideration of wildlife corridors, which will be necessary for species migration due to climate change and should be considered and included in PM&E measures.

Regarding Geologic Features, much of this information can be obtained from the Geology Guide to the Foothills Trail: 77 miles of trail, 1.2 billion years of geology (SCDNR; Morrow, Robert H., Ranson, William A., Arrington, Tanner).

Comment 7 requests revisions/clarifications to SD1 3.2.2 (Aquatic Resources, Terrestrial Resources and Threatened and Endangered Species); and PAD 6.1.5, 6.2.1, 6.2.3, 6.2.4, 6.3.1, 6.3.7, 6.3.8, 6.3.10.2, 6.5, 6.5.1, 6.5.2.2, 6.5.3, 6.6, 6.7, 6.7.1.2, 6.7.1.3, 6.7.2, 6.7.3, 6.9, 7.1.6.3, 7.1.1.1.

COMMENT 8: Proposed PM&E should be clear and consistent. Discrepancies between SD1 and the PAD create confusion on Duke's future intent regarding the Trail; these documents should be clear and consistent. With no consideration of recreation at the Reservoir and recreational access on Lake Jocassee provided by the separate KT License, the Foothills Trail should be the focus of recreational requirements of the New License.

Please note, FTC comments regarding a comprehensive RUN study are included in Comment #9.

8a) The SD1 indicates that Duke does not propose to include the Foothills Trail in the New License, and it diminishes the role of the Trail in discussion throughout various sections. Specifically, SD1 Section 3.1.1 (page 6) states "Duke Energy does not propose to include the Foothills Trail as a project recreation facility under the new license."

The 43-mile section of Trail represents the preponderance of the recreation provided as part of the Original License; it fills a range of recreational needs that would be nearly impossible to replace. The Trail is an important and unique recreational and educational resource that improves the quality of life throughout the region.

Continued support of the Foothills Trail is a critical component of the New License and expansion of the recreational provisions should be considered to account for the population growth, increased demand for outdoor recreational needs, and expansion of project operations from the ongoing upgrades.

8b) SD1 Section 3.2.2 (page 11) Recreation, Land Use, and Aesthetics outlines minimal considerations, with two of the three bullets only applicable if construction of the proposed Complex occurs. This section should be expanded to a full recreational use and needs (RUN) study that considers current and future recreational needs for the license renewal, including additional measures to be included if construction of the Complex is pursued. Full comments regarding the RUN study are discussed in Comment #9.

8c) SD1 Section 5.0 (page 18) Proposed Studies #8 Recreation and Public Safety study is currently limited to construction and operation of the Complex, or new facilities. The study should be expanded to consider public safety concerns along the Trail, including the need for enhanced safety measures at parking lots and access points. See WYFF: Thieves, vandals strike Foothills Trail parking lot, leaving hikers stranded, woman says 5/30/22).

Comment 8 requests revisions/clarifications to SD1 3.3.1, 3.2.2, 5.0; and PAD 5.2, 6.8.3, 6.8.3.1, 6.8.5, 7.1.6.1.

COMMENT 9: The RUN Study should be expanded. The proposed Recreational Use and Needs (RUN) Study should be comprehensive and specifically for recreation related to the Bad Creek Project.

A comprehensive Recreational Use and Needs (RUN) Study should be conducted to evaluate the need for expansion and enhancement of trail facilities to meet the current population, which has already grown significantly since the Original License in 1977. Additionally, the RUN should evaluate needs through 2077, the potential end of the New License period.

A previous comment outlines the inappropriateness of using the outdated and unrelated 2013 RUN Study completed to evaluate water-based recreation needs associated with the Keowee-Toxaway Relicensing (FERC Project No. P-2503) and requests revisions of PAD 6.8.3.1 (2013 Recreation Use and Needs Study).

9a) PAD Section 7.1.6.3 (Proposed Studies) outlines the proposed new RUN Study and notes that it would focus on the Foothills Trail, Canebreak access point (note corrected spelling is "Canebrake"), and the Laurel Creek Foothills Trail access points and parking areas. We appreciate the proposal for a RUN Study focused on the recreational requirements of the Bad Creek Project and request the focus area be expanded to include all land and water access points and all spur trails along the 43-mile section of Trail. Of particular importance is the land access location within the Bad Creek Project Boundary.

Additionally, the study should be expanded to evaluate if the current recreational opportunities are meeting demands, and if not – why. Simply counting existing trail users will not identify deficiencies that may be keeping people from using the Trail. For example, a recent spree of vandalism to vehicles at parking lots at Trail access points may discourage people from utilizing any parking lots for hiking in the area, even if they are active hikers with interest in the Trail. (See WYFF: Thieves, vandals strike Foothills Trail parking lot, leaving hikers stranded, woman says 5/30/22). Study methods and focus areas should be expanded to improve accuracy of estimation of recreational needs.

Many nearby State Parks, featuring similar terrain and hiking challenges, have experienced significant surges in visitor use[9] and at times cannot accommodate demand. The heavy demand has even pushed one Park to implement a parking reservation system and turn people away during busy weekends.[10] If evaluation shows lower demand for Trail resources than State Parks, a comparison of features offered would inform the conversation on future needs for this Project.

Based on FTC members' expertise and experience, we request evaluation for the following additions or upgrades: expansion of the Trail and construction of additional spur trails to connect to additional points of interest (e.g., Walhalla, Stumphouse, Lake Toxaway, Panthertown Valley); improved access/parking (safety, etc.), additional and improved campsites (e.g., flatter areas to accommodate tents, pit toilets, bear proof lockers), etc.

FTC anticipates safety becoming an increasing concern. With expanding development, shrinking bear habitat, and more people on our trails, it's no surprise that bear encounters are increasing in our area.[11] Backpackers are often the most vulnerable to dangerous bear encounters. Properly hanging a food bag is an art (especially after a long day of hiking), and black bears are becoming increasingly skilled at gaining access to food bags. Food-conditioned bears are often bolder with human encounters, sometimes becoming aggressive, and often leading to the bear being euthanized. (See https://www.usatoday.com/story/news/nation/2022/06/14/bear-euthanized-scratching-woman-child-national-park/7626099001/) Some National Parks and long-distance trails in bear territory provide bear proof lockers at designated campsites to simplify proper food storage and enhance safety for humans and bears. This option should be considered for campsites throughout the Trail as a preventive safety measure.

9b) SD1 Sections 3.2.2 (Recreation, Land Use, and Aesthetics) and 5.0 (Proposed Studies #7 Recreation) should be revised to be consistent with the RUN Study outlined in the PAD, as expanded per revisions requested by FTC.

9c) PAD Section 6.1.3.1 (Land Cover) states that the primary reason the Bad Creek Reservoir and Lake Jocassee have no or minor residential development, respectively, is that Duke partnered with state agencies to designate a significant amount of the land adjoining Lake Jocassee for public recreation and resource conservation. However, a significant portion of Duke's 43-mile section of the Foothills Trail, required by the Original License, is located on property that Duke may intend for development. Duke transferred land ownership of a 6,694.8-acre parcel (Oconee County Parcel ID 016-00-01-013), which houses an important stretch of the Foothills Trail, several times throughout the Original License period. Online records show

[9] North Carolina State Parks Report Record 22.8 Million Visitors in 2021. https://www.ncdcr.gov/news/press-releases/2022/01/25/north-carolina-state-parks-report-record-228-million-visitors-2021

[10] https://southcarolinaparks.com/jones-gap

[11] https://www.outsideonline.com/outdoor-adventure/environment/bears-north-carolina-encounters/

transfer of this parcel on 7/8/2008 from Crescent Resources Inc to Duke Ventures LLC for a sales price of $29,215,248; then an additional transfer on 7/9/2009 from Duke Ventures LLC to Duke Venture Real Estate LLC for $0.[12] Development of this parcel would drastically change Land Cover within this watershed, while also degrading the quality of the Foothills Trail. Widening the Trail corridor should be closely evaluated to ensure protection of the natural resources and user experience along the Trail.

9d) The RUN Study should evaluate the potential impact if land use surrounding the Trail corridor was modified and discussion in PAD Section 6.8.5 (Non-Recreational Land Use and Management) should be expanded. Currently, the land surrounding the Trail corridor is nearly entirely undeveloped and provides hikers with a wilderness-like experience. As such, information should be provided on potential non-recreational land use and management of all land parcels that Duke's 43-mile section crosses. Duke should provide information on how the recreational quality and benefits of the Foothills Trail will be preserved – and expanded to meet growing recreational needs – throughout the new License period.

Additionally, expansion of the Trail corridor width will be of particular importance if land use changes occur throughout this region. Currently, the large areas of undeveloped land are providing critical habitat and supporting the resiliency of species. If surrounding lands are developed, the Trail corridor could provide the only connection between critical habitats. Considering the anticipated acceleration of species migration due to climate change, the Trail corridor could become vital to supporting genetic diversity - or even the survival of - some species. The USDA's *Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways Manual* (2008)[13] recommends minimum widths for corridors to support various species - invertebrates can utilize the narrowest corridors (100-200 feet) and large predator mammals need the largest corridors (330 feet to ≥3 miles). The Manual also notes that as "the length of the corridor increases, so should the width." Consideration must be given to the increased importance of the Trail corridor should the surrounding land develop within the next 50 years.

9e) PAD Section 7.1.6.1 (Potential Issues – Existing Project) offers to continue maintaining this 43-mile section of trail and two lake access locations for the New License. Our region's population has skyrocketed since the Original License was approved in 1977 and the demand for outdoor recreation has increased significantly. Considering this, improved and expanded recreational resources are necessary.

The FTC welcomes the opportunity to participate in future discussions regarding an updated Recreational Management Plan (RMP), including enhanced and expanded facilities, possibilities for permanent land agreements to secure the Trail's continued existence, and the anticipated ongoing maintenance needs.

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[12] Oconee County Property Records [accessed 03 Jun 2022] https://qpublic.schneidercorp.com/Application.aspx?AppID=1030&LayerID=21692&PageTypeID=4&PageID=9258&KeyValue=016-00-01-013

[13] https://www.csu.edu/cerc/researchreports/documents/ConservationBuffersDesignGuidelinesForBuffersCorridorsGreenways2008B.pdf

Comment 9 requests revisions/clarifications to SD1 3.2.2, 3.3.1, 5.0; and PAD 5.2,6.1.3.1, 6.8.3, 6.8.3.1, 6.8.5, 7.1.6.1, and 7.1.6.3.

COMMENT 10: Expanded information should be included in some sections to provide a more accurate, updated, and comprehensive understanding of conditions.

10a) PAD Sections 6.11 (Socioeconomic Resources) and 6.11.1 (Population) provide information limited to Oconee County, in which the Bad Creek Project is located. However, the existing Project serves a much larger area. In fact, the Original License noted that the "additional peaking capacity of the proposed project will also be of benefit to the entire Virginia-Carolina (VACAR) Subregion of the Southern Electric Reliability Council (SERC).." (page 4). Also, PAD Section 1.2, indicates that population and household growth in the Carolinas is exceeding the national average. South Carolina is identified as the fifth fastest growing state in the nation, spurred by relocation of people from other states.[14]

These sections should be expanded to provide a comprehensive evaluation of the population and socioeconomics in the area serviced by the existing Project, the additional population that would be served by the proposed expansion, and the population (including future projections) of the Upstate region – the Greenville-Spartanburg-Anderson, SC Combined Statistical Area.

10b) PAD Section 6.1.2 (Climate) includes climate data limited to averages through 2010 and does not include more current data from the last 12 years. The climate evaluation should include current and comprehensive data. In addition to averages, maximums and minimums should be included for temperatures and rainfall. Including more current data may show significant differences in climate conditions. For example, a new record annual rainfall for the state was set in 2018, just 3 miles from the Bad Creek Project.[15] This new record of 123.45" is significantly different from the maximum of 100" annual precipitation noted in the PAD. This section should also include a discussion of changing climate conditions and projected future conditions. This should include, but not be limited to, discussion of increasing nighttime temperatures, seasonal precipitation patterns, annual rainfall, and drought.

The impacts of climate change should also be evaluated and discussed in the following PAD sections: 6.3.9 ([Water Resources] Known or Potential Adverse Effects and Proposed PM&E Measures: Existing Operations), 6.7.3 ([Rare, Threatened, and Endangered Species] Known or Potential Adverse Effects and Proposed PM&E Measures: Existing Operations), and 6.7.4 ([Rare, Threatened, and Endangered Species] Known or Potential Adverse Effects and Proposed PM&E Measures: Bad Creek II Complex).

In relation to climate change, wildlife habitats, migration corridors, and species resiliency and survival are of particular interest and should be considered through 2077 - the potential life of the proposed new license. Wildlife corridors, which may be necessary for species migration due to climate change, should be considered and PM&E measures should be identified for both

[14] Post and Courier (12/21/2021) https://www.postandcourier.com/news/us-sees-slowest-population-growth-on-record-but-sc-among-fastest-growing-states/article_7873e424-6274-11ec-81ba-9793bea986ef.html

[15] SCDNR: https://www.dnr.sc.gov/news/2019/may/may2_recordrainfall.php

relicensing of Existing operations and additional considerations if the proposed Complex expansion moves forward.

Widening the Trail corridor width will become increasingly important as climate change impacts this ecologically diverse region. Currently, the large areas of undeveloped land are providing critical habitat and supporting the resiliency of species. If surrounding lands are developed, the Trail corridor could provide the only connection between critical habitats. Considering the accelerated need for species migration due to climate change, the Trail corridor could become vital to supporting genetic diversity - and even the survival of - some species. The USDA's *Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways Manual* (2008)[16] recommends minimum widths for corridors to support various species - invertebrates can utilize the narrowest corridors (100-200 feet) and large predator mammals need the largest corridors (330 feet to ≥3 miles). The Manual also notes that as "the length of the corridor increases, so should the width." Consideration must be given to the increased importance of the Trail corridor should the surrounding land develop within the next 50 years.

10c) PAD Section 7.1.1.1 (Geology and Soils Potential Issues – Existing Project) outlines geology and soils-related issues from the "existing" project, but additional information should be included. For example, it notes that there "is active slope movement in the Project" and that these areas are monitored but does not provide information on severity or locations of this activity. Additionally, it is important to recognize that Duke is currently modifying operations and equipment to increase capacity at Bad Creek by 40% beyond the capacity in the original license. It is unclear if the increased impacts from the current expansion activities have been evaluated. This section should be revised to fully discuss impacts from the increased capacity provided by the upgrades currently being installed, including any expanded erosion prevention and recreational mitigation measures being taken to address the current impacts that are beyond that expected in the Original License.

Comment 10 requests revisions/clarifications to PAD 6.1.2, 6.3.9, 6.7.3, 6.7.4, 6.8.3.1, 6.11, 6.11.1, and 7.1.1.1.

COMMENT 11: Construction of the Complex should require additional evaluation and PM&E measures. The proposed Bad Creek Complex II Expansion would double the already upgraded capacity of the Bad Creek Project. A complete analysis of permanent and temporary construction impacts and potential introduction/expansion of invasive species should be thoroughly evaluated and additional PM&E, including expanded recreational requirements, should be required.

11a) PAD Section 6 (Description of the Existing Environment and Resource Impacts) should include more detailed evaluation of potential impacts and PM&E measures for the construction and operation of the proposed Complex II and should propose consideration of current and future recreational needs.

16 https://www.csu.edu/cerc/researchreports/documents/ConservationBuffersDesignGuidelinesForBuffersCorridorsGreenways2008B.pdf

11b) PAD Section 6.3.10 (Known of Potential Adverse Effects and Proposed PM&E Measures: Bad Creek II Complex) includes limited discussion as it does not acknowledge water uses beyond the Project. As noted in earlier comments, Howard Creek receives a substantial portion of flow from the Bad Creek Reservoir and a discussion regarding potential impact of continued and modified operations as well as PM&E. Impacts of climate change should also be evaluated and discussed.

11c) PAD Section 6.3.10.2 (Impacts to Project Streams) should include the estimated amount of impact (linear footage of streams, acreage of wetlands or open water), classification and condition of proposed impacted resources, and duration of impacts (e.g., during construction or permanent). This section should also discuss potential impacts to the streams along the 43-mile section of the Foothills Trail, including spur trails and access locations, that is Duke's responsibility to construct and maintain under the Original License. Additional discussion should be included if construction or operation of the Complex could directly impact the Foothills Trail, either temporarily or permanently.

11d) Additional discussion regarding the "Known or Potential Adverse Impacts and Proposed PM&E Measures for Bad Creek II Complex" should be included for the following PAD sections:

- 6.4.7 [Fish and Aquatic Resources], 6.5.4 [Wildlife and Botanical Resources], and 6.7.4 [Rare, Threatened, and Endangered Species] – land disturbance is often a gateway for introduction of additional invasive species, introduction of diseases, and expansion of existing invasive species populations. Each of these require thoughtful planning and control measures to prevent, limit, or mitigate potential impacts. Climate change is an important consideration for wildlife and botanical resources and should be considered throughout the life of the proposed new license. Potential wildlife corridors, which may be necessary for species migration due to climate change, should be investigated.
- 7.1.4 (Wildlife and Botanical Resources) - Proposed environmental measures should be expanded to ensure impacts are avoided and minimized wherever possible, as well as include efforts to enhance these species either within or outside of the Project Boundary.

11e) PAD Section 7.1.2.2 ([Water Resources] Potential Issues – Bad Creek II Complex) indicates that the operation of the proposed Bad Creek II Complex has the potential to impact water surface elevations of Lake Jocassee. Further information should be provided regarding specifics of anticipated changes in water levels, for how long, and at what time(s) of day/night.

This section also indicates that increased sediment loading to the Whitewater River arm of Lake Jocassee is expected during construction. In addition to SCDHEC permit(s), the addition of fill to a WOTUS and WoS may require a permit from the USACE. Extra care should be taken to prevent and minimize erosion to avoid degradation of the high-quality downstream waters, which are classified as Outstanding Resource Waters, Trout Natural, and Trout: Put, Grow and Take.

Additionally, this section states that disposal of the overburden from construction activities is expected to include addition of fill to streams and wetlands within the project area. As noted previously in these comments, the waters in this area have uncommonly high-water quality and are designated as Outstanding Resource Waters, Trout Natural, and Trout Put, Grow and Take waters – SC's most protective designations. Alternative disposal locations should be utilized to avoid filling such high-quality waterways.

11f) PAD Section 7.1.5.2 ([Wetlands and Riparian Habitat] Potential Issues – Bad Creek II Complex) notes that approximately 4 million cubic yards of spoil material will need to be disposed of and indicates that to do so within the Project Boundary will involve permanent impacts to water resources. Considering the unique habitat for many At-Risk species within this area, Duke should evaluate alternate locations for disposal of spoil material.

Duke Energy does not propose any PM&E measures be included in the New License as compensatory mitigation will be required if waters of the U.S. are impacted. We understand this process is separate from FERC's relicensing and urge Duke to consider permittee-sponsored mitigation to ensure protection and enhancement of waters and habitats similar to the unique and high-quality habitat provided in the Project area.

11g) PAD Section 7.1.6.2 ([Recreation and Land Use] Potential Issues – Bad Creek II Complex) indicates that temporary impacts from construction of the Bad Creek II Complex will include prohibiting public access within the Project Boundary for five years. This section should be revised to clearly indicate what parking lots and access points will be impacted. As noted previously, a popular parking lot and access point to hiking trails are located within the Project Boundary. Both the Lower Whitewater Falls Trail and the Bad Creek Spur Trail are located partially within the Project Boundary.

The FTC welcomes the opportunity to participate in additional discussions regarding these potential temporary – but long-term – impacts and possible mitigation strategies.

11h) PAD Section 7.1.7 (Aesthetic Resources) outlines the visible Project elements and should be expanded to include visual conditions and impact along the Trail. For example, the Bad Creek Reservoir and transmission lines are visible from locations along the Foothills Trail and additional viewpoints throughout the area. These locations should be identified and potential issues from the existing project or proposed Complex should be evaluated for additional consideration.

Comment 11 requests revisions/clarifications to PAD 6, 6.3.10, 6.3.10.2, 6.4.7, 6.5.4, 6.7.4, 7.1.2.2, 7.1.4, 7.1.4.2, 7.1.5, 7.1.5.2, 7.1.6.2, and 7.1.7.

COMMENT 12: <u>The proposed Project Boundary should be expanded to include all Project-related infrastructure.</u>

12a) Throughout the documents (e.g., Section 6.8.5; Appendix C), the Project Boundary Map should be clearly labeled and expanded to include the weir in Lake Jocassee that was installed to reduce impacts from the Bad Creek reservoir discharge. The weir is described in Section 5.4.5 (Submerged Weir in Lower Reservoir).

12b) In several places throughout the documents, Duke notes that no public recreation is provided within the proposed Project Area. However, public access is currently provided in and adjoining the proposed Project Boundary. The public utilizes Bad Creek Road to access a public parking lot, Foothills Trail kiosk, and a spur trail providing access to the Foothills Trail and to the Lower Whitewater Falls. Each of these infrastructure components are shown on the map and should be labeled appropriately.

12c) Additionally, recreational areas that are provided to meet FERC License Agreements are regularly included within the Project Boundaries; as such, the entirety of Duke's 43-mile section of the Foothills Trail should be included within the Project Boundary and related maps.

Comment 12 requests revisions/clarifications to PAD 5.4.5, 6.8.5, 7.1.6, 7.1.6.1, 7.1.7; and Appendix C.

COMMENT 13: Specific minor revision requests are listed below.

13a) The Foothills Trail Conservancy contact information should be updated in the Bad Creek Pumped Storage Project (FERC No. 2740) Distribution List (included in NOI and PAD Appendix A), to the following:

Andrew Gleason
Chairman, Board of Directors
Foothills Trail Conservancy
andrewandwilla@hotmail.com

Dr. Bill Ranson
Member, Board of Directors
Foothills Trail Conservancy
bill.ranson@retiree.furman.edu

Glenn Hilliard
Founder and Advisor
Foothills Trail Conservancy
glenn@hilliardgroup.com

13b) SD1 Section 8.0 (page 21-23) should include the most current version of Comprehensive Plans; for example, the list includes the SC State Comprehensive Outdoor Recreation Plan (SCORP) from 2008, but the SCORP was updated in 2019 and is available online https://p.widencdn.net/bzuwqi/2019-South-Carolina-SCORP-FINAL.

13c) PAD Section 4.4.1 (Maintenance of Public Website) – Duke commits to maintaining a public Project website during the course of the licensing process. To assist stakeholders and the general public with understanding Duke's compliance with the Licensing Agreements, we recommend maintaining this website (including compliance reports) into the future.

13d) PAD Section 6.8.1.1 (FERC-Approved Recreation Facilities at the Project) states that "Prior to the construction of the Project, the first portion of the Foothills Trail was built linking Table Rock State Park to Oconee State Park." This wording is confusing and could be misunderstood that the first portion of the Trail connected Table Rock State Park to Oconee State Park. In fact, Table Rock State Park and Oconee State Park represent the current end points – and the section between is the entire 77-mile Foothills Trail, including the 43-mile central section Duke constructed and continues to maintain. This section should be clarified to accurately describe the initial section built prior to construction of the Bad Creek Project.

Comment 13 requests revisions/clarifications to NOI; SD1 8.0; PAD 4.4.1, 6.8.1.1; and PAD Appendix A.

ELECTRONICALLY FILED

June 23, 2022

The Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street N.E.
Washington, DC 20426

Alan Stuart
Duke Energy Carolina, LLC
Mail Code EC012Q
526 Church Street
Charlotte, NC 28202

Re: **Bad Creek Pumped Storage Project (FERC No. 2740-053)**
Comments on Preliminary Application Document and Scoping Document 1

Dear Secretary Bose and Mr. Stuart:

Upstate Forever is a nonprofit organization that works to balance growth with the protection of our natural resources by working on conservation, water quality, and sustainable development issues in the Upstate region of South Carolina. Our mission is to protect critical lands, waters, and the unique character of the Upstate of South Carolina, including the Upper Savannah Watershed where many of our members live, work, and recreate. Over the past two decades, we have successfully partnered with public and private landowners, local, state and federal governments, utilities, non-governmental agencies, and other stakeholders to protect the natural assets that make the Upstate special, such as our farmlands, forests, natural areas, rivers, and clean air.

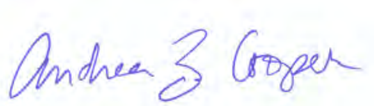
On February 23, 2002, Duke Energy ("Duke") filed a Notice of Intent and Pre-Application document for its Bad Creek Pumped Storage Project (FERC No. 2740, "Project"). The existing FERC license for the Bad Creek Project expires on July 31, 2027. The Project is the first in a series of impoundments in the Savannah River Basin that include Lake Jocassee, Lake Keowee, Lake Hartwell, Lake Russell, and Lake Thurmond. Located near the Town of Salem in northern

Oconee County, the Project utilizes a reservoir created by impounding Bad Creek and West Bad Creek, tributaries of Howard Creek and Lake Jocassee, in the Whitewater River Watershed (HUC 0305010101-05) in the uppermost headwaters of the Savannah River Basin.

Water in the Bad Creek reservoir originates primarily by pumping water from the lower reservoir (Lake Jocassee) through the Bad Creek Complex and into the upper (main) reservoir. During periods of high energy demand power is generated using the water stored in the main reservoir, then refilled from the lower reservoir when demand is low. Duke is currently evaluating the technical and economic feasibility of installing the Bad Creek II Complex ("Complex"), which would increase the power generation capacity – from 1,400 Megawatts (MW) to 2,800 MW – and pumped storage return of the Project by installing an additional conveyance system and powerhouse. The evaluation also includes the potential need for additional transmission lines. The second complex would allow Duke to generate power using either system while simultaneously maintaining, upgrading, or repairing the other complex as needed. If Duke Energy decides not to pursue a second complex in its final licensing proposal, Duke plans to continue to operate the Project under the conditions of the existing license.

From 2010-2014, Upstate Forever participated in the relicensing of the Keowee-Toxaway Hydroelectric Project (FERC No. 2503), which culminated in the successful renewal of the FERC license for that project. Through the ILP relicensing process, we collaborated with Duke Energy and other stakeholders to develop protection, mitigation, and enhancement measures as well as environmental and recreation resource enhancements for the region. Following the completion of the relicensing process, Upstate Forever has served on the grant review committee for the Keowee-Toxaway Habitat Enhancement Program and participated as a stakeholder with the Lake Keowee Source Water Protection Team. We are pleased to participate as a stakeholder for the relicensing of the Bad Creek Project. Our primary interests in this Project are related to water quality and quantity, fish and wildlife habitat, recreation resources and opportunities, and land conservation. We look forward to working with Duke Energy and other stakeholders to ensure that the new license provides for the protection, restoration, and mitigation of the natural resources within the Upper Savannah Watershed. We have completed a review of the Preliminary Application Document (PAD) and Scoping Document 1 (SD1) and are pleased to offer the following comments and additional study requests.

Sincerely,



Andrea Cooper
Executive Director

5.4.1 EXISTING PROJECT FACILITIES – UPPER RESERVOIR AND DAM

This section describes the project facilities including reservoirs and dams. The final paragraph refers to stream augmentation facilities, which consisted of a "system of intakes, pipes, and sluice gates" to augment flows to Howard Creek. However, the stream augmentation system is not currently used. Howard Creek is a tributary of Lake Jocassee, classified as Outstanding Resource Waters (ORW) by the SC Department of Health and Environmental Control (SCDHEC), and receives anywhere from 40% to 80% of its flow from Bad Creek and West Bad Creek by way of seepage from the Main Dam and West Main Dam. Please elaborate the purpose and need for the stream augmentation on Howard Creek, and further explain why the system is no longer in use.

6.1.2 CLIMATE

This section of the PAD provides climate data for two 30-year periods from 1971-2000 and 1981-2010, and appears to be sourced from a recent (2021) SCDNR study. Although more recent and more descriptive data is probably available, it is not included here. The Upstate has seen a dramatic increase in the frequency and intensity of extreme weather events not only over the past several decades but in just the past few years, including high intensity rainfall, flash flooding, and prolonged periods of drought. If possible, please update this section to include climate data that captures recent extreme weather events. We would like to see more descriptive data through 2020 such as maximum and minimum rainfall amounts, number of days with or without rain, longest period without rainfall, number of days above average, severe weather events, and any other descriptive data.

6.1.3.1 MAJOR LAND AND WATER USES – LAND COVER

Section 6.1.3 of the PAD describes major land and water uses within the Project boundary using the U.S. Geological Survey's National Land Cover Database. Both Table 6.1-3 and Figure 6.1-3 include areas categorized as "cultivated crops" (3.7% of Project boundary) or "hay/pasture" (10.1% of Project boundary), neither of which would be consistent with typical land management practices around a high priority dam, nor do they appear to agree with the images of the Main Dam in Figure 5.4-2 and the West Dam in Figure 5.4-3. Please confirm whether any cultivated crops or areas of hay or pasture do indeed exist within the project boundary, or clarify the land uses immediately adjacent to the Main Dam and West Dam.

6.2.5.2 SHORELINES AND STREAM BANKS

Section 6.2.5.2 of the PAD describes the modeling framework used to evaluate the potential operational impacts of the proposed Bad Creek II Complex in the Whitewater River arm of Lake Jocassee, including potential shoreline erosion. Results of the computational flow dynamics

(CFD) model indicate that the addition of the Complex is unlikely to increase the shoreline erosion potential of the Lake Keowee shoreline. Please update this section of the PAD with more information regarding the modeling results, including graphic depictions of peak velocities, discharge points, and shoreline impacts.

6.3.7 EXISTING WATER QUALITY DATA

This section of the PAD provides a summary of existing water quality data collected for waters within the Project Boundary and vicinity but is limited to the upper reservoir (6.3.7.1 Bad Creek Reservoir) and lower reservoir (6.3.7.2 Lake Jocassee). No water quality data is included for either Howard Creek, which receives seepage flows from the Main Dam and West Dam and is a tributary of Lake Jocassee, or Whitewater River, which is the receiving water from daily Project operations and the location of a submerged weir designed to minimize the effects of Project operations on lake stratification, protect cold-water fish habitat, and dissipate energy from discharged water. Similarly, no water quality data is provided for Bad Creek or West Bad Creek, which according to Section 6.3.1 of the PAD are only “partially to mostly submerged.”

In addition, neither the upper reservoir nor its tributaries have historically been monitored for water quality, which is an erroneous oversight providing no baseline water quality data for waters in the Project vicinity. Flow data is provided for Howard Creek in Table 6.1-1 but only for a brief period from 1989 to 1996. According to the current implementation of the Waters of the US (WOTUS)[1], Pre-2015 Regulatory Definition and Practice, the Bad Creek Reservoir is included under WOTUS and Waters of the State (WoS) protections because it was formed by the impoundment of two free-flowing rivers or streams, Bad Creek and West Bad Creek, and as such regulatory designations do apply. More information is needed for these Project-related water resources to better understand the Project’s impact on existing watershed health. Please provide a rationale for excluding these significant water resources in the Whitewater River Watershed and include measures for updating and collecting water quality data in the PAD and proposed studies for relicensing.

6.3.7.2.2 WATER QUALITY MONITORING

Duke Energy proposes to develop a Water Quality Monitoring Plan in consultation with agencies for Project construction (pre-, during, and post-construction) and operations, including monitoring locations, methods, and reporting criteria for major parameters such as DO, temperature, pH, specific conductance, and turbidity. Duke should include nutrients (nitrogen and phosphorus) to the list of parameters they monitor as land use practices can contribute to increased nutrient levels in surface waters. The Upstate is seeing an increasing trend with rising nutrient levels in reservoirs, which can lead to harmful algal blooms, and ultimately result in lost recreation opportunities, decreased property values, and poor water quality that is expensive for water utilities to treat. Because the nearby Lake Keowee is a popular recreation

[1] https://www.federalregister.gov/documents/2021/12/07/2021-25601/revised-definition-of-waters-of-the-united-states

destination and drinking water source for over 250,000 people in the Upstate, this should be of considerable importance. Furthermore, in continuation with our concerns regarding the absence of water quality data for Project-related waters, please include a plan for establishing and monitoring water quality data for Bad Creek, West Bad Creek, Howard Creek, and White River.

6.5.2.2 INVASIVE SPECIES

Section 6.5.2.2 of the PAD lists numerous invasive species observed during field surveys conducted throughout the transmission line corridors in 2021. However, there is no indication of field surveys conducted in other Project areas, including access areas or on the faces of the project dams. Many of these species already are or will soon be extremely problematic for land management if left unattended. Furthermore, the PAD does not provide any other detail about current or proposed vegetation management at the project and should include information describing management activities for native and non-native invasive species in the Project boundary and vicinity.

6.6.1.1.1 WETLANDS, RIPARIAN, AND LITTORAL HABITAT – RELATIVELY PERMANENT WATERS WITH SEASONAL FLOW

This section appears to be mis-titled. Based on context of the section paragraph, this section should instead be titled as "Relatively Permanent Waters with *Perennial* Flow."

6.6.3 KNOWN OR POTENTIAL ADVERSE EFFECTS AND PROPOSED PM&E MEASURES: BAD CREEK II COMPLEX

The PAD estimates approximately 4 million cubic yards of spoil material will need to be disposed as a result of constructing the proposed new Complex. That is the equivalent to approximately 250,000 dump trucks. Both Section 6.6.3 and the Natural Resource Assessment in Appendix E discuss the potential for disposing spoils in wetlands and surface waters, including dredging, filling, clearing, and de-watering. However, there is no discussion in this section of transporting the spoil material off site for alternative uses or disposal. In addition, Table 6.6-7 of this section lists potential spoil locations and the estimated impacts to wetlands and surface waters, including preferred spoil locations (denoted by an asterisk *). However, the PAD does not discuss the criteria used to assess the potential spoil disposal areas, nor does it provide an explanation of why some areas are preferred over others. The Clean Water Act requires consideration for avoiding and minimizing impacts before a Section 404 permit can be obtained for placing fill in waters of the US, and before a water quality certification can be awarded by the State. Off-site transport should be included in the criteria and considered the only option unless other disposal methods can be justified. Please update this section to include a comprehensive discussion of these criteria with the addition of off-site removal, including how the potential spoil disposal areas are being identified, sized, assessed, and selected as Duke Energy's preferred locations for this purpose off-site removal.

During construction of Complex II, it is anticipated that several trucks and other large equipment will be transported over roads to access the Project. This additional traffic will increase turbidity levels in stormwater runoff in both reservoirs as well as the tributary streams. Duke should include a discussion of the type and number of BMPs (e.g., vegetation, matting, silt fencing) proposed to prevent runoff from negatively impacting water quality. Furthermore, Duke should include plans for stabilizing soils at construction sites and staging areas during and after construction activities making sure to use only native vegetation in the project vicinity to stabilize and re-establish habitats.

6.8 RECREATION AND LAND USE

Section 6.8 of the PAD provides a thorough description of recreation facilities and opportunities in the Project vicinity, including the Foothills Trail and other nearby recreation resources. Notably, there is considerable emphasis on off-Project recreation areas likely due to the restricted nature of the upper reservoir. Because there is no access to the Bad Creek reservoir for recreation purposes, fulfillment of the Recreation component (Exhibit R) of the original license was provided through the creation and management of a 43-mile central section of the Foothills Trail. Exhibit R included public access and parking, trail kiosks and directional signs, additional spur trails, and stream crossings as well as continual maintenance and operational activities for limited recreation uses, primarily hiking. For this section of the PAD Duke should provide a comprehensive summary of its fulfilment of Exhibit R requirements under the original license, including a history of any modifications to Exhibit R that may have occurred during the license term.

Unfortunately, language in both the PAD and Scoping Document 1 creates confusion regarding Duke's long-term plans for continued management of the Foothills Trail. Specifically, Section 7.1.6.1 of the PAD states, "The segment of the Foothills Trail and two undeveloped access areas on non-Project lands that were developed per the Original License will continue to be maintained by Duke Energy in the New License term as a non-Project facility and potentially under a separate agreement with regional stakeholders." Meanwhile, SD1 states that "Duke Energy does not propose to include the Foothills Trail as a project recreation facility under the new license." These two documents should be reconciled to clarify Duke's intentions and the fate of the Trail.

The Foothills Trail system provides important recreational and educational opportunities to both Upstate residents and visitors from around the world. However, the Upstate is experiencing unprecedented and accelerating population growth and is expected to continue growing for decades to come. By 2040, our region's population is projected to reach nearly 1,750,000 – an increase of 64% since 1990.[2] Already our natural resources are stretched thin, and the current pandemic has revealed how fragile and overburdened our public recreation areas have become. Continued support of the Foothills Trail is a critical component of the New

[2] https://www.upstateforever.org/files/files/2017.7.20_SOF_FINAL_Report.pdf

License and expansion of the recreation provisions should be considered to account for the population growth, increased demand for outdoor recreational needs, and expansion of project operations from the ongoing upgrades. Ensuring that recreation opportunities centered on the Foothills Trail continue to provide quality recreation opportunities in perpetuity and that the Foothills Trail can continue to grow to meet additional demand should be paramount in this licensing. Such consideration should include all or some of the following:

1. An endowment given to the Foothills Trail Conservancy for ongoing management and maintenance of the Foothills Trail system;
2. Fee-simple donations of land to be included in the Foothills Trail system, or to State resource agencies for various purposes, including recreation, habitat management, and water quality protection;
3. Conservation easements on lands owned by Duke Energy, which would protect the Foothills Trail corridor, or allows for other recreation opportunities (a conservation easement would limit specific land development practices but could allow for recreation uses and even Project related activities), including the 6,700-ac tract surrounding the Project;
4. Expand the Foothills Trail system to connect with other trail systems, including the Palmetto Trail at Stumphouse Tunnel, the Panthertown trail system, the Tuskegee National Forest trail system, the Art Loeb Trail in Pisgah National Forest, and the Appalachian Trail; and
5. Providing a financial contribution to the Oconee County Conservation Bank, which would then be used to protect additional lands in the County beyond the Project boundary.

We encourage Duke to update this section of the PAD to include the options above, which are vital tools for creating, protecting, and managing open space for public recreation uses outside the Project boundary.

Throughout the PAD, much consideration is given for the Keowee-Toxaway Hydroelectric Project (FERC No. 2503). However, the Keowee-Toxaway Project operates under a separate and distinct license from the Bad Creek Pumped Storage Facility. It is often confusing how one project relates to the other, and sometimes reads as if requirements under one license are used to offset obligations under the other. While both projects are indeed impacted by the other, and may influence operations at other projects (e.g., Oconee Nuclear Station), the relicensing processes, including studies, commitments, obligations, and other agreements are specific to those projects. Specifically, there is an impression that some recreation opportunities lost from the exclusivity of the Bad Creek project were remedied on Lake Jocassee, which may or may not have been negotiated during the relicensing of the Keowee-Toxaway project. During the Keowee-Toxaway relicensing, stakeholders were not able to consider lost recreation opportunities of the Bad Creek project. The same is true for fishery resources and work plans conducted in coordination with SCDNR through the Keowee-Toxaway relicensing, as well as the Recreation, Use, and Needs Study (RUN Study) conducted in 2013, which failed to consider the recreation opportunities provided by the Foothills Trail. In summary, these projects are clearly complementary and inextricably linked, but do not necessarily satisfy individual license requirements.

While water-based recreation such as boating and swimming at the Bad Creek reservoir are understandably overlooked due to fluctuating water levels and public safety concerns, management components related to traditional recreation activities such as fly-fishing and birdwatching should have been considered under the original license and should be addressed in the current licensing. Therefore, due to the lack of water-based recreation opportunities available for this Project, the RUN Study should consider alternatives to water-based recreation opportunities in off-Project areas. Furthermore, a thorough RUN Study should be included as part of the general licensing requirements and completed regardless of whether Duke decides to pursue the additional Complex II.

Similarly, with the increased strain on public recreation areas resulting in overuse and overcrowded experiences, the RUN Study should evaluate the need for expanded facilities, spur trails, connectivity, camping, and other attributes, including public safety concerns throughout the Foothills Trail system. Vandalism and wild animal encounters have increased in Upstate recreation areas, including the Foothills Trail system. Public safety needs to assessed along the trail corridor, and at access and parking areas, observation areas, and any other facilities associated with the trail system. Lastly, the RUN Study should be re-evaluated periodically, and a new study conducted at least every ten years throughout the next license term.

Finally, the original license refers to the Bad Creek Pumped Storage Project as the preferred alternative to a proposed Long Spur Ridge project, which was also under consideration as a similar pumped storage facility. The creation of future projects in the vicinity of the existing Project, including the Limber Pole Creek Project and the Coley Creek Project, should be considered particularly given that obligations for recreation are satisfied beyond the project boundary. These two projects would be situated on an expansive 6,700-acre tract owned by Duke Ventures Real Estate, LLC, a subsidiary of Duke Energy. While Duke Energy may not consider these as viable projects at this time, things may change dramatically over the course of the next license term, which may result in drastic changes in land use and development in the Project vicinity. We believe protection of this tract in particular (Oconee County parcel #016-00-01-013) is key to ensuring long-term high-quality habitat and recreation resources for the Upstate, and for ensuring abundant high-quality water resources for the region. If developed, this tract would have permanent and devastating impacts to water quality in the Whitewater River Watershed and would diminish all the proactive accomplishments that our resource agencies and conservation community have achieved over the past 50 years. (See the "Water Quality Sensitivity in the Bad Creek Project Vicinity" map appended at Attachment 1.)

7.1.1 GEOLOGY AND SOILS

This section of the PAD provides a brief description of soil classifications in the Project vicinity. However, it does not include an analysis of Prime Soils or Soils of Statewide Importance. Duke should consult with USDA/NRCS to provide a summary of soils that have the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, and oilseed crops, and is available for such use, and develop a plan for protecting those areas during the next licensing term. The Oconee County Conservation Bank has provided grant funding for projects that permanently protect lands with Prime or Important Soils with conservation easements held by Upstate Forever or Oconee County's Soil and Water Conservation District.

8.0 COMPREHENSIVE PLANS

This section should include the most recent future land use maps and comprehensive plans available for the project area in both Transylvania and Jackson counties of North Carolina, and Oconee County, South Carolina. Oconee County recently adopted its "Unified 2020 Comprehensive Plan"[3] on March 3, 2020. From October 2018 through December 2019, Oconee County engaged its local citizens through numerous public meetings, newspaper inserts highlighting the elements of the plan, and a survey for public input. Because the character and density of land that abuts the Project will not be determined solely by Duke Energy, management of the Project as well as the lands in the Project vicinity should consider the vision for the future expressed by Oconee County residents and captured in their plan.

GENERAL COMMENTS

- **CLIMATE CHANGE**

The PAD includes no discussion of climate change and how it may affect various aspects of the Project, including operations and management of Project resources. Climate change is an important consideration for wildlife and botanical resources, recreation, water quality and water quantity, and land planning, use, and policy. It should be included for consideration in each section of the PAD, as well as every proposed study in this licensing process, and continue to inform Project management and operation decisions throughout the life of the proposed new license. In addition, how will climate change considerations be reflected in the design and operations of Duke's current and proposed hydroelectric facilities?

As previously discussed, SC has seen a dramatic increase in the frequency and intensity of extreme weather events over the past several decades, including flooding and drought. These extreme conditions will continue to have implications on the operations and management of these facilities and the natural resources. This should include, but not be limited to, discussion of increasing nighttime temperatures, changing seasonal precipitation patterns, increased frequency in extreme weather events, and increased periods of drought. Wildlife corridors, which may be necessary for species migration due to climate change, should be considered and PM&E measures identified for both relicensing of existing operations.

- **SEPARATE LICENSES WITH SPECIFIC REQUIREMENTS**

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[3] https://oconeesc.com/documents/planning-zoning/comprehensive-plan/unified-2020-comprehensive-plan.pdf

Throughout the PAD, much consideration is given for the Keowee-Toxaway Hydroelectric Project (FERC No. 2503). However, the Keowee-Toxaway Project operates under a separate and distinct license from the Bad Creek Pumped Storage Facility. It is often confusing how one project relates to the other, and sometimes reads as if requirements under one license are used to offset obligations under the other. While both projects are indeed impacted by the other, and may influence operations at other projects (e.g., Oconee Nuclear Station), there are resources and obligations singular to each project. As already mentioned, there is an impression that some recreation opportunities lost from the exclusivity of the Bad Creek project were remedied on Lake Jocassee, which may or may not have been negotiated during the relicensing of the Keowee-Toxaway project. During the Keowee-Toxaway relicensing, stakeholders were not able to consider lost recreation opportunities of the Bad Creek project. The same is true for fishery resources and work plans conducted in coordination with SCDNR through the Keowee-Toxaway relicensing, as well as the Recreation, Use, and Needs Study (RUN Study) conducted in 2013, which failed to consider the recreation opportunities provided by the Foothills Trail. In summary, these projects are clearly complementary and inextricably linked, but do not necessarily satisfy individual license requirements.

COMMENTS ON SCOPING DOCUMENT 1

3.1.2 EXISTING PROJECT OPERATION

Throughout SD1 and the PAD, the Project is presented as an isolated pumped storage project seemingly without influence or relationship to other facilities or project operations. However, most of the volume in the upper reservoir originates from Lake Jocassee, which also plays a major role in the operations of both the Keowee-Toxaway Hydroelectric Project (FERC No. 2503) and the Oconee Nuclear Plant. All three projects depend on water levels in Jocassee to provide abundant water to safely generate power for Duke Energy customers. This section of the Scoping Document and the PAD should include a description of how the water level in Lake Jocassee affects these projects, including an extreme low inflow scenario where operations of Bad Creek may need to be curtailed or ceased to maintain operations at other projects.

Furthermore, the Project presently operates within the upper 50 to 60 feet of full pond level. However, the existing license authorizes a 160-foot maximum drawdown. Currently, the Project is undergoing pump-turbine upgrades, and Duke has proposed the construction and operation of a second powerhouse as part of this relicensing. Both the upgrades and the new Complex will increase the range within which Project operations will impact water levels, creating larger and more rapid fluctuations in both the Bad Creek reservoir and Lake Jocassee. Therefore, the increased operating band may also affect a variety of environmental parameters, including but not limited to water quality, shoreline habitat, and fish entrainment.

3.2.2 PROPOSED ENVIRONMENTAL MEASURES

Under the Aquatic Resources portion of this section, we believe the Fisheries MOU and 10-Year Work Plans for fishery resources that Duke has completed in partnership with SCDNR should be included. Activities included in the 10-Year Work Plans were designed to develop and enhance management strategies for fish in these areas and included fisheries surveys and inventories, water quality and aquatic habitat evaluations, fish stocking, recreation, and shoreline impacts. Duke Energy entered an MOU with SCDNR for the long-term management and maintenance of high-quality fishery resources in Lake Keowee and Lake Jocassee *as well as their tributary streams*. While the current MOU is in effect through 2027 and intended to mitigate for fish entrainment, we don't currently know what contribution the proposed Complex will have on entrainment. Therefore, we believe that Duke should extend the MOU and workplans through the term of the new license.

4.1.2 RESOURCE ISSUES – AQUATIC RESOURCES

We support all the issues identified in this section. However, we have particular concerns that no water quality data has been collected for the Bad Creek Reservoir and associated tributaries making it impossible to determine if the current or proposed operations have or will have any negative impacts on water quality. (See our previous comment regarding Section 6.3.7.2.2 of the PAD on Water Quality Monitoring.)

Furthermore, we have concerns regarding the effects of construction-related erosion, sedimentation, and spoils disposal on water quality, aquatic habitat, and aquatic biota in the Bad Creek reservoir, Lake Jocassee, and surrounding tributaries. Four million cubic yards of debris is expected from the construction of Complex II, which is the equivalent of at least 250,000 dump trucks. The resulting construction activity will heavily impact roads in the watershed and create additional runoff and turbidity in nearby streams and reservoirs. In addition, Duke has proposed to dispose of spoils in several nearby locations, including wetlands, forested uplands, tributaries, and the weir. Most of the waters in the Project vicinity are characterized as extremely high-quality streams with designations including Outstanding Resource Waters, Trout Natural, and Trout Put, Grow and Take, which our State's most protective water classifications. ***Filling wetlands and tributaries is not an acceptable option***.

It is also not clear how the spoil locations were selected or why no consideration was given to transporting materials off site. Upland disposal of construction debris that results in impacts to streams or wetlands, as well as placement of rock spoils at the submerged weir, will require an Individual Permit from the USACE as well as a Water Quality Certification from SCDHEC under the authorities of Sections 404 and 401 of the Clean Water Act. Further, as part of the Mitigation Rule, it is a requirement for Duke Energy to consider all steps to *avoid and minimize* impacts to water resources before undertaking activities that negatively impact waters. Duke Energy expects to initiate this parallel regulatory process in conjunction with the relicensing process. However, to avoid impacts to water resources, we strongly recommend that spoils be transported off site rather than used to fill wetlands and streams. (See our previous comments regarding Section 6.6.3 of the PAD on Known or Potential Adverse Effects and Proposed PM&E Measure: Bad Creek II Complex.)

4.1.3 RESOURCE ISSUES – TERRESTRIAL RESOURCES

In addition to assessing the effects of project construction, operation, and maintenance activities on ecological communities and protected terrestrial species, we believe that the effects on *potential* habitat should also be assessed. Furthermore, we believe this should be expanded to include the effects of non-native, invasive, and noxious species on ecological communities and potential habitat areas as well. Habitat and corridor protection is one of the most critical needs for the protection and preservation of species. Assessing the direct impact of the Project on target species is only one component to ensuring that the species have the greatest chance of survival. Rather, the assessment should explicitly examine the amount of available habitat and habitat needs for healthy, diverse, and viable populations of the target species. The assessment should examine past habitat availability, current habitat availability, and determine trends for habitat loss or creation through the term of the new license based on the identified trends. This information can then be used to identify target values for habitat protection and restoration in and near the Project. Lastly, the impacts of climate change should also be evaluated and discussed. Wildlife habitat corridors may be necessary for species migration due to climate change and should be of particular interest throughout the life of the proposed new license.

4.1.4 RESOURCE ISSUES – THREATENED AND ENDANGERED SPECIES

Upstate Forever has the same comments and concerns regarding the effects of project construction, operation, maintenance, and project-related recreation on RT&E species as we do on Section 4.1.3 above, including climate related impacts. In addition, both this section and Section 4.1.3 should consider Project impacts on species not included in this section of SD1. The US Fish and Wildlife Service provided a "List of Threatened, Endangered, Candidate, and Proposed Species Generated by ECOS-IPaC Website on Aprill 11, 2022," (List) which is available on the FERC's eLibrary for this docket. The List includes ten (10) migratory bird species considered Birds of Conservation Concern (BCC), which warrant special attention in the project vicinity. These birds are protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act.

4.1.5 RESOURCE ISSUES – RECREATION, LAND USE, AND AESTHETICS

As previously mentioned, language in both the PAD and Scoping Document 1 creates confusion regarding Duke's long-term plans for continued management of the Foothills Trail. Specifically, Section 7.1.6.1 of the PAD states, "The segment of the Foothills Trail and two undeveloped access areas on non-Project lands that were developed per the Original License will continue to be maintained by Duke Energy in the New License term as a non-Project facility and potentially under a separate agreement with regional stakeholders." Meanwhile, SD1 states that "Duke Energy does not propose to include the Foothills Trail as a project recreation facility under the new license." These two documents should be reconciled to clarify Duke's intentions and the fate of the Trail.

We support all the issues identified in this section. In addition, we believe that land use should be further reviewed in the context of shoreline habitat around the upper reservoir. Because there is no public access to the Bad Creek Reservoir shoreline, permitting policies addressed through a Shoreline Management Plan and Shoreline Management Guidelines are unnecessary. However, due to limited interference from human activities, much of the shoreline around the upper reservoir can and should be managed to provide prime riparian and littoral habitat. The impacts of climate change should also be evaluated and discussed.

Furthermore, because there is no recreational access to the Bad Creek reservoir, the recreation component (Exhibit R) of the original license was provided through the creation and management of a 43-mile section of the Foothills Trail. Exhibit R included public access and parking, trail kiosks and directional signs, additional spur trails, and stream crossings as well as continual maintenance and operational activities for limited recreation uses, primarily hiking. However, while water-based recreation such as canoeing and swimming are understandably overlooked due to fluctuating water levels and public safety concerns, management components related to traditional recreation activities such as fly-fishing and birdwatching should have been considered and should be addressed in the current licensing.

The Foothills Trail system provides important recreational and educational opportunities to both Upstate residents and visitors from around the world. Meanwhile, the Upstate is experiencing unprecedented and accelerating population growth and is expected to continue growing for decades to come. Already our natural resources are stretched thin, and the current pandemic has revealed how fragile and overburdened our public recreation areas have become. Continued support of the Foothills Trail is a critical component of the New License and expansion of the recreation provisions should be considered to account for the population growth, increased demand for outdoor recreational needs, and expansion of project operations from the ongoing upgrades. Ensuring that recreation opportunities centered on the Foothills Trail continue to provide quality recreation opportunities in perpetuity and that the Foothills Trail can continue to grow to meet additional demand should be paramount in this licensing. Such consideration should include all of the following:

1. An endowment given to the Foothills Trail Conservancy for ongoing management and maintenance of the Foothills Trail system;
2. Fee-simple donations of land to be included in the Foothills Trail system, or to State resource agencies for various purposes, including recreation, habitat management, and water quality protection;
3. Conservation easements on lands owned by Duke Energy, which would protect the Foothills Trail corridor, or allows for other recreation opportunities (a conservation easement would limit specific land development practices but could allow for recreation uses and even Project related activities), including the 6,700-ac tract surrounding the Project;
4. Expand the Foothills Trail system to connect with other trail systems, including the Palmetto Trail at Stumphouse Tunnel, the Panthertown trail system, the Tuskegee National Forest trail system, the Art Loeb Trail in Pisgah National Forest, and the Appalachian Trail; and
5. Providing a financial contribution to the Oconee County Conservation Bank, which would then be used to protect additional lands in the County beyond the Project boundary.

The original license also refers to the Bad Creek Pumped Storage Project as the preferred alternative to a proposed Long Spur Ridge project, which was also under consideration as a similar pumped storage facility. The creation of future projects in the vicinity of the existing Project, including the Limber Pole Creek Project and the Coley Creek Project, should be considered particularly given that obligations for recreation are satisfied beyond the project boundary. These two projects would be situated on an expansive 6,700-acre tract owned by Duke Ventures Real Estate, LLC, a subsidiary of Duke Energy. While Duke Energy may not consider these as viable projects at this time, things may change dramatically over the course of the next license term, which may result in drastic changes in land use and development in the Project vicinity. We believe protection of this tract in particular (Oconee County parcel #016-00-01-013) is key to ensuring long-term high-quality habitat and recreation resources for the Upstate, and for ensuring abundant high-quality water resources for the region. If developed, this tract would have permanent and devastating impacts to water quality in the Whitewater River Watershed and would diminish all the proactive accomplishments that our resource agencies and conservation community have achieved over the past 50 years.

(See the "Water Quality Sensitivity in the Bad Creek Project Vicinity" map appended at Attachment 1, and our previous comments on Section 6.8 of the PAD regarding Recreation and Land Use.)

1.0 PROPOSED STUDIES

The proposed Fish and Aquatic Resources studies are limited in scope and should be expanded to include the Bad Creek Reservoir and associated tributaries, or Duke should include an additional study to collect water quality data for Project-related streams. Currently no water quality data exists for Bad Creek Reservoir and the surrounding streams making it impossible to assess current and future water quality conditions in these locations. (See our previous comment regarding Section 6.3.7.2.2 of the PAD on Water Quality Monitoring, and Section 4.1.2 of SD1 regarding Resource Issues – Aquatic Resources.)

8.0 COMPREHENSIVE PLANS

As previously mentioned in our comment on Section 8.0 of the PAD, this section should include the most recent future land use maps and comprehensive plans available for the project area in both Transylvania and Jackson counties of North Carolina, and Oconee County, South Carolina. Oconee County recently adopted its "Unified 2020 Comprehensive Plan"[4] on March 3, 2020. From October 2018 through December 2019, Oconee County engaged its local citizens through numerous public meetings, newspaper inserts highlighting the elements of the plan, and a survey for public input. Because the character and density of land that abuts the Project will not be determined solely by Duke Energy, management of the Project as well as the lands in the Project vicinity should consider the vision for the future expressed by Oconee County residents and captured in their plan.

[4] https://oconeesc.com/documents/planning-zoning/comprehensive-plan/unified-2020-comprehensive-plan.pdf

ADDITIONAL STUDY PLAN REQUEST

Environmental Justice Study

In comments submitted to FERC on June 16, 2022, Stephen Bowler, South Branch Chief of the Division of Hydropower Licensing for FERC included a request for an Environmental Justice Study (see "Staff Comments on the Pre-Application Document and Study Request for the Bad Creek Pumped Storage Project"). Upstate Forever supports this study request and believes it would provide important information related to how the Bad Creek Project relicensing, operations, and proposed construction activities might affect underserved communities ("environmental justice communities") in the Project vicinity. The proposed Environmental Justice Study has five objectives:

(1) to identify presence of environmental justice communities that may be affected by the relicensing of the Bad Creek Project, including the construction of the Complex, and identify outreach strategies to engage the identified environmental justice communities in the relicensing process, if present;

(2) to identify the presence of non-English speaking populations that may be affected by the project and identify outreach strategies to engage non-English speaking populations in the relicensing process, if present;

(3) to discuss effects of relicensing the project on any identified environmental justice communities and identify any effects that are disproportionately high and adverse;

(4) to identify mitigation measures to avoid or minimize project effects on environmental-justice communities; and

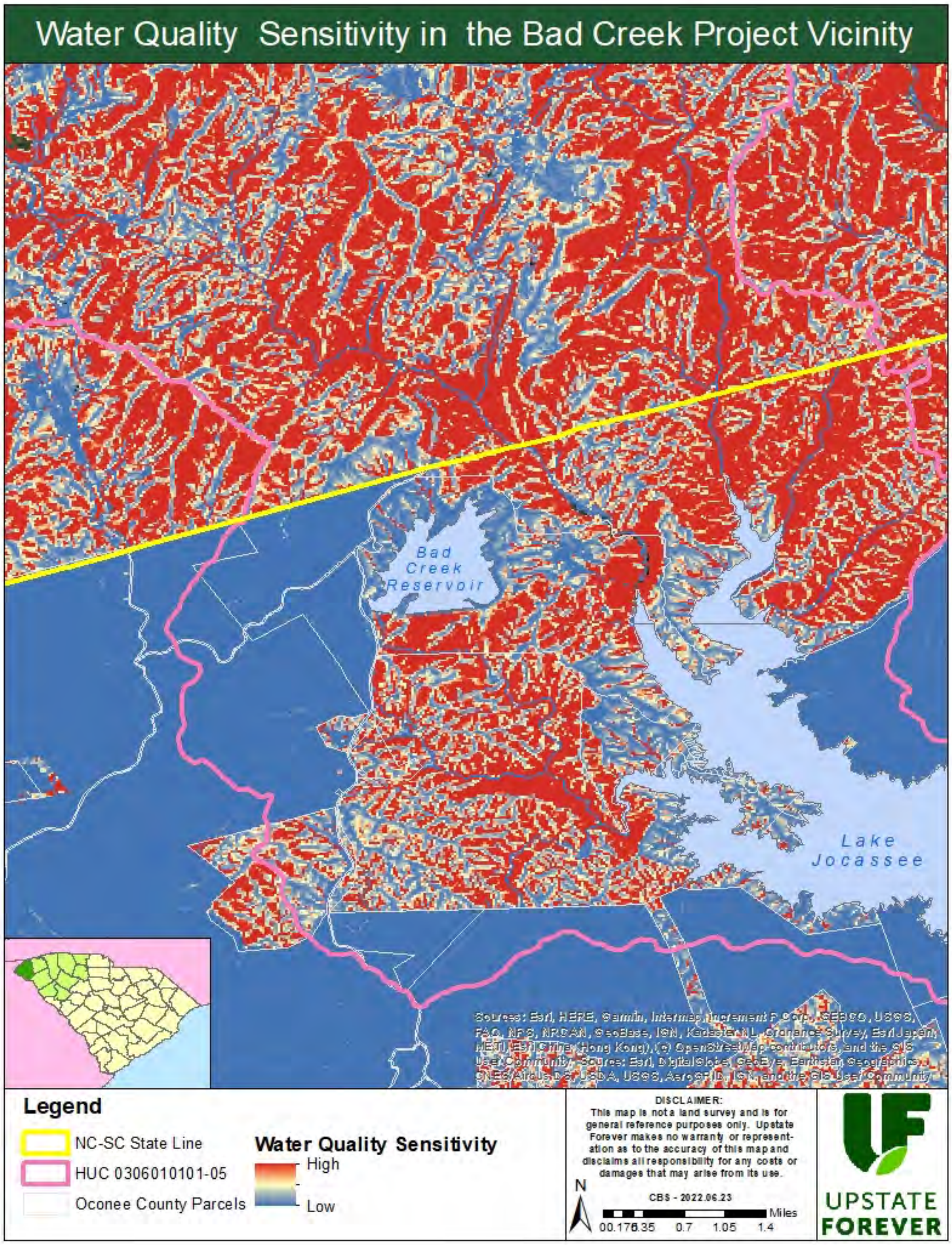
(5) to identify sensitive receptor locations within the project area and identify potential effects and measures taken to avoid or minimize the effects to such locations, if they are present.

Project construction, operation, and maintenance has the potential to affect human health or the environment in environmental justice communities. Examples of resource impacts may include, but are not necessarily limited to, project-related effects on: erosion or sedimentation of private properties; groundwater or other drinking water sources; subsistence fishing, hunting, or plant gathering; access for recreation; housing or industries of importance to environmental justice communities; and construction-or operation-related air quality, noise, and traffic.

ATTACHMENT 1

Water Quality Sensitivity in the Bad Creek Vicinity

This map shows the sensitivity of *unprotected* tracts of land in terms of impacts to water quality if developed. Areas in *red* show a *high sensitivity*, which means that water quality would be severely impacted by development. Note that almost all the unprotected land in the Project vicinity is highly sensitive and water quality would be greatly diminished if developed.



Salazar, Maggie

Subject: FW: [EXTERNAL] Three species of ferns found for the first time in South Carolina at Lake Jocassee
Attachments: 21PhytoN-SCFerns.pdf

From: Chris Starker <cstarker@upstateforever.org>
Sent: Monday, June 27, 2022 12:57:53 PM
To: Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; melanie.olds@fws.gov <melanie.olds@fws.gov>; wes.cooler@mac.com <wes.cooler@mac.com>; Glenn Hilliard <glenn@hilliardgrp.com>; Andy Douglas <adoug41@att.net>; RigginL@dnr.sc.gov <RigginL@dnr.sc.gov>; Rachel.McNamara@ferc.gov <Rachel.McNamara@ferc.gov>; Erika Hollis <ehollis@upstateforever.org>
Subject: [EXTERNAL] Three species of ferns found for the first time in South Carolina at Lake Jocassee

Good afternoon, everyone. I just learned this morning about the discovery (nearly five years ago) of three new fern species at Lake Jocassee. There is no mention of any of these ferns in the PAD. Despite the deadline for comments on the PAD and SD1 last week, I feel like this is important information relevant to the Bad Creek Project that should be included in both documents as well as any related studies. A link to the journal article published in 2018 (also attached) as well as the December 2017 issue of "The Blue Wall Weekly" are below.

https://www.phytoneuron.net/2018Phytoneuron/21PhytoN-SCFerns.pdf

https://www.jocasseelaketours.com/component/acymailing/listid-1/mailid-149-blue-wall-weekly-december-18-2017?tmpl=component&tmpl=component

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Upstate Forever is a conservation organization that protects critical lands, waters, and the unique character of the Upstate of South Carolina. Learn more at upstateforever.org.

McMillan, P.D., E.B. Pivorun, R.D. Porcher, C. Davis, D. Whitten, and K. Wade. 2018. Three remarkably disjunct fern species discovered in Pickens County, South Carolina. Phytoneuron 2018-21: 1–5. Published 25 April 2018. ISSN 2153 733X

THREE REMARKABLY DISJUNCT FERN SPECIES DISCOVERED IN PICKENS COUNTY, SOUTH CAROLINA

PATRICK D. MCMILLAN
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Clemson, South Carolina 29634

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DAN WHITTEN
South Carolina Native Plant Society
Greenville, South Carolina 29602

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Jocassee Lake Tours
Salem, South Carolina 28676

ABSTRACT

Three species of fern in the family Pteridaceae are reported as new to South Carolina: *Astrolepis sinuata* (Lag. ex Sw.) Benham & Windham subsp. *sinuata*, *Bommeria hispida* (Mett. ex Kuhn) Underw., and *Pellaea wrightiana* Hook. One of these, *Bommeria hispida*, is the first record for eastern North America. All three occur in a cliff habitat in Pickens County created in 1968-1971 by quarrying of granite to build the adjacent Jocassee Dam. All three are native to the western USA and are hypothesized to have colonized this site along the leading edge of the Blue Ridge Escarpment as winds from the Southwest continue to bring in spores.

In 2017 Ms. Kay Wade located a large population of a strange fern growing on outcrops near the Jocassee Dam in Pickens Co., South Carolina. She brought this population to the attention of local native plant enthusiast and South Carolina Native Plant Society member Mr. Dan Whitten. Dan visited the site with Kay and confirmed that the plants were a species of *Pellaea*, possibly *Pellaea atropururea* (L.) Link. Mr. Whitten was aware that *Pellaea atropurpurea* was found on calcareous or mafic substrata and thus sent a photograph of the fern to retired University of South Carolina, Upstate professor Gillian Newberry. Dr. Newberry suggested the species was a western species, likely *Pellaea wrightiana*, not *Pellaea atropurpurea*.

Wade took McMillan to the site on December 3, 2017 and McMillan immediately recognized the plant as *Pellaea wrightiana* Hook., a species with which he was intimately familiar from his work in western Texas and North Carolina. McMillan managed to scale up the rock face to secure a sample of the fronds and confirmed this identification upon returning to Clemson University. A return visit with Kay Wade, Edward Pivorun and Richard Porcher on December 6, 2017 allowed a more thorough examination of the cliff with binoculars. The group identified two additional species: *Astrolepis sinuata* (Lag. ex Sw.) Benham & Windham subsp. *sinuata* and *Bommeria hispida* (Mett. ex Kuhn) Underw. (this determination was suggested by Alan Weakley of the University of North Carolina after examining photographs). McMillan collected one frond from each of these species but most of the cliff was outside the range of hands and binoculars. The team returned to the site on 13December 2017 with a member of McMillan's staff, Mr. Cody Davis, an expert climber. Mr. Davis secured fronds of all three species and thoroughly explored the extent of the cliff for other oddities that might be encountered.

All determinations were confirmed by George Yatskievych via a loan of specimens to the University of Texas at Austin. Taxonomy follows Weakley (2015). Vouchers are as follow.

ASTROLEPIS SINUATA (Lag. ex Sw.) Benham & Windham subsp. *sinuata*

South Carolina. Pickens Co.: Approximately 300-400 vigorous clumps growing along approximately 50 meters of shoreline of Lake Jocassee on exposed granitic outcrops created during the construction of Lake Jocassee dam; plants located in vegetation mats and fissures in the rock face on west and southwest-facing exposures, with *Pellaea wrightiana*, *Bommeria hispida*, *Woodsia obtusa*, *Asplenium platyneuron*, *Andropogon virginicus*, *Chrysopsis mariana*, *Solidago canadensis*, and various bryophytes, 34°58'11.59" N 82°54'45.27" W, 6 Dec 2017, *McMillan s.n.* with Wade, Porcher, and Pivorun (CLEMS); same location, 14 Dec 2017, *McMillan s.n.* with Davis, Maddox, Pivorun, and Huffman (CLEMS, NCU).

BOMMERIA HISPIDA (Mett. ex Kuhn) Underw.

South Carolina. Pickens Co.: Two clumps located shoreline of Lake Jocassee on exposed granitic outcrops created during the construction of Lake Jocassee dam; plants found in fissures in the rock face on south and southwest-facing exposures, with *Astrolepis sinuata*, *Pellaea wrightiana*, *Woodsia obtusa*, *Asplenium platyneuron*, *Andropogon virginicus*, *Chrysopsis mariana*, *Solidago canadensis*, and various bryophytes, 34°58'11.59" N 82°54'45.27" W, 14 Dec 2017, *McMillan s.n.* with Davis, Maddox, Pivorun, and Huffman (CLEMS, NCU).

PELLAEA WRIGHTIANA Hook.

South Carolina. Pickens Co.: Over 2000 vigorous clumps growing along approximately 150 meters (0.1 mile) of shoreline of Lake Jocassee on exposed granitic outcrops created during the construction of Lake Jocassee dam; plants dominant in fissures in the rock face on south, southwest and west-facing exposures, with *Astrolepis sinuata*, *Bommeria hispida*, *Woodsia obtusa*, *Asplenium platyneuron*, *Andropogon virginicus*, *Chrysopsis mariana*, *Solidago canadensis*, and various bryophytes, 34°58'11.59" N 82°54'45.27" W, 3 Dec 2017, *McMillan s.n.* with Wade and Whitten (CLEMS); same location, 14 Dec 2017, *McMillan s.n.* with Davis, Maddox, Pivorun, and Huffman (CLEMS, NCU).

Discussion

All three of these species typically occur far to the west of Lake Jocassee. These discoveries add three species to the flora of South Carolina as well as the first record for *Bommeria hispida* in eastern North America.

The occurrence of ferns in the Southeast with a much more western distribution is not without precedent. *Pellaea wrightiana* is known from two locations in the piedmont of North Carolina, *Myriopteris rufa* Fée from Virginia and West Virginia, *Myriopteris gracilis* Fée from Virginia, *Astrolepis sinuata* subsp. *sinuata* from a single location in Georgia, *Astrolepis integerrima* (Hook.) D.M. Benham & Windham from Alabama, and most remarkably *Pellaea ternifolia* (Cav.) Link subsp. *arizonica* Windham from approximately 7.25 miles northeast of the Lake Jocassee site in Pickens County (Wagner 1965; Knobloch & Lellinger 1969; Wiebolt & Bentley 1982; Mellichamp et al. 1987;

Benham & Windham 1993; Allison & Stevens 1999; Heafner 2001). The Jocassee Gorges region has long been known for the remarkable diversity of ferns found there. One species, the mostly tropical *Hymenophyllum tunbrigense* (L.) J.E. Smith, which was located during surveys of the nearby Eastatoe River gorge (approximately 6.7 miles northeast of the Lake Jocassee site), is still known from only this single metapopulation in the continental USA (Taylor 1938). *Asplenium monanthes* L., another species with a mostly tropical distribution, is present at many locations in the Jocassee Gorges region. A review of published records and herbarium specimens, combined with field work for the preparation of this article indicates that the area of Pickens/Oconee counties now hosts 68 species of fern and fern relatives. Pickens County alone is home to 65 species. The discovery of three additional species certainly places this small region into a category of extremely high regional pteridophyte diversity.

Most, if not all, of the locations of fern species that are far disjunct to the east from more western ranges are reports of a single species per locale. The Jocassee site is remarkable for the presence of three species displaying such a pattern.

Pellaea wrightiana is a common species found on acidic-reaction outcrops in Texas, Oklahoma, New Mexico, Arizona, southern Colorado, and southern Utah and was formerly known from only two other populations east of Texas. It was erroneously reported for South Carolina by Platt and Townsend (1996). The plants originally thought to be *P. wrightiana* from Pickens County were found to be the first record of *Pellaea ternifolia* Link subsp. *arizonica* in eastern North America (Heafner 2001). The population reported here is the first record for South Carolina and is the most extensive population in eastern North America. The closest populations to the Lake Jocassee site are in Alexander Co., North Carolina (roughly 120 miles northeast), with an initially reported population of approximately 100 clumps growing on granite and Stanly Co., North Carolina (roughly 140 miles east-northeast), with an initially reported population of approximately 500 plants. Since their initial discovery, both of the North Carolina populations have apparently declined. Heafner (2001) found the Alexander County population had dropped to only around 25 clumps while the Stanly County population had also declined by half. The Lake Jocassee site is estimated to consist of no less than 2000 clumps. The discovery of the South Carolina population indicates that this species should be searched for on other acidic-reaction rock outcrops throughout the southern Appalachian region. Heafner (2001) reported that there was very little variation in the allozymes between the two North Carolina populations and they were likely to represent dispersal from a single eastward immigration event. Among the populations sampled from the western range, he found that plants in North Carolina were most similar to those sampled from Jeff Davis Co., Texas.

Astrolepis sinuata subsp. ***sinuata*** is also a common species on acidic-reaction outcrops in Arizona and New Mexico east to central Texas. The species is remarkably disjunct from central Texas to a bridge piling in Beauregard Par., Louisiana, and Merriweather Co., Georgia, where it was found on a granite flatrock next to a natural gas distribution station (Benham & Windham 1993; McMillan et al. 2013; L.L. Gaddy, pers. comm. 2017). The Pickens County location is the first for South Carolina and only the second report from east of the Mississippi River; it is the largest population east of central Texas.

The Pickens County location represents the first known station in the eastern USA for ***Bommeria hispida***. This species is remarkably disjunct from the nearest known populations in Brewster Co., Texas (more than 1200 miles to the southwest). This staggering distance might at first seem unique but it is identical to the disjunction in range found in the nearby population of *Pellaea ternifolia* subsp. *arizonica*.

Establishment at the Pickens County site

The site at which all of the observations were made is a human-created habitat. The cliff habitat was created in 1968-1971 by quarrying activity for the material to build the adjacent Jocassee

Dam. The area is known as "The Wall" and is a 10–40 meter high quarry of granitic rock. The entire hill and face of the mountain was denuded with no natural vegetation left during construction. For a better idea of the scale of disturbance, the construction of the site can be seen on video during the opening minutes of the movie *Deliverance*. The habitat these ferns have colonized was barren, newly exposed rock during the construction of the dam.

The resulting cliff forms a horseshoe shape with the upstream portion facing south and ranging to southwest, west, and northwest exposures as it proceeds downstream. All three of the species are limited to southwest and west-facing faces. The base of the cliff extends to the water for the entire length and is well over 150 feet tall along a large portion of its length. This shape, in addition to the fact that the widest portion of the lake extends from the cliff habitat, has created conditions that receive the full impact of the predominant southwest winds that dominate the region. The winds eddy and swirl in this cove and may provide the opportunity for enhanced settling of the spores that brought these ferns to the cliff.

Astrolepis sinuata subsp. *sinuata* (2n = 87, triploid) relies on apogamous reproduction while *Pellaea wrightiana* (2n = 116, allotetraploid) and *Bommeria hispida* (2n = 60) both reproduce sexually (Benham & Windham 1993; Gastony & Haufler 1976). Spore resiliency and longevity has been shown to be high in members of the family Pteridaceae, with spores preserved on herbarium sheets remaining viable for over 40 years (Windham, Wolf, & Ranker 1986). It is hypothesized that spores were transported along prevailing southwest winds and settled on the newly exposed cliff face where competition with local species was reduced or absent due to the disturbance. The site is along the leading edge of the Blue Ridge Escarpment.

An alternative hypothesis is that nearby populations of these species provided spores for colonization of the newly exposed habitat, but we searched thoroughly along the entire shoreline outcrop habitats of Lake Jocassee and located no other populations. We also searched the exposed rock outcrops above the cliff. The area above the cliff was completely denuded during dam construction.

An alternative hypothesis could include the introduction of spores via machinery used in the construction. Several factors argue against this, notably the absence of any non-pteridophyte species from farther west on the site or nearby. Weed seeds would seem to just as easily be moved. Finally, the presence of another nearby species of fern with a similar distribution (*Pellaea ternifolia* subsp. *arizonica*) and the presence of *Pellaea wrightiana* at two sites in North Carolina, where they are assumed to have naturally colonized their habitats, supports the fact that spores must travel these distances and be able to successfully colonize new habitats.

ACKNOWLEDGEMENTS

The authors would like to thank George Yatskievych of the University of Texas for confirming our identifications and his patient search for intact sporangia to determine the subspecies of *Astrolepis sinuata*. Alan Weakley of the University of North Carolina was extremely patient and helpful in discussions concerning these ferns. We also would like to thank Brooks Wade of Jocassee Lake Tours for helping to provide the opportunity to make such discoveries possible, Zachary Maddox for providing boat transportation to the site and Rick Huffman of the South Carolina Native Plant Society for joining us and always encouraging, promoting, and participating in the continued discovery of our native flora. Guy Nesom reviewed and edited the paper.

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Friends of Lake Keowee Society

Dedicated to the preservation and enhancement of Lake Keowee and its watershed through advocacy, conservation and education.

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Email: keoweefolks@charter.net

June 20, 2022

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE, Room 1A,
Washington, DC 20426

RE: Comments on the Bad Creek Pumped Storage Project (FERC No. 2740), Oconee County, South Carolina Notice of Intent (NOI) to File License Application; the Pre-Application Document (PAD), request for comments on the PAD and Scoping Document, and Associated Study Requests for the Bad Creek Pumped Storage Complex II Project.

Dear Ms. Bose:

The Friends of Lake Keowee Society has reviewed the pertinent documents pertaining to the Bad Creek Pumped Storage Project (FERC No. 2740) dated April 22, 2022, which include the Notice of Intent (NOI), the Pre-Application Document (PAD), the Request for Comments on the PAD and Scoping Document, and Identification of Issues and Associated Study Requests for a new license using the Integrated Licensing Process (ILP) for the Bad Creek II Pump Storage project.

At this time, we have no issues or concerns with the proposed relicensing of the Bad Creek Pumped Storage Project or with the ILP for a new license for the Bad Creek Pumped Storage Complex II. The studies identified for the environmental assessment for the Bad Creek Pumped Storage Complex II appear to cover the areas of major concern for FOLKS and our members. We look forward to working with the study groups, FERC, Duke Energy, and others throughout the process to meet our collective goals of supplying clean and green energy to the grid.

Best regards,

Dale Wilde

Dale Wilde - President, FOLK

phil mitchell, salem, SC.
Request addition of study to encompass “Emergency Preparedness” during construction.
Justification :
Remote location with currently located remote emergency services available to the area. Usage of explosives and major underground work increases the inherent risks and therefore the likelihood of needing this study.

ISSUES :
One project access road, Bad Creek Road, with NO other road egress or exit to 21 home sites. If a life safety emergency , such as fire or complications due to excavation (project involves excavation and thousands of feet of underground work) occurs which prevents road usage then home owners are trapped. Suggest a temporary rough cut secondary access road with possible later usage for recreation.

Project should study impact / benefit of adding an emergency services boat and dock to address fire and life safety during construction and operation due to the remote nature and potential hazards.

Project should study impact / benefit of supporting the addition of another, closer, Fire House on Highway 130 / 281 coming from the Toxaway , NC side of the Bad Creek project to address response time, due to remote location and likelihood of the need for emergency, such as fire and life safety issues.

Study should include issues with emergency communications plans with home owners (due to only one access road in and out).

Bad Creek Study Plan Development and Stakeholder Resource Committees - Meeting Invitations

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Subject: FW: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Aquatics)

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Friday, June 24, 2022 6:12 AM
To: gcyantis2@yahoo.com; Elizabeth Miller <MillerE@dnr.sc.gov>; jhains@g.clemson.edu; ehollis@upstateforever.org; amedeemd@dhec.sc.gov
Cc: Abney, Michael A <Michael.Abney@duke-energy.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>
Subject: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Aquatics)

Dear Aquatics Resource Team Members:

Thank you for agreeing to participate on the Aquatics Resource Team for relicensing of the Bad Creek Hydroelectric Project. As Alan Stuart mentioned during the Relicensing Stakeholder Kick-off Meeting on May 31, Duke Energy has formed six (6) resource teams to develop study plans necessary for the relicensing of Bad Creek I Complex and the new license application for the potential Bad Creek II Complex (i.e., Aquatics, Cultural Resources, Recreation & Aesthetics, Water Quality, Operations, and Wildlife & Botanical). Duke Energy received an additional study request from FERC on June 16, 2022 to perform an Environmental Justice Study. We will include this study in the Operations Resource Team in case you are interested in this study plan.

I (John Crutchfield) will serve as the Technical Coordinator for each Resource Management Team to set meeting dates and ensure we develop the study plans in a timely fashion for FERC submittal. Duke Energy looks forward to working with each of you during the relicensing process.

A first step in the Integrated Licensing Process (ILP) is to develop necessary study plans for the relicensing application and submit those to FERC by August 7. Duke is currently drafting study plan elements for review and discussion with Resource Teams during meetings the week of July 18-22.

I will be sending a Doodle Poll to Resource Team members for potential time and meeting dates to begin this study plan development process. <u>Please respond to this Doodle Poll by Friday, July 1 COB.</u> This initial meeting will be virtual via Microsoft Teams. Given the tight deadline that Duke Energy has to submit the study plans, please be flexible and try to clear your schedule the week of July 18-22 to make the meeting. This will help us meet the tight time schedule.

We anticipate this study plan meeting to last 3 hours. The Doodle Poll will have 3 hour meeting blocks from Monday, July 18 through Friday, July 22. I will try to schedule the Resource Team meeting that fits participants schedules but please note we have 6 resource teams meeting that week so there may have to be some juggling of schedules to accommodate all meetings. We will conclude the meeting early if we finish before the allotted time.

I will send out a meeting agenda to you prior to our Resource Team meeting. We will provide an overview of the draft study plan elements during the meeting.

If you have any questions regarding the study plan development and Resource Team meeting, please let Alan Stuart and me know.

Regards,

John Crutchfield
Project Manager II, Water Strategy & Hydro Licensing
Regulated & Renewable Energy
Duke Energy
526 S. Church Street, EC12Q | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

Subject: FW: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Cultural Resources)

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Friday, June 24, 2022 6:10 AM
To: Elizabeth Miller <MillerE@dnr.sc.gov>; adoug41@att.net; cstarker@upstateforever.org; amedeemd@dhec.sc.gov
Cc: Churchill, Christy <Christy.Churchill@duke-energy.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>
Subject: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Cultural Resources)

Dear Cultural Resources Team Members:

Thank you for agreeing to participate on the Cultural Resources Team for relicensing of the Bad Creek Hydroelectric Project. As Alan Stuart mentioned during the Relicensing Stakeholder Kick-off Meeting on May 31, Duke Energy has formed six (6) resource teams to develop study plans necessary for the relicensing of Bad Creek I Complex and the new license application for the potential Bad Creek II Complex (i.e., Aquatics, Cultural Resources, Recreation & Aesthetics, Water Quality, Operations, and Wildlife & Botanical). Duke Energy received an additional study request from FERC on June 16, 2022 to perform an Environmental Justice Study. We will include this study in the Operations Resource Team in case you are interested in this study plan.

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If you have any questions regarding the study plan development and Resource Team meeting, please let Alan Stuart and me know.

Regards,

John Crutchfield
Project Manager II, Water Strategy & Hydro Licensing
Regulated & Renewable Energy
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Office 980-373-2288| Cell 919-757-1095

Subject: FW: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Recreation and Aesthetics)

Importance: High

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Friday, June 24, 2022 6:23 AM
To: adoug41@att.net; suewilliams130@gmail.com; dwilde@keoweefolks.org; andrewandwilla@hotmail.com; Elizabeth Miller <MillerE@dnr.sc.gov>; cstarker@upstateforever.org; charris@scprt.com; amedeemd@dhec.sc.gov
Cc: Bennett, Jennifer Wright <Jennifer.Bennett@duke-energy.com>; 'Kelly.Kirven@KleinschmidtGroup.com' <Kelly.Kirven@KleinschmidtGroup.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>
Subject: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Recreation and Aesthetics)
Importance: High

Dear Recreation and Aesthetics Resource Team Members:

Thank you for agreeing to participate on the Recreation and Aesthetics Resource Team for relicensing of the Bad Creek Hydroelectric Project. As Alan Stuart mentioned during the Relicensing Stakeholder Kick-off Meeting on May 31, Duke Energy has formed six (6) resource teams to develop study plans necessary for the relicensing of Bad Creek I Complex and the new license application for the potential Bad Creek II Complex (i.e., Aquatics, Cultural Resources, Recreation & Aesthetics, Water Quality, Operations, and Wildlife & Botanical). Duke Energy received an additional study request from FERC on June 16, 2022 to perform an Environmental Justice Study. We will include this study in the Operations Resource Team in case you are interested in this study plan.

I (John Crutchfield) will serve as the Technical Coordinator for each Resource Management Team to set meeting dates and ensure we develop the study plans in a timely fashion for FERC submittal. Duke Energy looks forward to working with each of you during the relicensing process.

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If you have any questions regarding the study plan development and Resource Team meeting, please let Alan Stuart and me know.

Regards,

John Crutchfield
Project Manager II, Water Strategy & Hydro Licensing
Regulated & Renewable Energy
Duke Energy
526 S. Church Street, EC12Q | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

Subject: FW: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Wildlife and Botanical)

Importance: High

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Friday, June 24, 2022 6:20 AM
To: adoug41@att.net; suewilliams130@gmail.com; dwilde@keoweefolks.org; bill.ranson@retiree.furman.edu; Elizabeth Miller <MillerE@dnr.sc.gov>; cstarker@upstateforever.org; wes.cooler@mac.com; amedeemd@dhec.sc.gov
Cc: Abney, Michael A <Michael.Abney@duke-energy.com>; Fletcher, Scott T <Scott.Fletcher@duke-energy.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>
Subject: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Wildlife and Botanical)
Importance: High

Dear Wildlife and Botanical Resource Team Members:

Thank you for agreeing to participate on the Wildlife and Botanical Resource Team for relicensing of the Bad Creek Hydroelectric Project. As Alan Stuart mentioned during the Relicensing Stakeholder Kick-off Meeting on May 31, Duke Energy has formed six (6) resource teams to develop study plans necessary for the relicensing of Bad Creek I Complex and the new license application for the potential Bad Creek II Complex (i.e., Aquatics, Cultural Resources, Recreation & Aesthetics, Water Quality, Operations, and Wildlife & Botanical). Duke Energy received an additional study request from FERC on June 16, 2022 to perform an Environmental Justice Study. We will include this study in the Operations Resource Team in case you are interested in this study plan.

I (John Crutchfield) will serve as the Technical Coordinator for each Resource Management Team to set meeting dates and ensure we develop the study plans in a timely fashion for FERC submittal. Duke Energy looks forward to working with each of you during the relicensing process.

A first step in the Integrated Licensing Process (ILP) is to develop necessary study plans for the relicensing application and submit those to FERC by August 7. Duke is currently drafting study plan elements for review and discussion with Resource Teams during meetings the week of July 18-22.

I will be sending a Doodle Poll to Resource Team members for potential time and meeting dates to begin this study plan development process. Please respond to this Doodle Poll by Friday, July 1 COB. This initial meeting will be virtual via Microsoft Teams. Given the tight deadline that Duke Energy has to submit the study plans, please be flexible and try to clear your schedule the week of July 18-22 to make the meeting. This will help us meet the tight time schedule.

We anticipate this study plan meeting to last 3 hours. The Doodle Poll will have 3 hour meeting blocks from Monday, July 18 through Friday, July 22. I will try to schedule the Resource Team meeting that fits participants schedules but please note we have 6 resource teams meeting that week so there may have to be some juggling of schedules to accommodate all meetings. We will conclude the meeting early if we finish before the allotted time.

I will send out a meeting agenda to you prior to our Resource Team meeting. We will provide an overview of the draft study plan elements during the meeting.

If you have any questions regarding the study plan development and Resource Team meeting, please let Alan Stuart and me know.

Regards,

John Crutchfield
Project Manager II, Water Strategy & Hydro Licensing
Regulated & Renewable Energy
Duke Energy
526 S. Church Street, EC12Q | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

Subject: FW: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Water Quality)

Importance: High

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Friday, June 24, 2022 6:17 AM
To: ehollis@upstateforever.org; gcyantis2@yahoo.com; dwilde@keoweefolks.org; Elizabeth Miller <MillerE@dnr.sc.gov>; amedeemd@dhec.sc.gov
Cc: Raber, Maverick James <Maverick.Raber@duke-energy.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>
Subject: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Water Quality)
Importance: High

Dear Water Quality Resource Team Members:

Thank you for agreeing to participate on the Water Quality Resource Team for relicensing of the Bad Creek Hydroelectric Project. As Alan Stuart mentioned during the Relicensing Stakeholder Kick-off Meeting on May 31, Duke Energy has formed six (6) resource teams to develop study plans necessary for the relicensing of Bad Creek I Complex and the new license application for the potential Bad Creek II Complex (i.e., Aquatics, Cultural Resources, Recreation & Aesthetics, Water Quality, Operations, and Wildlife & Botanical). Duke Energy received an additional study request from FERC on June 16, 2022 to perform an Environmental Justice Study. We will include this study in the Operations Resource Team in case you are interested in this study plan.

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John Crutchfield
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Regulated & Renewable Energy
Duke Energy
526 S. Church Street, EC12Q | Charlotte, NC 28202
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Salazar, Maggie

Subject: FW: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Operations)

Importance: High

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Friday, June 24, 2022 6:15 AM
To: Elizabeth Miller <MillerE@dnr.sc.gov>; jhains@g.clemson.edu; James Keane <jtk7140@me.com>; charris@scprt.com; amedeemd@dhec.sc.gov
Cc: Bruce, Ed <Ed.Bruce@duke-energy.com>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>; Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>
Subject: Bad Creek Relicensing -- Study Plan Development and Stakeholder Resource Teams Meetings (Operations)
Importance: High

Dear Operations Resource Team Members:

Thank you for agreeing to participate on the Operations Resource Team for relicensing of the Bad Creek Hydroelectric Project. As Alan Stuart mentioned during the Relicensing Stakeholder Kick-off Meeting on May 31, Duke Energy has formed six (6) resource teams to develop study plans necessary for the relicensing of Bad Creek I Complex and the new license application for the potential Bad Creek II Complex (i.e., Aquatics, Cultural Resources, Recreation & Aesthetics, Water Quality, Operations, and Wildlife & Botanical). Duke Energy received an additional study request from FERC on June 16, 2022 to perform an Environmental Justice Study. We will include this study in the Operations Resource Team in case you are interested in this study plan.

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Regulated & Renewable Energy
Duke Energy
526 S. Church Street, EC12Q | Charlotte, NC 28202
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Appendix C

Appendix C – Water Resources Study Plan

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APPENDIX C

WATER RESOURCES PROPOSED STUDY PLAN

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

August 2022

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WATER RESOURCES PROPOSED STUDY PLAN
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740

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ACRONYMS AND ABBREVIATIONS

Bad Creek (or Project)	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
CFD	Computational Fluid Dynamics
CHEOPS	Computer Hydro-Electric Operations and Planning Software™
CWA	Clean Water Act
DO	dissolved oxygen
Duke Energy or Licensee	Duke Energy Carolinas, LLC
ft	feet/foot
ft msl	feet above mean sea level
FERC or Commission	Federal Energy Regulatory Commission
KT Project	Keowee-Toxaway Hydroelectric Project
mg/L	milligrams per liter
mi^2	square miles
MOU	Memorandum of Understanding
ORW	Outstanding Resources Waters
PAD	Pre-Application Document
PSP	Proposed Study Plan
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SEPA	Southeastern Power Administration
TN	Trout Natural
TPGT	Trout Put, Grow, and Take
TR	Trout Waters
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
WQMP	Water Quality Monitoring Plan

1 Study Requests and Formal Comments

The Federal Energy Regulatory Commission's (FERC or the Commission) April 22, 2022 Scoping Document 1 identified the following environmental resource issues to be analyzed in the National Environmental Policy Act document for the Bad Creek Pumped Storage Project (Project) relicensing related to water resources. These resource issues address the effects of continued Project operations under the Existing License as well as potential construction and operation of a second powerhouse during the New License term for the Bad Creek II Power Complex (Bad Creek II Complex):

1) Effects of construction-related erosion, sedimentation, and spoils disposal on water quality, aquatic habitat, and aquatic biota in Lake Jocassee and streams in the Project vicinity.
2) Effects of Project operation on water levels in Lake Jocassee.
3) Effects of Project operation on water quality in Lake Jocassee, including water temperature, dissolved oxygen (DO) concentrations, and vertical mixing of DO.
4) Effects of reservoir fluctuations associated with Project operation on aquatic habitat and biota in Lake Jocassee.
5) Effects of vertical mixing of DO associated with Project operation on fish populations in Lake Jocassee.

In Section 7.1.2.3 of the Pre-Application Document (PAD) (Duke Energy 2022), Duke Energy Carolinas, LLC (Duke Energy or Licensee) proposed to conduct a Water Resources Study in support of the proposed Bad Creek II Complex. More specifically, the Water Resources Study will include: 1) a summary of existing water quality data and state water quality standards, 2) an evaluation of reservoir water levels and water exchange rates, 3) vertical mixing in the Whitewater River arm (also called Whitewater River cove) of Lake Jocassee and the potential expansion of the submerged weir, and 4) an assessment of impacts related to upland spoil disposal and construction on existing surface waters.

The items listed above, in addition to comments received from stakeholders (Appendices A and B), are addressed by two separate studies in this Proposed Study Plan (PSP) as follows:

(1) The Water Resources Study (Appendix C) focuses on historical water quality data of Lake Jocassee, potential impacts to surface waters due to construction of the new Bad

Creek II Power Complex (Bad Creek II Complex), and water resources affected by a second inlet/outlet structure in the Whitewater River arm of Lake Jocassee

(2) The Aquatic Resources Study (Appendix D) will evaluate impacts associated with construction and operation of the proposed Bad Creek II Complex on water quality and water resources as they relate to aquatic life and habitat.

No formal study requests related to water resources were received during the scoping process; however, formal comments regarding water resources were received from the Commission, South Carolina Department of Natural Resources (SCDNR), Foothills Trail Conservancy, Upstate Forever, and the U.S. Environmental Protection agency (USEPA). Requests and comments pertinent to the Water Resources Study were considered in the development of this PSP and summaries of comments and responses are included in Appendix A. Copies of all comments are provided in Appendix B.

2 Goals and Objectives

While there are no anticipated additional adverse effects to water resources and water quality due to the continued operation of the Project, potential adverse effects resulting from the construction and operation of the Bad Creek II Complex need to be evaluated. The goal of the Water Resources Study is to evaluate the Project effects, as well as any potential effects or impacts due to the construction and operation of the proposed Bad Creek II Complex using existing and new information.

Duke Energy will conduct a Water Resources Study for the Project relicensing to include the following main objectives:

1. Evaluate water resources and water quality impacts of current Project operations using existing data.
2. Evaluate water resources and water quality impacts potentially resulting from the construction and operation of the Bad Creek II Complex.
3. Address stakeholder concerns regarding water resources in the Project Boundary with clear nexus to the Project and the proposed Bad Creek II Complex.

The main objectives will be met through the following activities:

- Perform a literature review including: (a) available water quality data collected in the Project Boundary and Lake Jocassee since approximately 1973 and (b) current designated uses and water quality standards applicable to the Project.
- Develop a Water Quality Monitoring Plan (WQMP) in consultation with relicensing stakeholders for the proposed Bad Creek II Complex. The WQMP will encompass pre-construction, construction, and post-construction activities, including identification of applicable and appropriate threshold values for water quality parameters and monitoring means and methods. The WQMP may also address potential impacts of placement of excavated material in surface waters and wetlands in planned upland disposal areas.
- Use the Computational Fluid Dynamics (CFD) model to evaluate water velocities in the Whitewater River arm due to the addition of a second powerhouse inlet/outlet structure and associated potential effects on shoreline erosion in the Whitewater River arm.
- Use the CFD model to evaluate flow velocities related to the addition of a second powerhouse and extent of vertical mixing in the Whitewater River arm and downstream of the submerged weir due to the addition of a second inlet/outlet structure.
- Use the existing Computer Hydro-Electric Operations and Planning Software™ (CHEOPS) model (developed for the Keowee-Toxaway [KT] Hydroelectric Project relicensing) to evaluate reservoir elevation effects associated with water exchange rates, magnitude, and duration between Bad Creek Reservoir and Lake Jocassee.
- Gather information in support of Clean Water Act (CWA) 404/401 permitting related to impacts to streams/wetlands in potential upland spoil locations and Lake Jocassee impacts from construction activities and submerged weir expansion.

3 Study Area

The study area for the Water Resources Study is shown on Figure 3-1 and includes the upper reservoir, lower reservoir (Whitewater River arm only), preliminary transmission line alignment, and main (expanded) Project site.

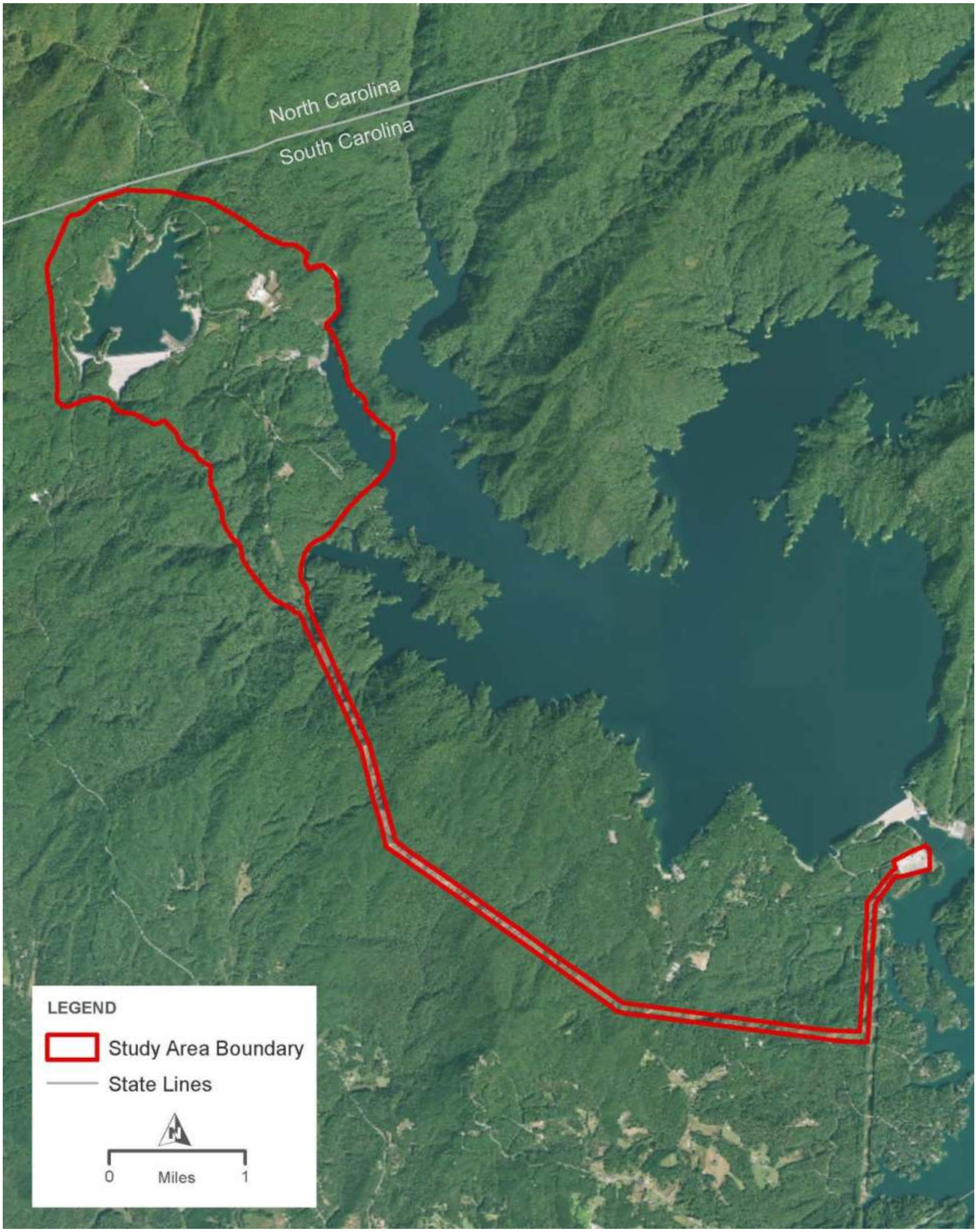

Figure 3-1. Water Resources Study Area

4 Background and Existing Information

Existing relevant and reasonably available information regarding water resources, watershed description, and water quality in the Project vicinity was presented in Sections 6.1 and 6.3 of the PAD (Duke Energy 2022). The Bad Creek upper reservoir has a drainage area of approximately 1.5 square miles (mi^2). Prior to impoundment, Bad Creek and West Bad Creek were tributaries of Howard Creek (a tributary to Lake Jocassee) near the toe of the Main Dam and West Dam, respectively. Howard Creek flows from the northwest and through the southern border of the Project Boundary with a drainage area of approximately 4.3 mi^2 at its downstream confluence with Limber Pole Creek. Seepage through the two earthen dams now flows into Howard Creek near the toe of each dam. Average seepage flows from the Main Dam and the West Dam are approximately 5.0 cubic feet (ft) per second combined. Water from Bad Creek Reservoir is exchanged directly with Lake Jocassee. Due to the small drainage area of Bad Creek Reservoir, inflows are minimal and have no effect on the operation of the Project.

Lake Jocassee, which operates as the lower reservoir for the Bad Creek Project, was formed by impounding the Keowee River at river mile 343.6, just downstream of the confluence of the Whitewater and Toxaway rivers. Lake Jocassee has a drainage area of 145 mi^2, a surface area of approximately 7,980 acres, and approximately 92 miles of shoreline at full pond (1,110 ft above mean sea level [msl]).

4.1 Water Standards and Classifications

North Carolina and South Carolina have assigned state water quality standards commensurate with a designated use of a waterbody and both states have similar categories of designated use. Some of the tributaries flowing into Lake Jocassee are wholly within North Carolina, some are wholly within South Carolina, and some flow through both states. Variations of sub-sets of general classifications between the two states exist; however, both states have recognized and distinguished between general use to maintain and support aquatic life and general contact recreation, trout habitats, and high value resource areas.

Under the authority of the South Carolina Pollution Control Act, the South Carolina Department of Health and Environmental Control (SCDHEC) Water Classification & Standards is responsible for establishing appropriate water uses and protection classifications, as well as general rules and specific water quality criteria to protect existing water uses, establish anti-degradation rules, protect public welfare, and maintain and enhance water quality. Streams with the following Water Classifications are found within the Project Vicinity: Outstanding Resources Waters (ORW); Trout Natural (TN); and Trout Put, Grow, and Take (TPGT). The Whitewater River is classified as ORW, Howard Creek is classified as TN, and Whitewater River tributaries are classified as ORW and TPGT (SCDHEC 2021; NCDEQ 2021). Lake Jocassee is designated as TPGT. TPGT are freshwaters suitable for supporting growth of stocked trout populations and a balanced indigenous aquatic community of fauna and flora. These waters are also suitable for contact recreation and as a drinking water supply source after conventional treatment. A summary of the designated use classification for the Lake Jocassee watershed is provided in Table 4-1. These waters are subject to SCDHEC's anti-degradation rules and activities such as discharges to these waters may be prohibited to maintain their classification.

Table 4-1. Surface Water Classifications of Waterbodies within the Lake Jocassee Watershed

Name	State	Description	Surface Water Classification
Bear Camp Creek	NC	From source to state line	C; TR
Bear Creek	NC	From source to state line	C; TR
Bear Creek	SC	Portion of the creek from state line to Lake Jocassee	TN
Corbin Creek	SC	The entire creek tributary to Devils Fork	ORW (TPGT)
Devils Fork Creek	SC	Portion of the creek from confluence of Corbin Creek and Howard Creek to Lake Jocassee	TN
Horsepasture River	NC	From a point approximately 0.60 mile downstream of N.C. Hwy 281 (Bohaynee Rd) to state line	B; TR, ORW
Howard Creek	SC	Portion of the creek from its headwaters to 0.3 mile below Hwy 130 upstream of the flow augmentation system at the Bad Creek Bad Creek Main Dam.	ORW (TPGT)
Howard Creek	SC	The portion below Bad Creek Dam to Lake Jocassee	TN
Lake Jocassee	SC	The entire lake	TPGT
Laurel Fork Creek	SC	The entire creek tributary to Lake Jocassee	TN
Limber Pole Creek	SC	The entire creek tributary to Devils Fork	TN

Name	State	Description	Surface Water Classification
Rock Creek	SC	Portion of the creek within South Carolina	TN
Thompson River	NC	From source to state line	C, TR
Thompson River	SC	Portion of the river from state line to Lake Jocassee	TN
Toxaway River	NC	From dam at Lake Toxaway Estates, Inc. to state line	C
Whitewater River	NC	From Little Whitewater Creek to state line	C, TR, HWQ
Whitewater River	SC	Portion of the river from state line to Lake Jocassee	ORW (TPGT)
Write Creek	SC	The entire creek tributary to Lake Jocassee	ORW (TPGT)
Coley Creek	SC	The portion of the creek in SC	TPGT
Devils Hole Creek	SC	The entire creek tributary to Lake Jocassee	TPGT
Jackie's Branch	SC	The entire creek tributary to Lake Jocassee	TN
Mill Creek	SC	The entire creek tributary to Lake Jocassee	TPGT

B- Primary Recreation, Fresh Water; C- Aquatic Life, Secondary Recreation, Fresh Water; HQW- High Quality Waters; ORW- Outstanding Resource Waters; TN- Trout-Natural; TPGT- Trout-Put, Grow, and Take; TR- Trout Waters

Sources: SCDHEC. 2021. SC Watershed Atlas. Accessed 03/02/2021. [URL]: https://gis.dhec.sc.gov/watersheds/; NCDEQ. 2021. NC Surface Water Classifications. Accessed 03/02/2021. [URL]: https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=6e125ad7628f494694e259c80dd64265.

Lake Jocassee is included in the highest water quality classification (i.e., excellent rating) as designated by SCDHEC and preservation of existing conditions is recommended, with most tributaries within the watershed fully supporting their designated use. Lake Jocassee is one of only a few reservoirs in South Carolina possessing the necessary aquatic habitat (water temperatures and dissolved oxygen [DO]) to support both warmwater and coldwater (salmonid [trout]) fisheries year-round (USACE 2014). Lake Jocassee is designated TPGT waters and subject to daily average DO concentrations of 6.0 milligrams per liter (mg/L) or higher[1]. DO concentrations measured in the forebay and tailwater areas of Lake Jocassee routinely have concentrations above that threshold. As stated above, SCDHEC has consistently identified Lake

[1] As part of the assessment methodology for Use Support Determination by the SCDHEC, water quality criteria and classifications are determined by sampling at a depth of 0.3 meter for a surface measurement (SCDHEC undated). For the purposes of Use Support Determination, only surface samples are used in standards comparisons and trends assessments.

Jocassee, as well as downstream Lake Keowee, among the cleanest South Carolina reservoirs based on data from 1980-1981, 1985-1986, and 1989-1990 studies (USACE 2014). Recent data continue to indicate Lake Jocassee (main lake and downstream of the weir), the Toxaway Arm, and the Whitewater Arm fully support aquatic life and recreational designated uses (USACE 2014 [Appendix C]).

A summary of water quality standards for South Carolina applicable to Project waters is included in Table 4-2.

Table 4-2. South Carolina Numeric State Water Quality Standards Applicable to Project Waters

Parameter	South Carolina Water Quality Standard
Temperature (applies to heated effluents only)	Not to exceed 2.8°C (5°F) above natural temperatures up to 32.2°C (90°F) Trout Waters: Not to vary from levels existing under natural conditions, unless determined some other temperature shall protect the classified uses
Dissolved Oxygen	Daily average not less than 5.0 mg/L Instantaneous low of 4.0 mg/L Trout Waters: Not less than 6.0 mg/L
pH	Between 6.0 and 8.5 Trout Waters: between 6.0 and 8.0
Turbidity	FW Except for lakes: Not to exceed 50 NTUs provided existing uses are maintained. FW Lakes Only: Not to exceed 25 NTUs provided existing uses are maintained. Trout Waters: Not to exceed 10 NTUs or 10% above natural conditions, provided existing uses are maintained.
Phosphorus	Blue Ridge - Shall not exceed 0.02 mg/L. Piedmont - Shall not exceed 0.06 mg/L.
Nitrogen	Blue Ridge - Shall not exceed 0.35 mg/L. Piedmont - Shall not exceed 1.5 mg/L.
Chlorophyll a	Blue Ridge - Shall not exceed 10 µg/L. Piedmont - Shall not exceed 40 µg/L.

SCDHEC 2020. R. 61 - 68 Water Classifications and Standards. Columbia, SC. URL: https://live-sc-dhec.pantheonsite.io/sites/default/files/media/document/R.61-68.pdf (Accessed March 2021)

4.2 Water Quality

Bad Creek Reservoir was created specifically to support operations for the existing Project and has not historically been monitored for water quality due to frequent and large fluctuations in water levels resulting in sampling complications and safety concerns; however, Duke Energy has monitored water quality conditions in Lake Jocassee in some capacity since the reservoir's formation in 1973. Water quality monitoring data has generally included monthly, quarterly, or annual in situ temperature, DO, conductivity and pH measurements at several locations in the lake.

As a condition of the Original License for the Bad Creek Project, and as described in Section 1.6 of the PAD, Duke Energy entered into a Memorandum of Understanding (MOU) with the SCDNR for the long-term management and maintenance of high-quality fishery resources in Lake Keowee, Lake Jocassee, and their tributary streams. The MOU and first 10-Year Work Plan were approved pursuant to Article #32(b)(1) of the Original License for the Bad Creek Project on May 1, 1997. License Article #32(b)(2) covers Lake Jocassee pelagic trout habitat and License Article #34 covers Lake Jocassee water quality. Through this MOU, SCDNR and Duke Energy personnel work cooperatively, and include third parties as necessary, to design and implement data collection and other activities to develop and enhance management strategies for fish in these areas. Activities included in the 10-Year Work Plans are focused on fisheries surveys and inventories, water quality and aquatic habitat evaluations, fish stocking, recreation, and shoreline impacts (documents supporting these environmental agreements and plans are included in the Aquatic Resources Study Plan [Appendix D of this PSP].

Based on existing information, continued Project operations are not expected to adversely affect water quality in Lake Jocassee and as a task of the Water Resources Study, Duke Energy will summarize existing water quality data in Lake Jocassee. Potential water quality impacts from construction and operation of the Bad Creek II Complex will be evaluated as an objective of the Water Resources Study.

During the New License term, Duke Energy proposes to continue to implement activities established by the MOU, as may be modified in consultation with stakeholders through the relicensing process, and will continue to implement Protection, Mitigation, and Enhancement activities established under the KT Project Relicensing Agreement. Duke Energy plans to further consult with SCDHEC and relicensing stakeholders through the ILP regarding final proposed mitigation and enhancement measures directed at operation of the existing Project and the proposed Bad Creek II Complex to be included in the Final License Application.

4.3 Water Use

Because the Bad Creek and KT projects are in the headwaters of the Savannah River Basin, there are no upstream dams; however, there are numerous dams and projects downstream of the Project affected by Bad Creek and KT project operations. In 1968, the U.S. Army Corps of Engineers (USACE) and the Southeastern Power Administration (SEPA) entered into an Operating Agreement (1968 Operating Agreement) with Duke Energy's predecessor company, Duke Power Company. The purpose of this agreement was to ensure the uppermost developments (KT Project) were operated so the USACE and SEPA would be able to meet their hydropower generating requirements at the time. Although there were many changes in both the USACE and Duke Energy systems since its inception, the 1968 Operating Agreement had never been modified. Therefore, a New Operating Agreement was signed in 2014 by the USACE, SEPA, and Duke Energy which incorporated the modified conditions of the USACE and KT Project operations and superseded the 1968 Operating Agreement. The New Operating Agreement establishes rules for determining how water is managed between the KT Project, Bad Creek Project and the USACE Projects (Hartwell, Russell and Thurmond) on the Savannah River. Operation of the Bad Creek Project during the New License term, with or without inclusion of the proposed Bad Creek II Complex, is not expected to have any impact on the New Operating Agreement.

5 Project Nexus

There are no anticipated additional potential adverse effects to existing water resources or water quality in the upper or lower reservoirs or uplands streams/wetlands due to the continued operation of the Project.

Construction and operation of the Bad Creek II Complex may impact water resources in Lake Jocassee (faster exchange of water between the upper and lower reservoirs; increased vertical mixing; water quality impacts [DO, turbidity, temperature], as well as upland water resources due to construction runoff and potential impacts of rock and spoil disposal.

6 Methods

6.1 Task 1 – Summary of Existing Water Quality Data and Standards

Duke Energy will perform a literature and desktop review of available water quality data collected (dating back to 1973) in the Project Boundary and Lake Jocassee. Data will be summarized to represent baseline water quality conditions. Data will also be evaluated against current designated uses and water quality standards applicable to the Project.

6.2 Task 2 – Water Quality Monitoring in Whitewater River Arm

Historical water quality data were collected by Duke Energy at three locations in the Whitewater River arm and downstream of the Whitewater River arm (Stations 564.1, 564.0, 560.0) shown on Figure 6-1. Historic datasets represent temperature and DO profile data (i.e., non-continuous) ranging from 1976 to 2017, depending on the location. Duke Energy will gather continuous temperature data and periodic DO (bi-weekly) from the three historic locations to gather current-day representative (i.e., baseline) water quality information in 2023 and 2024. Data collection in 2023 will represent conditions under two-unit operations at the Project with a lowered upper reservoir. Duke Energy also proposes to monitor water quality (continuous temperature and bi-weekly DO) in 2024 to capture conditions under all four upgraded units and normal upper reservoir operations. Due to the relatively short residence time of water in the upper reservoir, warming impacts due to solar radiation and mixing in the upper reservoir are limited. However, data collected in 2023 and 2024 will cover June 1 through September 30 of each year when temperatures are expected to be warmest, therefore representing conservative (i.e., worst case) conditions.

To better understand the effectiveness of the existing submerged weir, continuous temperature data collection is proposed for sampling locations 564.1, 564.0, and 560.0. At each location, temperature loggers will be deployed vertically at several depths to capture changes in thermal stratification resulting from Project operations (under both generation and pumping modes). Station 564.1 is located between the Project's inlet/outlet structure and the submerged weir and is approximately 140 ft deep (based on data from historic water quality monitoring at this location). Station 564.0 is located on the downstream side of the submerged weir and just upstream of the confluence of the Whitewater River arm and the Thompson River arm of Lake Jocassee. The depth at this location is approximately 200 ft. Station 560.0 is located downstream of the confluence of the Whitewater River arm and Thompson River arm and is approximately 260 ft deep.

Potential elevations of interest for continuous temperature monitoring include (elevations subject to change based on field conditions data collection):

- Approximately 3 ft below the water's surface (full pond elevation is 1,110 ft msl);
- Elevation 1,080 ft msl, which is the normal maximum Lake Jocassee drawdown elevation;
- Elevation 1,060 ft msl, which is the crest of the submerged weir;
- Elevation 1,040 ft msl, which is approximately 20 ft below the crest of the submerged weir; and
- Elevation 970 ft msl, which is near the lake bottom at Station 564.1 and typically below the thermocline at Stations 564.0 and 560.0.

Water temperature and DO data collected during the discrete bi-weekly sampling events will extend from the water's surface to the lake bottom (in approximately 6 ft [2 meter] increments) at all three monitoring locations.

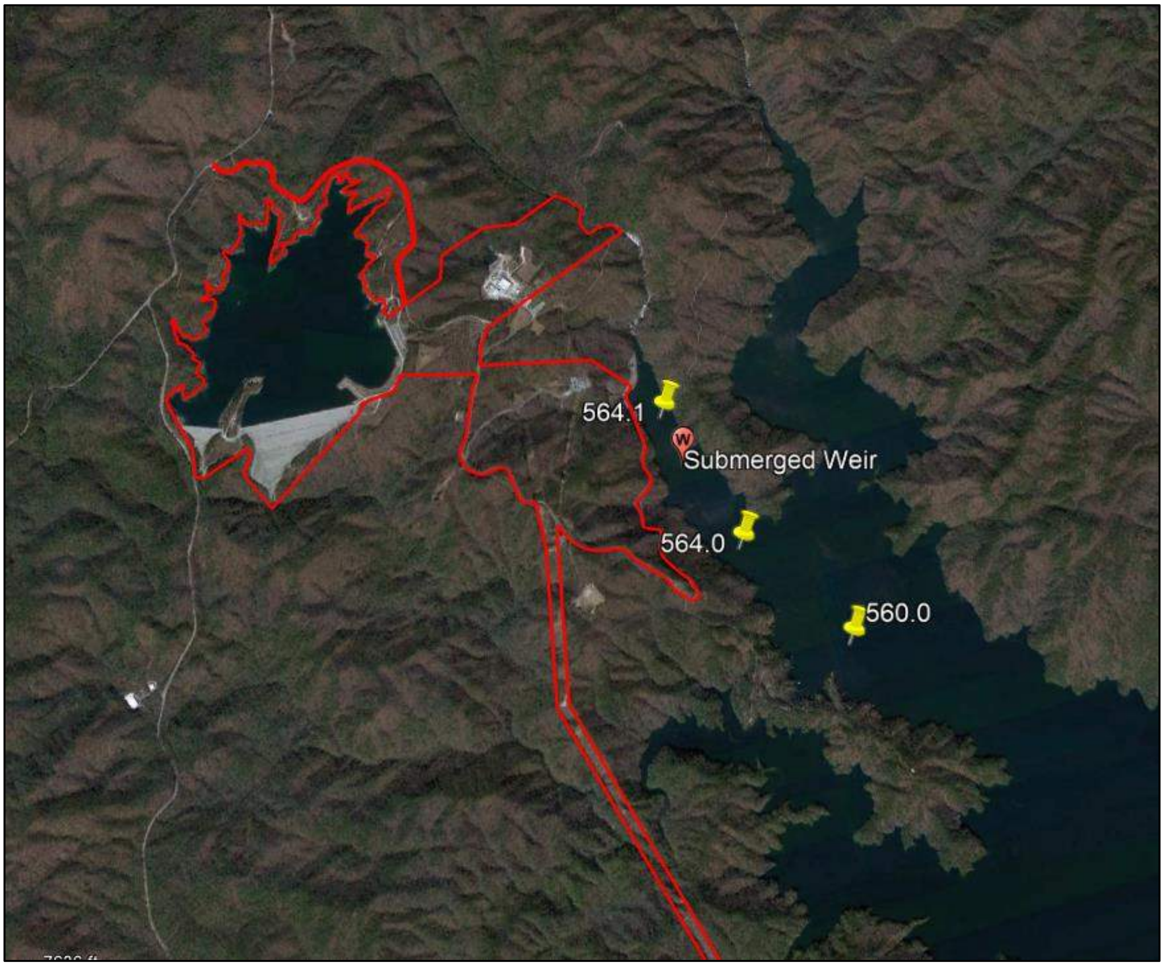

Figure 6-1. Historic Water Quality Monitoring Locations and Existing FERC Project Boundary

6.3 Task 3 – Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse

A second powerhouse could lead to more mixing of the water column downstream of the new inlet/outlet structure. Duke Energy will use the existing CFD model to determine the spatial extent of vertical mixing in the Whitewater River arm both upstream and downstream of the submerged weir due to the addition of a second inlet/outlet structure. In advance of CFD modeling, a hydraulic model will be developed to determine the approximate affected area (associated with Bad Creek and Bad Creek II operations) and the CFD model boundary condition will be established based on the hydraulic model results.

The 12 scenarios listed in Table 6-1 will be evaluated to help determine the impact of Project operations on mixing in the Whitewater River arm with and without expanding the existing submerged weir (in both generating and pumping mode; and at full pond and maximum drawdown). Results from these scenarios will also help evaluate the need for additional water quality modeling to evaluate potential impacts to thermal and DO stratification in the main body of Lake Jocassee.

Additionally, shoreline impacts on the opposite bank of the Whitewater River arm due to additional discharge (i.e., increased velocities) were assessed during the Feasibility Study for the Bad Creek II Complex using the existing CFD model. These findings will be reported in the Revised Study Plan (Appendix I – Geology and Project Feasibility).

Table 6-1. Proposed CFD Model Scenarios

Station	Operating Mode	Submerged Weir Configuration	Reservoir Elevation (ft msl)
Bad Creek Only	Generating	Existing	1,110
			1,080
	Pumping		1,110
			1,080
Bad Creek and Bad Creek II	Generating	Existing	1,110
			1,080
	Pumping		1,110
			1,080
	Generating	Expanded	1,110
			1,080
	Pumping		1,110
			1,080

6.4 Task 4 – Water Exchange Rates and Lake Jocassee Reservoir Levels

Operation of the proposed Bad Creek II Complex, which will add pumping and generating capacity to the Project, has the potential to impact water surface elevation rate of change in Lake Jocassee compared to typical conditions, but will not change the allowable fluctuation in Lake Jocassee under the KT Project License and associated agreements. Adding pumping and generating capacity to the Project through the construction of the Bad Creek II Complex would reduce the time for maximum drawdown and refill of the upper reservoir; however, it would not result in additional water level rise in Lake Jocassee (above the Normal Maximum Elevation of 1110 ft msl), as the overall volume of water contained in the upper reservoir will not change. Additionally, the operating band of the upper reservoir is not proposed to be modified under the New License. Duke Energy proposes to use the existing CHEOPS model to evaluate the difference in water exchange rate, frequency, and magnitude between Bad Creek Reservoir and Lake Jocassee due to the addition of a second powerhouse.

6.5 Task 5 – Future Water Quality Monitoring Plan Development

Pursuant to the existing MOU between Duke Energy and the SCDNR and subsequent 10-Year Work Plans, Duke Energy continues to collect water quality data in Lake Jocassee to support annual aquatic habitat evaluations. As part of the New License Duke Energy plans to continue this long-term water quality monitoring program and also will develop a Water Quality Monitoring Plan in consultation with agencies focused on the proposed Bad Creek II Complex. The WQMP will include three phases: pre-construction, construction, and post-construction of Bad Creek II, including identification of applicable and appropriate threshold values for water quality parameters and monitoring means and methods. Areas to be addressed in the plan include:

6.5.1 Construction of Inlet/Outlet Structure and Submerged Weir Expansion

Similar to the construction-related impacts of the existing Project, temporarily elevated turbidity levels are anticipated in the Whitewater River arm of Lake Jocassee during construction of the Bad Creek II inlet/outlet structure and expansion of the existing submerged weir by placement of rock materials excavated during tunneling activities. Turbidity data summarized under Task 1 will be reviewed to better understand the potential for elevated turbidity levels associated with in-water construction activities. Duke Energy will also implement best management practices, as required by water quality permit(s) issued by SCDHEC, to reduce sedimentation.

6.5.2 Construction in Upland Areas

Increased sediment loading during rainfall runoff events could impact existing streams and waterbodies (including wetlands) during construction of access roads, equipment laydown areas, tunneling activities, and the new electric transmission facilities. While no long-term degradation of water quality and aquatic habitat is expected to result from construction of the Bad Creek II Complex, these activities could lead to temporarily elevated turbidity levels which could impact aquatic habitat in the Whitewater River arm of Lake Jocassee.

6.5.3 Potential Upland Spoil Disposal

Overburden (i.e., soil and rock) material from the construction activities could potentially be deposited in several spoil locations throughout the site. Estimates for proposed material removal from underground excavations indicate approximately 4 million cubic yards of rock and spoil material for the Project infrastructure will need to be deposited into on-site spoil locations and/or adjacent to the existing submerged weir in Lake Jocassee. Siting for spoil location alternatives is ongoing by Duke Energy; however, due to the amount of material to be managed, existing topography, and prevalence of headwater streams and seeps located throughout the site, it is unlikely there would be a practicable alternative identified that will result in zero impacts to steams, wetlands, and tributaries to Lake Jocassee. Potential spoil locations and estimated impacts to water resources (reported in length of stream or size of area) are documented in the Natural Resources Assessment included in the PAD. As described in Section 5.6.3.3 of the PAD, placement of excavated rock removed from the underground excavations on the downstream slope of the existing submerged weir in Lake Jocassee, as was done for the construction of the existing Project, would significantly reduce the amount of material placed at upland disposal sites, reducing impacts to existing streams and wetlands.

Duke Energy proposes to perform a desktop study to further analyze and summarize the amount of spoil placement that could potentially be placed at each preliminary location and potential impacts. Upland disposal resulting in impacts to streams or wetlands, as well as placement of rock spoils at the submerged weir will require an individual permit from the USACE as well as a water quality certification from SCDHEC under the authorities of Sections 404 and 401 of the CWA. Duke Energy expects to initiate this parallel regulatory process in conjunction with the relicensing process. This task will also include preliminary actions for gathering data to help inform the 401/404 permitting process.

6.6 Analysis and Reporting

Results of this study will be summarized in the Initial and Updated Study Reports. Duke Energy anticipates the Water Resources Study report will include Project information and background, a depiction and description of the study area, methodology, results, and analysis and discussion. The report will also include relevant stakeholder correspondence and/or consultation, as well as literature cited.

7 Schedule and Level of Effort

The preliminary schedule for this study is outlined in Table 7-1. The estimated level of effort for this study is approximately 2,000 hours. Duke Energy estimates the Water Resources Study will cost approximately $300,000 to complete.

Table 7-1. Proposed Water Resources Study Schedule

Task	Proposed Timeframe for Completion
Study Planning and Existing Data Review	August – December 2022
Task 1 – Summary of Existing Water Quality Data and Standards	January 2023 – April 2023
Task 2 – Water Quality Monitoring in Whitewater River Arm	June 2023 – September 2023 June 2024 – September 2024
Task 3 – Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse	April 2023 – October 2023
Task 4 – Water Exchange Rates and Lake Jocassee Reservoir Levels	April 2023 – October 2023
Task 5 – Future Water Quality Monitoring Plan Development	January 2024 – December 2024
Distribute Draft Study Report with the Initial Study Report	January 2024
Distribute Revised Study Report with the Updated Study Report	January 2025

8 References

Duke Energy Carolinas, LLC (Duke Energy). 2022. Pre-Application Document for the Bad Creek Pumped Storage Station. FERC No. 2740. February 2022.

South Carolina Department of Health and Environmental Control (SCDHEC). 2020. Regulations 61 - 68 Water Classifications and Standards. Columbia, SC. URL: https://live-sc-dhec.pantheonsite.io/sites/default/files/media/document/R.61-68.pdf (Accessed July 2022).

U.S. Army Corps of Engineers (USACE). 2014. New Operating Agreement between U.S. Army Corps of Engineers, Southeastern Power Administrations, and Duke Energy Carolinas, LLC Final Environmental Assessment for Hydropower License. October 2014.

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Appendix D

Appendix D – Aquatic Resources Study Plan

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APPENDIX D

AQUATIC RESOURCES PROPOSED STUDY PLAN

Bad Creek Pumped Storage Project
FERC Project No. 2740

August 2022

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AQUATIC RESOURCES PROPOSED STUDY PLAN
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
CFD	Computational Fluid Dynamics
CHEOPS	Computer Hydro-Electric Operations and Planning Software™
CPUE	catch per unit effort
CWA	Clean Water Act
DO	dissolved oxygen
Duke Energy or Licensee	Duke Energy Carolinas, LLC
FERC or Commission	Federal Energy Regulatory Commission
ft	feet/foot
ft msl	ft below mean sea level
KT Project	Keowee-Toxaway Hydroelectric Project
m	meter
mg/L	milligram per liter
MOU	Memorandum of Understanding
PAD	Pre-Application Document
PM&E	Protection, Mitigation, and Enhancement
PSP	Proposed Study Plan
RBP	Rapid Bioassessment Protocol
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

1 Study Requests and Formal Comments

The Federal Energy Regulatory Commission's (FERC or the Commission) April 22, 2022 Scoping Document 1 identified the following environmental resource issues to be analyzed in the National Environmental Policy Act document for the Bad Creek Pumped Storage Project (Project) relicensing related to aquatic resources. These resource issues address the effects of continued Project operations under the Existing License as well as potential construction and operation of a second powerhouse during the New License term for the Bad Creek II Power Complex (Bad Creek II Complex):

1) Effects of construction-related erosion, sedimentation, and spoils disposal on water quality, aquatic habitat, and aquatic biota in Lake Jocassee and streams in the Project vicinity.
2) Effects of Project operation on water levels in Lake Jocassee.
3) Effects of Project operation on water quality in Lake Jocassee, including water temperature, dissolved oxygen (DO) concentrations, and vertical mixing of DO.
4) Effects of reservoir fluctuations associated with Project operation on aquatic habitat and biota in Lake Jocassee.
5) Effects of vertical mixing of DO associated with Project operation on fish populations in Lake Jocassee.
6) Effects of Project operation on aquatic habitat and biota in Howard Creek.
7) Effects of Project-induced impingement, entrainment, and turbine mortality on fish populations in Lake Jocassee.

In Section 7.1.3.3 of the Pre-Application Document (PAD) (Duke Energy 2022), Duke Energy Carolinas, LLC (Duke Energy or Licensee) proposed to conduct an Aquatic Resources Study in support of the proposed Bad Creek II Complex, which included a proposal to consult with agencies and other Project stakeholders regarding results of the updated desktop entrainment assessment, study updates, or modifications to address impacts of the Bad Creek II Complex; and if the Bad Creek II Complex is pursued, a presence/absence mussel survey and other protected aquatic species (if applicable) of potentially impacted streams in upland spoil locations.

The items above, in addition to comments received from stakeholders (see Appendix A and B), are addressed by two separate studies in this Proposed Study Plan (PSP) as follows:

(1) The Water Resources Study (Appendix C) focuses on historical water quality data of Lake Jocassee, potential impacts to surface waters due to construction of the new Bad Creek II Power Complex (Bad Creek II Complex), and water resources affected by a second inlet/outlet structure in the Whitewater River arm (also called Whitewater River cove) of Lake Jocassee.

(2) The Aquatic Resources Study (Appendix D) will evaluate impacts associated with construction and operation of the proposed Bad Creek II Complex on water quality and water resources as they relate to aquatic life and habitat.

No formal study requests related to aquatic resources were received during the scoping process; however, formal comments regarding aquatic resources were received from the U.S. Environmental Protection Agency (USEPA), South Carolina Department of Natural Resources (SCDNR), and Upstate Forever. Requests and comments pertinent to the Aquatic Resources Study were considered in the development of this PSP and summaries of comments and responses are included in Appendix A. Copies of all comments are provided in Appendix B.

2 Goals and Objectives

While there are no anticipated additional adverse effects to aquatic resources due to the continued operation of the Project, potential adverse effects resulting from the addition of Bad Creek II Complex need to be evaluated. Therefore, the goal of the Aquatic Resources study is to evaluate potential impacts to fish and aquatic life populations, communities, and habitats, due to the construction and operation of the proposed Bad Creek II Complex.

Duke Energy will conduct an Aquatic Resources Study for this relicensing to include and address the following objectives:

- Evaluate the potential for increased fish entrainment due to the addition of Bad Creek II Complex and consult with agencies and other Project stakeholders regarding results of the updated desktop Entrainment Study (Kleinschmidt 2021).
- Assess changes to pelagic and littoral aquatic habitat in Lake Jocassee resulting from the expanded underwater weir and additional discharge, using models developed for the

Water Resources Study and Keowee-Toxaway Hydroelectric Project (KT Project) relicensing.

- Evaluate potential direct impacts to aquatic habitat (including wetlands) related to Bad Creek II Complex construction activities and weir expansion by quantifying and characterizing surface waters, including resource quality. Presence/absence mussel surveys of streams located in upland areas where spoil deposition may occur will also be conducted. Note no aquatic biota sampling of the submerged weir will take place.

These objectives will be met through the following activities:

- Holding meetings with the Aquatic Resources Committee to discuss results of the updated Entrainment Study (Kleinschmidt 2021) and mitigation measures to minimize entrainment risk at the Project and Bad Creek II Complex.
- Using the Computational Fluid Dynamics (CFD) model (and potentially others, as necessary) developed for the Water Resources Study to evaluate potential effects on pelagic trout habitat due to water column mixing in Lake Jocassee.
- Using the existing operations Computer Hydro-Electric Operations and Planning Software™ (CHEOPS) model developed for the KT Project relicensing to inform evaluation of reservoir surface water elevation effects on littoral habitat in Lake Jocassee associated with water exchange rates, magnitude, and duration of operations between the Project and Bad Creek II Complex, and the Jocassee Pumped Storage Station.
- Describing potential direct impacts to surface waters related to Bad Creek II Complex construction and underwater weir expansion as indicated from the Water Resources Study, prior Natural Resource Assessment, presence/absence mussel surveys, and habitat quality surveys of streams in the potential spoil deposition areas.

3 Study Area

The study area for the Aquatic Resources Study is shown on Figure 3-1 and includes the upper reservoir, lower reservoir (Whitewater River arm only), preliminary transmission line alignment, and main (expanded) project site.

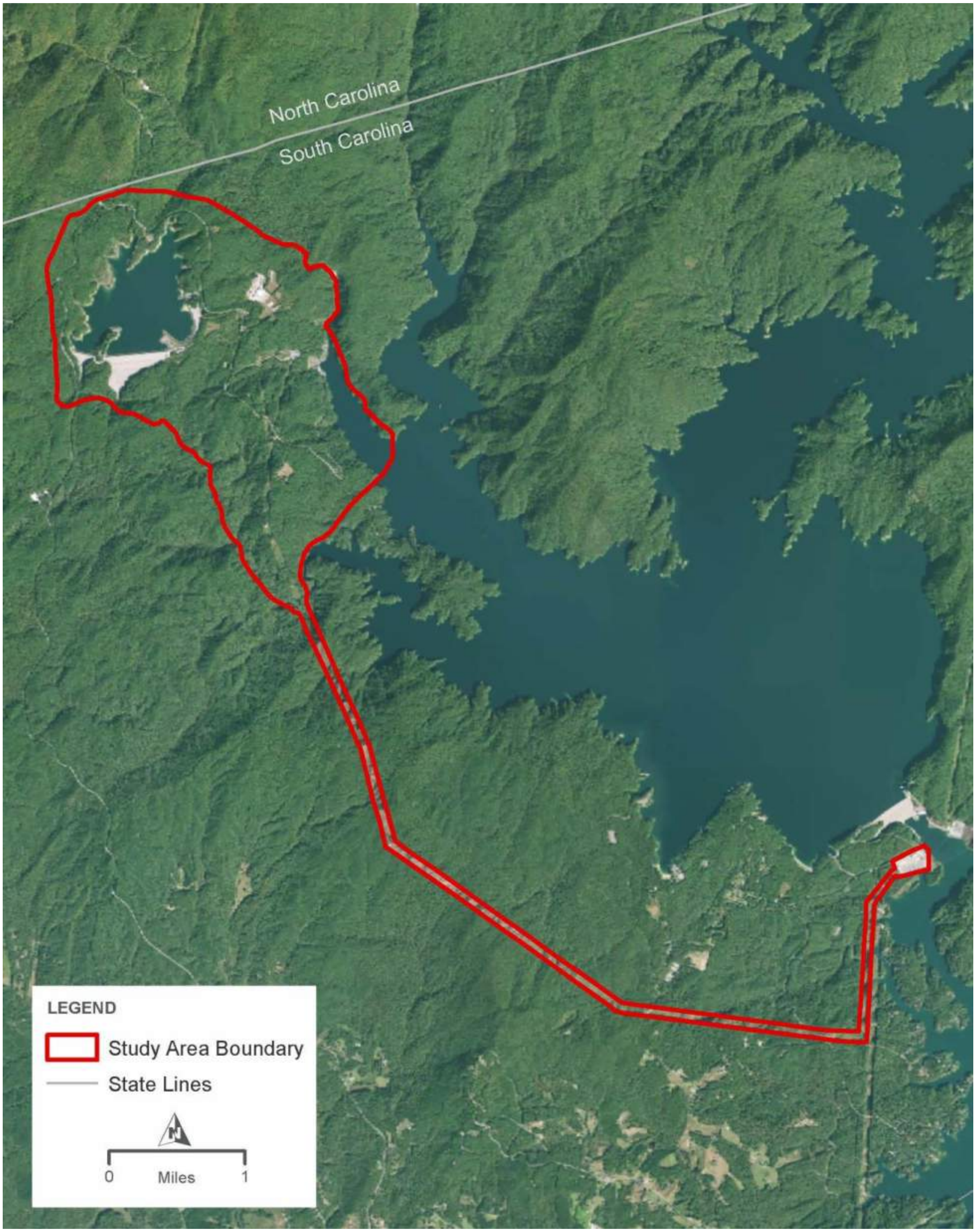

Figure 3-1. Aquatic Resources Study Area

4 Background and Existing Information

Existing and historic major protection, mitigation, and enhancement (PM&E) measures in place at the Project are primarily focused on fisheries, water quality, and recreation, and are established by the following:

- Bad Creek Pumped Storage Project Plans for Environmental Mitigation and Monitoring (License Articles 32, 34, 38, and 39)
- Duke Energy and SCDNR Memorandum of Understanding (MOU) and 10-Year Work Plans
- KT Project Relicensing Agreement

Due to the infeasibility of sampling and safety concerns under normal Project operations (frequent large fluctuations and influx from Lake Jocassee), water quality sampling is not performed in the upper reservoir. Since Bad Creek Reservoir was a newly created reservoir for the original Project and has no known designated uses, no additional impacts to fish and aquatic resources in the upper reservoir are expected from continued operation of the Project.

The combined operation of the existing Project and/or construction and operation of the Bad Creek II Complex has the potential to impact aquatic habitat in Lake Jocassee. Existing relevant and reasonably available information regarding fish and aquatic resources and environmental studies and agreements under the Existing License is included in Section 6.4 of the PAD (Duke Energy 2022). Within one year of the Original FERC License, Duke Energy filed Plans for Environmental Mitigation and Monitoring including License Articles 32, 34, 38, and 39, which address fish and wildlife PM&E measures. Plans outlined for mitigation and monitoring include information on wildlife and fisheries mitigation (Article 32), a water quality study plan (Article 34), pre-construction survey of endangered and threatened plan and animal species (Article 38), and a stream flow augmentation analysis (Article 39). Duke Energy and the SCDNR developed the MOU in 1996 to establish a framework to help maintain the high-quality fisheries of lakes Jocassee and Keowee (Duke Power and SCDNR 1996). The Bad Creek Fishery Resources Work Plan consists of three successive 10-Year Work Plans (i.e., 1996 – 2005; 2006 – 2016[1]; and 2017 – 2027). The activities and agreements in the 10-Year Work Plans include:

1) agreement on minimizing fish entrainment via the Project;
2) electrofishing of littoral fish populations;
3) water quality monitoring for trout habitat;
4) hydroacoustic monitoring of small pelagic fish;
5) cost-sharing for trout stocking; and
6) cost-sharing for fisheries research and enhancements.

The current 10-Year Work Plan (2017-2027; SCDNR and Duke Energy 2016) continues many of the management activities implemented in prior work plans. Duke Energy and SCDNR continue to cooperatively monitor the fishery in lakes Jocassee and Keowee while annually reviewing the results of the monitoring studies. Many of the studies and activities conducted at Lake Jocassee under the MOU are relevant to assessing potential environmental impacts associated with existing and continued operation of the Project. The current 10-Year Work Plan is composed of the same main components as the six listed above, with the exception of water quality monitoring for trout habitat (no. 3), which was completed under the 2006-2015 work plan; however, trout habitat monitoring in Lake Jocassee was adopted as a requirement of the KT Project Relicensing Agreement.

Duke Energy has monitored spring littoral fish populations in Lake Jocassee via boat-mounted electrofishing since 1996 (SCDNR and Duke Energy 1996) and continues every three years (i.e., 2017, 2020, 2023, and 2026) under the current 10-Year Work Plan (SCDNR and Duke Energy 2016). As part of the 1996-2005 Work Plan, gill netting was performed at five locations annually by SCDNR and funded by Duke Energy (SCDNR and Duke Energy 1996). The purpose of these studies was to contribute data to the longest-running database on the Jocassee fishery. Vertical profile surveys of temperature and DO have been conducted in Lake Jocassee since 1973 to monitor trout habitat. Continued monitoring of trout habitat thickness is performed under the KT

[1] Several activities conducted under the first two 10-year work plans were identified as PM&E measures under the KT Project (FERC No. 2503) and are now included in the KT Project Relicensing Agreement and the KT Project New License issued by FERC in 2016. As a result, the original 2006 – 2015 Work Plan was extended by one year to cover 2016.

Project Relicensing Agreement, which requires an annual model prediction and verification by a temperature and DO survey at the deepest location in Lake Jocassee (station 558.0) in February and September, respectively. Hydroacoustic monitoring of fish populations by Duke Energy to assess pelagic prey fish (i.e., Threadfin Shad and Blueback Herring) abundance and distribution began in 1997 (SCDNR and Duke Energy 1996). Complementary to hydroacoustic monitoring, purse seine sampling was also conducted in conjunction with the fall hydroacoustic monitoring from 1997 to 2012 to characterize species composition of the pelagic forage fish community. The Bad Creek MOU lists activities eligible for cost-sharing, including fisheries research, water quality studies, trout habitat studies, stream surveys, creel surveys, fish and habitat management, development of bank and stream-side access, and stream protection and enhancement.

Duke Energy completed a 3-year fish entrainment study developed in cooperation with the SCDNR and the U.S. Fish and Wildlife Service at Bad Creek during the first three years of Project operations (1991-1993) (Barwick et al. 1994). The rate of entrainment at Bad Creek was generally low (five fish/hour) during most of the study (October 1991-August 1993) (Barwick et al. 1994). Overall, an estimated 391,327 fish were entrained at the Bad Creek during 14,244 hours of pumping from 1991 to 1993. A total of 300,406 of these fish were Threadfin Shad and most were entrained in late 1993 in response to low water levels in Lake Jocassee (14 feet [ft] below full pond elevation). Blueback Herring, White Catfish, Redbreast Sunfish, and Bluegill were the only other taxa entrained in significant numbers. In addition to entrainment estimates, the Barwick et al. (1994) study identified operational periods associated with entrainment rates at the Bad Creek Project during pump-back operations. Results from this evaluation were used to establish operational guidelines and a communications protocol between Duke Energy and SCDNR to minimize entrainment impacts. As part of those operational guidelines, Duke Energy agreed to operate its facilities to minimize, to the extent practicable, the length of time during which the Lake Jocassee pool elevation is less than 1,099 ft below msl (msl) (SCDNR and Duke Energy 2016).[2] Lake Jocassee normal full pond elevation is 1,110 ft msl, therefore, 1,099 ft msl

[2] Site-specific studies have indicated fish entrainment can increase when Lake Jocassee pool elevations drop below 1,096 ft msl. Setting the threshold at 1,099 ft msl provides a 3-ft buffer to allow time for Duke Energy to notify and consult with SCDNR.

is equivalent to an 11-ft drawdown[3]. In accordance with the current 10-Year Work Plan, if Lake Jocassee pool elevation falls below 1,099 ft msl, Duke Energy will implement operational changes at the Bad Creek Project based on hydro unit availability and other operational considerations to minimize fish entrainment (FERC 2017). These protocols include turning lights off near the inlet/outlet structure so as not to attract fish to the area and implementing a unit startup and shutdown sequence to minimize fish entrainment.[4]

More recently, an updated desktop entrainment study was performed by Kleinschmidt Associates for Duke Energy in support of this relicensing and to evaluate potential impacts of the proposed Project expansion (i.e., Bad Creek II Complex). Specifically, this study considered the potential for entrainment of Lake Jocassee fishes through the Project under the proposed action (i.e., operation of two powerhouses at the Project). Like the existing Project, entrainment of fish at the Bad Creek II Complex during pumping has the potential to cause injury or mortality to fish as they pass through the water conveyance system and turbines. It is currently understood fish transferred to Bad Creek Reservoir via pumping entrainment are lost to the Lake Jocassee fishery since complete mortality has been assumed[5]. Previous studies demonstrate the overall numbers of fish entrained at the Project are primarily a function of fish density in the water column and the amount (volume) of water transferred. Although the proposed action will increase the rate at which water is pumped, the total volume of water passed during a pump back cycle is expected to remain about the same. Therefore, it is unlikely the proposed increase in pumping capacity will significantly increase the numbers of entrained fish during pumping at the Project. The full report is included in Appendix F of the PAD.

Lake Jocassee is recognized as a regional trout fishery, and maintaining this fishery is an important shared interest of SCDNR and Duke Energy. Under the current 10-Year Work Plan (2017-2027), Duke Energy will provide $80,000 (in 2017 dollars) per year to the SCDNR toward the growing and stocking of trout in Lake Jocassee and its tributaries. This funding will continue

[3] The Lake Jocassee Maximum Drawdown Elevation as specified in the KT Project Relicensing Agreement and the KT Project New License issued by FERC in 2016 is 1,080 ft msl, allowing a maximum 30-ft drawdown.

[4] The pumping protocol includes starting up Unit 4 first, followed by Units 2, 3, and 1 sequentially. Unit order is reversed during the shutdown sequence.

[5] Recent models suggest entrainment mortality may be less than 100%; therefore, Duke Energy may explore mortality rates in greater detail with stakeholders during entrainment discussions.

through 2027 and is adjusted annually based on the Consumer Price Index. This will assist in ensuring trout are available for maintaining the quality sport fishery in Lake Jocassee. Duke Energy proposes to consult with agencies and stakeholders through the relicensing process to determine appropriate PM&E measures for fishery impacts for the New License term.

No unanticipated effects to the population, abundance, or distribution of forage fish are expected from the proposed Bad Creek II Complex operations. Annual sampling and monitoring conducted as part of the current 10-Year Work Plan and MOU, as may be modified with stakeholders through the relicensing process, will likely continue during the New License term, and any changes in forage fish populations or diversity would be identified under those activities. The data collected as part of these studies would allow effective on-going monitoring of forage populations which are the primary food of trout and other predatory sportfish in Lake Jocassee and Lake Keowee.

Similarly, no effects on the littoral fish populations or changes in suitable habitat are anticipated as a result of the proposed Bad Creek II Complex operations. Annual electrofishing conducted as part of the current 10-Year Work Plan and MOU, as may be modified with stakeholders through the relicensing process, will likely continue during the New License term, to provide data (1) to determine species composition and to detect changes, (2) to obtain catch-per-unit effort data to detect increasing or decreasing population trends, and (3) to evaluate the relative condition of largemouth and spotted bass.

No impacts to the cost-sharing program for trout stocking are anticipated from the proposed Bad Creek II Complex; however, it is likely the addition of a second powerhouse would provide rationale for continuation of some level of cost-sharing for trout stocking in future years, to be considered in consultation with stakeholders through the relicensing process.

4.1 Proposed Protection, Mitigation and Enhancement Measures

During the New License term, Duke Energy proposes to continue to implement activities established by the 10-Year Work Plan and MOU, as may be modified in consultation with stakeholders through the relicensing process, and will continue to implement PM&E activities established under the KT Project Relicensing Agreement. Major measures include:

- Project operational measures and protocol to minimize risk of entrainment during certain environmental conditions (i.e., when Lake Jocassee is at or below 1,099 ft msl).

- Hydroacoustic monitoring of pelagic prey fish populations (e.g., Threadfin Shad and Blueback Herring) to monitor for effects to these species from the addition of Bad Creek II Complex operations.

- Pelagic trout habitat thickness monitoring is performed under the KT Project Relicensing Agreement, which requires an annual model prediction and verification by temperature and DO survey at the deepest location in Lake Jocassee (Station 558.0) in February and September, respectively.

- Duke Energy provided a one-time payment of $120,000 in 2017 to support Bad Creek MOU research and monitoring activities by SCDNR. Duke Energy also provided further funding of $90,000 in 2019 and will provide another $90,000 in 2025. Under the KT Project Relicensing Agreement, Duke Energy provided $100,000 to SCDNR to support tributary stream restoration efforts. Duke Energy expects to consult with agencies and other stakeholders regarding any need for additional PM&E measures focused on fisheries research and enhancements in the New License term through the relicensing process.

- Under the current 10-Year Work Plan (2017-2027), Duke Energy provides $80,000 (in 2017 dollars) per year to the SCDNR toward the growing and stocking of trout in Lake Jocassee and its tributaries. This funding will continue through 2027 and is adjusted annually based on the Consumer Price Index. Duke Energy proposes to consult with agencies and stakeholders through the relicensing process to determine any appropriate PM&E measures for trout for the term of the New License.

5 Project Nexus

The construction and operation of the Bad Creek II Complex has the potential to impact aquatic habitat and fish populations in Lake Jocassee. The construction of the Bad Creek II Complex and expansion of the underwater weir may cause direct, permanent and temporary impacts to aquatic resources in Lake Jocassee and in upland areas.

6 Methods

6.1 Task 1 – Consultation on Entrainment

Duke Energy proposes to consult with agencies and other Project stakeholders regarding results of this desktop entrainment assessment and study updates or modifications required to address entrainment impacts of the Bad Creek II Complex. Duke Energy commits to one meeting with agencies and stakeholders, with additional meetings (and timing of such) to be dictated by the Aquatic Resource Committee, if necessary. Conclusions of the study and existing mitigation measures to minimize entrainment will be discussed. Meeting notes will be taken and distributed to meeting participants for comment.

6.2 Task 2 – Effects of Bad Creek II Complex and Expanded Weir on Aquatic Habitat

The addition of operation activities by Bad Creek II Complex and proposed changes to the underwater weir have the potential to influence the temperature and DO dynamics in Lake Jocassee, which could affect trout lake habitat. The operations of Bad Creek II Complex will also influence water surface elevations in Lake Jocassee; specifically, the frequency, rate, and magnitude of water surface elevation changes, which may affect littoral zone habitat in the lake.

6.2.1 Evaluation of Potential Effects to Trout Lake Habitat

Lake Jocassee is one of only a few reservoirs in South Carolina containing a combination of water temperatures and DO levels supporting both a warmwater and a coldwater (trout) fishery year-round (USACE 2014). The success of the trout fishery in Lake Jocassee is dependent on adequate availability of suitable pelagic habitat, as defined by thermal and DO criteria. Vertical profile surveys of temperature and DO have been conducted in Lake Jocassee since 1973. Profile data allow evaluation of the vertical and horizontal distribution of trout habitat conditions, as measured by thickness/depth (meters, m) and volume (m^3), throughout the year and prediction of late-summer (i.e., September, when trout habitat would be expected to be at minimum) trout habitat thickness in the main body of the reservoir using an empirical model developed by Duke Energy (Foris 1991). Pelagic trout habitat is defined as water with temperatures ≤ 20.0 degrees Celsius (°C) and DO concentrations ≥ 5.0 milligrams per liter (mg/L) (Oliver et. al. 1978). The temporal and spatial distribution of trout habitat over the 1973-2015 period were consistent with typical temperature and DO regimes observed in Lake Jocassee (Duke Energy 2014; Duke Energy 2016) and provide sufficient habitat availability in Lake Jocassee to support a robust trout population.

The addition of the Bad Creek II Complex would influence hydrodynamics downstream of the inlet/outlet structure. While the expanded weir may minimize these affects (as the present weir has done for current Project operations), the increase in discharge and velocities has the potential to extend beyond the weir and result in water column mixing, disrupting trout habitat conditions and, potentially, sufficient trout habitat availability. Duke Energy proposes to use the results from the CFD model developed for the Water Resources Study to evaluate the degree and extent of water column mixing downstream of the weir, as indicated by velocity vectors, and how this may influence trout lake habitat. Effects of operations on trout lake habitat will be evaluated seasonally regarding habitat thickness and potential influence from velocities.

6.2.2 Evaluation of Potential Effects to Littoral Zone Habitat

The littoral fish habitat in Lake Jocassee resembles many undeveloped mountain lakes in North Carolina, comprising primarily rocky outcrops with small amounts of sand, emergent vegetation or stream confluences, residentially developed piers and riprap, clay, and cobble (Duke Energy 2014). Much of the littoral zone exhibits steep slopes, with areas of significant woody structure (large stumps).

The addition of the Bad Creek II Complex operations would result in changes to water surface elevations with respect to elevation change rates, magnitude, and duration, which could result in effects to littoral zone habitat in Lake Jocassee. Duke Energy proposes to use the CHEOPS™ model developed for the KT Project relicensing and used in the Water Resources Study to evaluate the changes in water surface elevations, with a qualitative analysis of how these changes could affect fish habitat in the littoral zone such as from dewatering/fluctuations, habitat availability, and species using these areas daily or seasonally (i.e., spawning).

6.3 Task 3 – Impacts to Surface Waters and Associated Aquatic Fauna

Construction of the Bad Creek II Complex would impact existing streams and waterbodies, including wetlands. Overburden (i.e., soil and rock) material from the construction activities are proposed to be deposited in several spoil locations throughout the site. Siting for spoil location alternatives is ongoing by Duke Energy; however, due to the amount of soil material required, existing topography, and prevalence of headwater streams and seeps located throughout the site, it is unlikely there would be a practicable alternative identified that will result in zero impacts to steams, wetlands, and tributaries to Lake Jocassee. Potential spoil locations and estimated impacts to water resources (reported in length of stream or size of area) are provided in Table 5-3 in Section 5 of the PSP. As described in Section 5.6.3.3 of the PAD (Duke Energy 2022), placement of excavated rock removed from the underground excavations to the downstream slope of the existing submerged weir in Lake Jocassee, as was done for the construction of the existing Project, would significantly reduce the amount of material placed at upland disposal sites, reducing impacts to existing streams and wetlands. However, while reducing the amount of spoil material necessary for deposit in upland locations, placement of rock for weir expansion will potentially result in temporary impacts to aquatic habitat in the Whitewater River arm of Lake Jocassee.

Duke Energy proposes to evaluate the aquatic resources (streams, wetlands, and Lake Jocassee) that may experience direct impacts from spoil placement or other construction activities. This will include a characterization of aquatic resources with respect to stream types as indicated from the Natural Resources Assessment, habitat quality, and potential fauna (mussels) presence. Field activities in support of this study are outlined below.

6.3.1 Stream Habitat Quality Surveys

As stated in the Water Resources Proposed Study Plan, upland disposal resulting in impacts to streams or wetlands, as well as placement of rock spoils at the submerged weir will require an individual permit from the U.S. Army Corps of Engineers (USACE) as well as a water quality certification from South Carolina Department of Health and Environmental Control (SCDHEC) under the authorities of Sections 404 and 401 of the Clean Water Act (CWA). In preparation for these expected regulatory processes, if Bad Creek II Complex is pursued, stream habitat quality surveys will be completed to provide a physical assessment of the potentially impacted streams.

The stream surveyors will conduct habitat assessments using the Rapid Bioassessment Protocols (RBP) for Use in Streams and Wadeable Rivers (Barbour et al. 1999). The purpose of the RBP is to provide a technical methodology for conducting cost-effective biological assessments in lotic systems; the matrix used to assess habitat quality is based on key physical characteristics of the waterbody and surrounding land contributing of stream habitat quality.

6.3.2 Mussel Surveys

As part of this study, presence/absence mussel surveys will be completed for streams proposed to be impacted in upland spoil locations. The freshwater mussel surveys will consist of timed searches; for Lake Jocassee, the amount of effort will be a minimum of 1 person-hour. Upland stream habitats will be assessed to determine whether conditions exist to support freshwater mussel assemblages; freshwater mussels do not commonly occur in high gradient systems with large substrate and low productivity. For upland streams capable of supporting mussels, the amount of effort will be a minimum of 0.5 person-hours.

Mussels will be collected visually and tactilely (grubbing) and placed in mesh bags. Mussels will be identified to species and enumerated. The total number of mussels, relative abundance of each species, and catch per unit effort (CPUE) will be determined. Habitat conditions at each sampling location will be recorded including substrate conditions, shoreline composition, and basic water quality parameters (water temperature, dissolved oxygen).

6.4 Analysis and Reporting

Results of this study will be summarized in the Initial Study Report and Updated Study Report. Duke Energy anticipates the Aquatic Resources Study report will include Project information and background, a depiction and description of the study area, methodology, results, and analysis and discussion. The report will also include relevant stakeholder correspondence and/or consultation, as well as literature cited.

7 Schedule and Level of Effort

The preliminary schedule for this study is outlined in Table 7-1. The estimated level of effort for this study is approximately 1,300 hours. Duke Energy estimates the Aquatic Resources Study will cost approximately $200,000 to complete.

Table 7-1. Proposed Aquatic Resources Study Schedule

Task	Proposed Timeframe for Completion
Study Planning	August – December 2022
Consultation on Entrainment Meeting	January – June 2023
Desktop Studies on Pelagic and Littoral Habitat Effects	Spring-Fall 2023
Mussel Surveys and Stream Habitat Quality Surveys	Summer 2023
Distribute Draft Study Report with the Initial Study Report	January 2024

8 References

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Duke Energy. 2014. License Application Keowee-Toxaway Project FERC No. 2503. Environmental Report (Exhibit E).

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_____. 2022. Pre-Application Document, Bad Creek Pumped Storage Project FERC Project No. 2740, Oconee County, South Carolina. February 23, 2022.

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Oliver, J.L, P.L. Hudson, and J.P. Clugston. 1978. Effects of a pumped-storage hydroelectric plant on reservoir trout habitat. Proc. ACSAFWA. 31:449-459.

U.S. Army Corps of Engineers. 2014. New Operating Agreement between U.S. Army Corps of Engineers, Southeastern Power Administrations, and Duke Energy Carolinas, LLC Final Environmental Assessment for Hydropower License. October 2014.

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Attachment 1

Attachment 1 – Documents Relevant to Existing Project Agreements and Work Plans

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LICENSE (MAJOR): AMENDMENT OF LICENSE

Before Commissioners: Richard L. Dunham, Chairman; Don S. Smith and John H. Holloman III.

DUKE POWER COMPANY, PROJECT NOS. 2740 AND 2503

ORDER ISSUING LICENSE (MAJOR) FOR PROJECT NO. 2740 AND AMENDING LICENSE FOR PROJECT NO. 2503

(Issued August 1, 1977)

On February 4, 1974, Duke Power Company (Applicant) of Charlotte, North Carolina, filed an application[1] for license under Section 4(e) of the Federal Power Act (Act)[2] to construct, maintain, and operate a 1,000 MW

[1] The application was supplemented by filings on May 29, and December 26, 1974; and January 5 and March 29, 1976.

[2] 16 U.S.C. § 797(e).

pumped storage hydroelectric project. The proposed Bad Creek Pumped Storage Project (FPC Project No. 2740) would be located on Bad and West Bad Creeks in Oconee County, South Carolina, and would include a 318-acre upper reservoir created by dams across Bad and West Bad Creeks; utilization of existing Lake Jocassee, part of FPC Project No. 2503, as the lower reservoir; a tunnel to connect the two reservoirs; an underground powerhouse containing four 250 MW reversible pumping-generating units; and approximately 18 miles of 525-kV transmission line and 9.5 miles of 100-kV transmission line.

Applicant supplies electric power to 50 counties in the Piedmont sections of North and South Carolina. Electric power generated from the proposed project would be used in Applicant's service area for public utility purposes and would be fed into its interconnected system for transmission across state lines. Therefore, the Bad Creek Pumped Storage Project would affect the interests of interstate commerce within the meaning of Section 23(b) of the Act.[3]

Public Notice

Public Notice of the filing of the application was given as required by the Act, with August 30, 1974, as the last date for filing protests or petitions to intervene. No protests, notices of intervention, or petitions to intervene were received.

The Commission staff prepared draft and final environmental impact statements covering the proposed Bad Creek Project. Notice of Availability of the DEIS was published in the *Federal Register* with November 14, 1975, as the last date for filing protests or petitions to intervene. None was received. Notice of availability of the FEIS was published in the *Federal Register* on March 14, 1977.

By letter dated June 3, 1974, the Secretary of the Commission forwarded copies of Applicant's application for license to relevant Federal, State, and local agencies for comment. Comments on the application were received from nine Federal and six State and local agencies. Most of the concerns raised by these agencies were addressed in the draft and final environmental impact statements prepared by the Commission staff. Consequently, we need not restate those comments herein except to the extent that they are incident to certain matters we deem in need of further clarification.

Nature of the Applicant and Financial Ability

Applicant is a corporation organized under the laws of the State of North Carolina, having its office and principal place of business at Charlotte, North Carolina and authorized to do business in the State of North Carolina. Applicant is also domesticated and qualified to do business in South Carolina.

[3] 16 U.S.C. § 817; see *F.P.C.* v. *Union Electric Company*, 381 U.S. 90 (1965).

Applicant states in its Exhibit G that it would finance the proposed project from the treasury of the Company or funds obtained through the issuance of notes, bonds, debentures or common stock. Applicant's financial ability to construct, maintain and operate the project is also adequately reflected in data in its FPC Form No. 1.

Compliance with State Law

Applicant states that there are no general laws of the State of South Carolina applicable to construction of the proposed project.

The Rules and Regulations of the South Carolina Department of Health and Environmental Control require a construction permit for the impoundment of one-tenth acre or more of water. Applicant would obtain such a permit prior to commencement of any construction.

Except for certain lands already held in fee by the Applicant, all lands within the proposed project area are owned in fee by Crescent Land and Timber Corporation, a wholly-owned subsidiary of the Applicant. Upon completion of construction of the proposed project, a field survey of the project boundary would be made and Crescent would convey the entire project area to Duke in fee. Thus, Applicant will have total ownership of the land and water rights that it proposes to use in the development of the Bad Creek Project, and it will be unnecessary to acquire land or water rights by purchase or condemnation proceedings.

Need for Power

Based on the Applicant's most recent load forecast for the period from 1977 to 1985, peak loads in Applicant's system are predicted to increase annually at a decreasing rate, from a growth rate of 6.3 percent in 1978 to a growth rate of 5.3 percent in 1985; however, the total peak load is expected to grow by some 38 percent, from 9,523 megawatts in 1977 to 15,400 megawatts in 1985. Without the proposed Bad Creek Project on line, reserve margins in 1984 and 1985 are estimated at 24 percent. With the proposed project, they are forecast at 27.4 and 30.5 percent, respectively.

We realize that the Applicant's forecast 24 percent reserve margins without the proposed project are based on optimistic assumptions regarding its load management program and timely addition of 7,226 MW of scheduled nuclear capacity. Applicant's concern regarding reliance of these factors is justifiable, and we agree that the proposed project should be developed to insure a reliable power supply during periods of peak demand. For instance if one of the scheduled 1,153 MW nuclear units would not be available, Applicant's reserve margin in 1984 and 1985 would be reduced to 16 and 16.6 percent, respectively.

The additional peaking capacity of the proposed project will also be of benefit to the entire Virginia-Carolina (VACAR) Subregion of the Southern Electric Reliability Council (SERC) of which Applicant is a member. The

1976 SERC Reports (issued April 1, 1977) forecast a reserve margin of 19.6 percent for VACAR in the year 1984 without the peaking capacity of the Bad Creek Project. The corresponding reserve margin for 1985 is forecast to be 19.7 percent.

Economic Feasibility

The Applicant's electric system has been studied using existing generating capacity, planned retirements, and a generation expansion mix consisting of planned generating additions through 1985, together with either Bad Creek or an alternative source such as another pumped storage project, combustion turbines, or combined cycle or coal-fired peaking plants. The generating mix was operated by economical dispatch to meet system demand, with the Bad Creek Project, or an alternative, included to determine the overall effect on system production costs.

The proposed Bad Creek project would have an economic advantage over all thermal-electric generating alternatives studied. Staff studies show that annual operating costs of the most economical thermal plant alternative, a combustion turbine, would be $15,094,000 more per year than the proposed project.

Staff estimates (assuming escalation of costs to the midpoint of construction in 1980) that the capital cost of the Bad Creek Project is $331,372,000, which is less than the other alternate pumped storage projects studied, except the Long Spur Ridge site, which has an estimated capital cost of $3,347,000 less than Bad Creek. The annual cost of the proposed project is also less than the other alternate pumped storage projects except, again, the Long Spur Ridge site, which would have annual costs $463,000 less than the Bad Creek Project.

The Long Spur Ridge site has the potential for a larger power installation than is proposed for Bad Creek. However, if sized to meet the capacity needs of the 1985 load level, with provisions made for the ultimate capacity installation, it would have a higher capital investment than that reflected in the 1,000 MW comparative study undertaken. Therefore, we consider the Bad Creek site a better choice for immediate development. The Long Spur Ridge site will be available for consideration at such future time as the larger installed capacity is needed in the system.

Conservation of Fuels

Pumped storage peaking capacity alters the loading of other generating units of the system in a manner which usually reduces the production costs of electrical energy and also reduces fuel consumption as compared to alternative forms of peaking capacity. Pumping energy is derived from the highly efficient base-load plants during off-peak hours when the system demand cannot absorb all of the base-load capacity. During peak-load periods, the pumped storage plants provide peaking capacity to displace the small inefficient fossil-fueled peaking units such as combustion turbines which would otherwise be required to operate.

The proposed Bad Creek Project would effect a saving of approximately 4,322 trillion Btu's of fossil fuels for Applicant's system in 1985 over the combustion-turbine alternative. This is equivalent to saving 690,000 barrels of oil in 1985.[4]

Safety and Adequacy

The design features of the existing Jocassee Dam were analyzed at the time the Commission issued its order granting license for Keowee-Jocassee Pumped Storage Project and have revealed no significant problems. Thus, further analysis of the existing lower reservoir structures is not necessary.

The Exhibit L drawings filed as part of the application for license have been examined and found to propose designs for safe and adequate project works if constructed in accordance with sound engineering principles. Certain revisions in plans have been made since the application was filed. Licensee has eliminated the originally planned surge tanks based on hydraulic transient studies, and the design of the dam has been changed due to the unavailability of certain material. Consequently, we have provided in Article 25 that the Licensee shall submit revised Exhibit L drawings for Commission approval prior to the commencement of construction. Article 25 requires further analysis of dam stability, hydraulic transient and governor stability. In addition, Article 25 requires submittal of plans, specifications, and a quality assurance program for earth dam construction.

The upper reservoir structure is designed to withstand the catastrophic natural phenomena of a probable maximum flood and an earthquake having a ground acceleration of 0.10 gravity. An emergency spillway in the upper reservoir would provide safety against overpumping in case of malfunction of the pumping trip-off devices. Transmission lines are designed to withstand high winds. The probability of flooding the powerhouse is very remote, but in the event of flooding, egress could be negotiated by one access tunnel and the vertical bus shaft. The project should have minimal impact upon public health and safety due to its remote location and the Applicant's intention to fence the entire upper reservoir area to prohibit public use of the area.

Based on the foregoing, we conclude that the proposed project would be safe and adequate. We have provided in license Article 26 for the installation of instrumentation to monitor seepage, uplift and performance of project structures and reservoir slopes. Article 27 will require the Licensee to file an emergency action plan to be followed in the event or immediate threat of sudden water releases or actual dam failure. Additionally, Article 36 requires

[4] Energy and Policy Conservation Act of 1975, Public Law 94–163, 89 Stat. 871, 940 approved December 22, 1975 (Sec. 382).

the Licensee to provide adequate safety measures in light of the hazardous conditions around outlet structures in Lake Jocassee.

The Commission staff will periodically inspect the project during construction. Article 28 will require the Licensee to engage a board of qualified engineering consultants to review design and construction to assure that the project as designed will be safe and adequate. Licensee's construction inspection program will be subject to the approval of our authorized representative pursuant to Article 4. We are confident that the public interest will be well served by strict adherence to the spirit and letter of these license provisions to assure safe and adequate project works.

Transmission Facilities

A switchyard would be located adjacent to the above-ground transformer bank at the proposed project, from which a 1,600-foot-long section of overhead 525-kV transmission line would lead to the proposed location of a future 525-kV tie station. From this future tie station, a proposed 525-kV line approximately 18 miles long would be built along a new right-of-way to the existing Jocassee-Oconee 230-kV transmission line right-of-way, and would then parallel that existing right-of-way to the Oconee Nuclear Station.

Prior to constructing this 525-kV line, and for the purpose of supplying power during construction, a 100-kV line would be built from the Jocassee Switchyard, paralleling the existing 230-kV line for 1.84 miles along a combined right-of-way totaling 338 feet in width, where it would then turn and follow a new 254-foot right-of-way for 7.67 miles into the Bad Creek site. Upon completion of project construction, this 100-kV line would serve as an emergency source of power to Bad Creek. Although these lines would be parallel within this segment, construction of the 100-kV line would precede the 525-kV line by about five years.

The first segment of transmission corridor from the Bad Creek tie station, containing the 100-kV line and then the added 525-kV line, would be on a new 254-foot wide right-of-way for 7.67 miles to a point adjacent to the existing Jocassee–Oconee 230-kV right-of-way. The 525-kV line would then follow new and existing rights-of-way, varying in combined widths from 320 feet to 445 feet, for 9.08 miles to the last 1.04-mile segment of 525-kV line which departs from the Jocassee–Oconee right-of-way on a new 200-foot wide right-of-way ending at the Oconee Nuclear Station.

The Applicant maintains that the 525-kV transmission line would not be a part of the Bad Creek Project works since it is planned, at some future date, to connect the line to an incoming line from the west at a tie station to be located at the Bad Creek Project site. Lines would be extended north and then east from the Oconee Nuclear Station and the Jocassee Pumped Storage Plant, thereby completing a transmission grid loop interconnecting Duke's system to the TVA and privately owned public utility systems. On this basis, the Applicant feels that the 525-kV line should be regarded as a part of its interconnected system and not as a primary transmission line subject to the Commission's licensing jurisdiction.

The Applicant states that the generation output and pumping power requirements at Bad Creek could be transmitted at 230-kV and interconnected to the Applicant's transmission system at the Jocassee Pumped Storage Plant. However, for reasons of economy, environmental compatibility, and for interconnection with other important generating plants in its own system and with the systems of adjacent public utilities, the Applicant has elected to transmit Bad Creek power at 525-kV and to tie into its interconnected transmission system at the Oconee Nuclear Plant switchyard.

A Commission staff study indicates that the 525-kV line will transmit only the power generated at the Bad Creek Project to the Applicant's interconnected system and the required pumping power from the interconnected system to the Bad Creek Project. Consequently, the line is required for the viability of the project and as such is a primary transmission line within the meaning of Section 3(11) of the Act[5] and should be licensed as a part of the Bad Creek Project, along with the generator leads and bus, the 20/525-kV step-up transformers, and appurtenant facilities to connect to the Oconee switchyard.

It is true that when the transmission grid loop envisioned by the Applicant is completed at some point in time, the nature and function of the 525-kV transmission line may change. If and when this happens, the Applicant can file, for our consideration, an application for amendment of license requesting that the line be excluded from the Bad Creek Project license.

Exhibits J, K and M do not include as a part of the project the transmission facilities (nor the transmission line rights-of-way) found to be primary and thus a part of the project works subject to licensing as determined herein. Article No. 42 will require the filing of revised Exhibits J, K and M.

Environmental Considerations

As stated above, a Final Environmental Impact Statement (FEIS) was prepared and issued by the Commission staff on March 14, 1977. Ten copies of the FEIS were mailed to the Council on Environmental Quality on the same date.

The environmental impacts associated with construction, operation, and maintenance of the project have been fully considered after reviewing the FEIS,[6] and all other materials in the record. A discussion of the more significant environmental impacts of this project, requiring special license conditions, follows below.

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[5] 16 U.S.C. § 796(11).

[6] See 18 CFR § 2.81.

1) Aquatic Ecosystem

Turbidity and siltation caused by runoff from construction sites and other land surface disturbances associated with construction activities could have an adverse impact on the aquatic ecosystems of the receiving waters. Licensee, by Articles 39 and 45, will be required to prevent or minimize these impacts on the aquatic ecosystem. In addition, Licensee will be required by Article 34 to continue its pre-construction water quality monitoring program on a monthly basis to establish further baseline data. After construction, a five-year water quality monitoring program will be required.

Discharges from proposed sanitary facilities at the construction yard into the Whitewater River arm of Lake Jocassee could impact nutrient levels and biochemical oxygen demands. Article 35 will require that the Licensee consult and cooperate with appropriate agencies and comply with Federal, State, and local regulations in the construction, operation, and maintenance of sanitary facilities used during construction and operation of the project. Additionally, Article 37 will require the Licensee to provide measures for vector control.

On August 9, 1976, the South Carolina Department of Health and Environmental Control issued a water quality certificate for the proposed project pursuant to Section 401 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500).[7]

2) Fish Habitat

Construction and operation of the project would adversely affect the coldwater fish habitat in Lake Jocassee and trout migration, spawning, and rearing in Howard Creek. This matter was the subject of considerable concern in the comments filed by the U.S. Department of the Interior, the South Carolina Wildlife and Marine Resources Department (SCWMRD), Trout Unlimited and others. Article 32 will require the Licensee to conduct studies to assess the effects of project operation on fishery resources. The Licensee is also required to prepare within one year of the issuance of the license a detailed plan to mitigate the adverse impacts of project operations on Lake Jocassee and stream fisheries. As a part of the mitigation plan to be filed, the Licensee will be required to include those items agreed to with SCWMRD. To mitigate project-induced fishery loss, Applicant, by letter dated January 10, 1977, agreed to and SCWMRD concurred to the following: (1) convey to SCWMRD certain lands it held in the Eastatoe Creek watershed; (2) provide for adequate sediment and erosion control; (3) restrict development around Lake Jocassee; and (4) restore damage to Howard Creek in a joint venture with SCWMRD.

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[7] 33 U.S.C. § 1341.

3) Wildlife

The proposed project will result in the loss of about 505 acres of wildlife habitat, including 370 acres within the impoundment area. Wildlife inhabiting this area will be forced to migrate to adjacent areas or perish. Detailed measures to mitigate or protect wildlife resources have not been provided. Accordingly, we will provide in Article 32 that a detailed wildlife mitigation plan be filed for our approval within one year of the issuance of the license. That plan will include, *inter alia,* an implementation schedule, a description of the location and acreage of lands to be managed for wildlife, and a map showing areas that will be revegetated for wildlife purposes and the vegetation selected for planting.

4) Rare or Endangered Species

Rare or endangered plant and animal species may be adversely affected during construction and maintenance of the project, including transmission line rights-of-way. A survey of vascular flora of the project area was conducted for the Applicant. The endangered plant species, Oconee Bells, was encountered along the proposed transmission line right-of-way and will require special attention. We will require in Article 38 that Applicant arrange for pre-construction surveys in areas not previously surveyed as well as procedures for protection and Commission notification in the event that rare or endangered plant species are encountered. Identical measures are required for rare or endangered animal species.

5) Archeological and Historical Resources

The South Carolina Department of Archives and History, by letter dated August 19, 1974, reported that no properties on or eligible for the National Register of Historic Places are in the area of the proposed project. An archeological survey of the project area did not identify any archeological resources in the area. The survey did not, however, include transmission line corridors, where additional reconnaissance is required. In Article 41 of this license, we will require the Licensee to conduct archeological surveys along the transmission corridors. Procedures to be followed in the event an archeological site is discovered are also provided therein.

6) Transmission Facilities

The construction and maintenance of transmission line rights-of-way and facilities will result in environmental and aesthetic impacts. Applicant's original plans in its initial application were revised by a filing on March 29, 1976, but do not present detailed, comprehensive plans for transmission line construction and maintenance. Accordingly, we are requiring in Article 33 that the Licensee, not later than one year prior to beginning construction of transmission facilities, file with the Commission a comprehensive plan to avoid or minimize damage to the environment and to protect and enhance the visual, cultural, and related natural resources values of areas that would be affected by the proposed transmission facilities.

7) Roads

Construction of the Bad Creek Reservoir will require the relocation of 0.4 mile of secondary road. In addition, construction of project transmission facilities may affect State roads that are crossed. The U.S. Department of Transportation, Coast Guard, reported by letter dated August 30, 1974, that close coordination would be required between the Applicant and the South Carolina Highway Department in order to ensure that the relocation and new intersection with S.C. Route 171 complies with the State Secondary Road Plan standards. Article 40 requires the Licensee to consult with appropriate Federal, State, and local agencies regarding construction affecting roads.

8) Recreation

Development of Bad Creek Reservoir would result in a loss of land and water resources now providing limited dispersed outdoor recreation opportunities in the proposed dam and reservoir Basin area. The water surface elevation of the upper reservoir would fluctuate rapidly on a daily basis. Therefore, Applicant intends to prohibit public use of project lands and waters as a safety precaution, and proposes to provide off-site recreation developments instead. A general recreational use plan (Exhibit R) has been submitted for a 31-mile hiking trail between the lower Whitewater Falls area and the Pinnacle Mountain area in Table Rock State Park on non-project lands owned by the Crescent Land and Timber Corporation.

At least three shelters and other features would be developed along the proposed hiking trail. The proposed trail would comprise a central link in the proposed Foothills Trail, which will ultimately join the Table Rock and Oconee State Park areas. The Applicant's portion of the trail would connect with several short segments to be developed by the U.S. Forest Service in the Whitewater River Unit of the Nantahala National Forest in North Carolina. The Foothills Trail would then extend southwest through the Keowee Unit of the Sumter National Forest to Stumphouse Mountain Tunnel Park, about 5 miles south of Oconee State Park.

Applicant's Exhibit R reflecting this proposed recreational development is in substantial conformance with our Regulations and will be approved. It is, however, preliminary in nature and does not show the precise location of the trails. We have therefore provided in Article 31 that Licensee shall file, within two years, an amendment to its Exhibit R providing detailed maps, drawings, and data relating to the 31-mile long trail. The proposed recreational development should make a significant contribution to meeting recreational needs in the general project area.

Comprehensive Development

The proposed project would be an integral part of the larger Keowee-Toxaway Power Production Complex. On September 26, 1966, the Commission issued a license for the Keowee-Toxaway Project, FPC Project No. 2503, authorizing construction of the 157.5 MW Keowee conventional hydroelectric plant on Lake Keowee and the 612 MW Jocassee Pumped Storage plant which utilizes Lake Keowee as its lower reservoir. The Project No. 2503 license further authorized the use of the Lake Keowee as a source of condenser cooling water for up to 3,000 MW of steam-generated electric power. The 2,659 MW Oconee Nuclear Plant has since been constructed on the shores of Lake Keowee. Utilizing Lake Jocassee as its lower reservoir, the proposed Bad Creek Pumped Storage Project would be another element in Applicant's overall scheme of development at Lakes Keowee and Jocassee.

There are no conflicting applications before the Commission, and the project would have no effect on a Government dam or any proposed development of water resources by the United States.

The U.S. Department of the Army, Corps of Engineers (Corps), by letter dated September 4, 1974, reported that the plans of project structures are satisfactory insofar as the interests of navigation are concerned. Although the Corps stated that the project would have no appreciable effect on flood control, it did recommend that the project be operated so as not to exceed downstream flood peaks which would have occurred in the absence of the project, and further that consultation with the Corps be required regarding reservoir filling and any modification of the existing operating agreement involving the Keowee-Jocassee reservoir system and the Corps' downstream Hartwell and Clark Hill projects. Articles 43, 44, 46 and 47 should satisfy the Corps' concerns.

As an integral part of the Keowee-Toxaway complex, we find that the proposed project, subject to the provisions of this order, will be best adapted to the comprehensive development of the waterways involved.

We have provided for the coordinated use of Lake Jocassee by these two projects in license Articles 48 and 49, which will be included in the license for Project No. 2740 and also in the license for Project No. 2503 numbered, however, as Articles 47 and 48, respectively. Article 48 requires coordinated operation of the two projects, and Article 49 addresses negotiation of a compensation agreement in the event ownership of either or both projects is vested in different entities.

Reference is made in the application to the construction of additional pumped storage projects on Lake Jocassee and the utilization of Lake Keowee as a source of condenser cooling water for an additional 4,000 MW of steam generated electric power. The sites of any additional steam electric generating plants to be constructed at Lake Keowee, nuclear fueled or otherwise, or of any additional pumped storage sites to be developed at Lake Jocassee, are not known at this time. Any future use of Lake Keowee as a source of cooling water, or of Lake Jocassee as the lower pool of a pumped storage project, would require Commission approval.

License Term

In accord with our general practice regarding the licensing of new-capacity projects, we will issue the license for Bad Creek Pumped Storage Project to remain in effect for a period of fifty years. The license shall be effective the first day of the month in which it is issued.

The Commission finds:

(1) The Bad Creek Pumped Storage Project, FPC No. 2740, as constituted under this license, affects the interests of interstate commerce within the meaning of Section 23(b) of the Act.

(2) The Applicant, Duke Power Company, a corporation organized under the laws of the State of North Carolina, is qualified to do business in the States of North Carolina and South Carolina and has submitted satisfactory evidence of compliance with the requirements of all applicable state laws insofar as necessary to effectuate the purposes of a license for the project.

(3) Public notice of the application for license has been given. No protests or petitions to intervene have been received by the Commission.

(4) No conflicting application is before the Commission.

(5) The project will not affect a Government dam, nor will the issuance of a license therefore, as herein provided, affect the development of any water resources for public purposes that should be undertaken by the United States.

(6) Subject to the terms and conditions hereinafter imposed, the project is best adapted to a comprehensive plan for improving or developing the waterways involved for the benefit of interstate or foreign commerce, for the improvement and utilization of water power development, and for other beneficial public uses, including recreational purposes.

(7) The installed horsepower capacity of the project hereinafter authorized for the purpose of computing the capacity component of the annual charge to be paid under the license for the cost of administration of Part I of the Federal Power Act is reasonable as hereinafter fixed and specified.

(8) The plans of project structures, insofar as the interests of navigation are concerned, have been approved by the U.S. Department of the Army, Corps of Engineers.

(9) A final environmental impact statement has been prepared in accordance with the National Environmental Policy Act of 1969, 42 U.S.C. § 4321, *et seq.,* after preparation and circulation of a draft environmental impact statement and receipt of comments thereon.

(10) The term of the license hereinafter authorized is reasonable.

(11) The following described transmission facilities are parts of the project within the meaning of Section 3(11) of the Act and should be included in the License for the project: the generator leads, the electrical bus housed in a vertical shaft about 520 feet high and 28 feet in diameter leading from the

underground powerhouse to four above-ground 20/525-kV step-up transformers, a 100-kV transmission line extending about 9.5 miles from the Bad Creek switchyard to the Jocassee switchyard, and a 525-kV transmission line extending about 18 miles from the Bad Creek switchyard to the Oconee switchyard.

(12) The exhibits designated and described in paragraph (B) below substantially conform to the Commission's Rules and Regulations and should be approved to the extent that they depict the general location, description, and nature of the project.

(13) There is a demonstrated need for the project's power in Applicant's system.

(14) The proposed project is superior to any alternative considered.

(15) The Applicant has demonstrated satisfactory evidence that it has the necessary financial capabilities to construct and operate the project.

(16) It is appropriate and in the public interest that the license for Project No. 2503 be amended to provide for coordinated operation with Project No. 2740.

The Commission orders:

(A) This license is hereby issued to Duke Power Company (Licensee) or Charlotte, North Carolina, under Section 4(e) of the Federal Power Act, for a term of fifty years commencing on the first day of the month in which this license is issued, for the construction, operation and maintenance of the Bad Creek Pumped Storage Project, FPC Project No. 2740, located on Bad and West Bad Creeks in Oconee County, South Carolina, affecting the interests of interstate commerce, subject to the terms and conditions of the Act, which is incorporated herein by reference as a part of this license, and subject to such rules and regulations as the Commission has issued or prescribed under the provisions of the Act.

(B) The Bad Creek Pumped Storage Project, FPC Project No. 2740, consists of:

(i) all lands constituting the project area and enclosed by the project boundary or the licensee's interests in such lands, the limits of which are otherwise defined, the use and occupancy of which are necessary for the purposes of the project; such project area and project boundary being shown and described by certain exhibits which form part of the application for license which are designated as follows:

Exhibit	*FPC Drawing No.*	*Entitled*
J Sheet 1	2740–1 (as revised 3–29–76)	Area Map
J Sheet 2	2740–2 (as revised 3–29–76)	General Map and profile
K Sheet 1	2740–4 (as revised 1–05–76)	General Plan
K Sheet 2	2740–5	Topography
K Sheet 3	2740–6	Topography
K Sheet 4	2740–7	Topography
K Sheet 5	2740–8	Topography

(ii) project works consisting of: (1) a 318-acre upper reservoir with a storage capacity of 33,323 acre-feet, of which 30,228 acre-feet is usable storage capacity between minimum elevation 2,150 feet m.s.l. and full pool elevation of 2,310 feet m.s.l.; (2) a rockfill impervious core dam with crest elevation at 2,315 feet m.s.l. about 2,600 feet long and 355 feet high across Bad Creek; (3) a rockfill impervious core dam with crest elevation at 2,315 feet m.s.l. about 900 feet long and 170 feet high across West Bad Creek; (4) a saddle dike with crest elevation at 2,313 feet m.s.l. about 900 feet long and 84 feet high across a natural depression on the eastern rim of the reservoir; (5) an ungated water intake structure in the upper reservoir; (6) a concrete-lined main shaft and power tunnel, 4,720 feet long and 29 feet in diameter, connecting by means of a manifold structure to 4 concrete, steel-lined penstocks about 300 feet long and varying from 9 to 14.5 feet in diameter; (7) an underground powerhouse containing four 250,000 kW reversible pumping-generating units, total capacity 1,000,000 kW; (8) 4 concrete-lined draft tube tunnels about 280 feet long and 14.5 feet in diameter, connecting by means of a manifold structure to two concrete-lined tailrace tunnels about 900 feet long and 26.5 feet in diameter; (9) an intake/outlet structure equipped with five 15-foot by 25-foot steel lift gates located in the existing Lake Jocassee which will serve as the lower reservoir; (10) transmission facilities consisting of (a) the generator leads, (b) the electrical bus housed in a vertical shaft about 520 feet high and 28 feet in diameter leading from the underground powerhouse to (c) four above ground 20/525-kV step-up transformers, (d) a 100-kV transmission line extending about 9.5 miles from the Bad Creek switchyard to the Jocassee switchyard, (e) a 525-kV transmission line extending about 18 miles from the Bad Creek switchyard to the Oconee switchyard; and (11) appurtenant facilities—the location, nature and character of which are more specifically shown and described by the exhibits hereinbefore cited and by certain other exhibits which also form part of the application for license and which are designated and described as follows:

Exhibit	*FPC Drawing No.*	*Entitled*
L Sheet 1	2740–9 (as revised 3–29–76)	General Plan
L Sheet 2	2740–10 (as revised 1–5–76)	Sections and Details
L Sheet 3	2740–11 (as revised 3–29–76)	Sections and Details
L Sheet 4	2740–12 (as revised 3–29–76)	Sections and Details

Exhibit M—consisting of five printed pages entitled "General Description of Mechanical, Electrical, and Transmission Equipment" with filing dates as follows:

Pages 1, 3, 4 filed 3/29/76
Page 2 filed 1/5/76
Page 5 filed 2/4/74

Exhibit R—as filed February 4, 1974, and amended January 5, 1976, and March 29, 1976, consisting of:

(1) Five pages of text, titled "Exhibit R—Recreation Plan"; and

(2) one drawing entitled "Exhibit R, Sheet 1"—FPC No. 2740–14, filed May 31, 1974.

(iii) all of the structures, fixtures, equipment, or facilities used or useful in the maintenance and operation of the project and located on the project area, and such property as may be used or useful in connection with the project or any part thereof, whether located on or off the project area, if and to the extent that the inclusion of such property as part of the project is approved or acquiesced in by the Commission; together with all riparian or other rights, the use or possession of which is necessary or appropriate in the maintenance or operation of the project.

(C) The exhibits designated and described in Paragraph (B) above are approved only to the extent that they depict the general location, description, and nature of the project.

(D) This license is also subject to the following terms and conditions set forth in Form L–11 (Revised October 1975, 54 FPC 1864) entitled "Terms and Conditions of License for Unconstructed Major Project Affecting the Interests of Interstate or Foreign Commerce," which terms and conditions, designated as Articles 1 through 23, are attached hereto and made a part hereof, and subject to the following special conditions set forth herein as additional articles:

Article 24. The Licensee shall commence construction of the project within two years from the effective date of the license and shall thereafter in good faith and with due diligence prosecute such construction and shall complete construction of such project works within 9 years from the issuance date of this license.

Article 25. The Licensee shall submit for Commission approval prior to the start of construction revised Exhibit "L" drawings showing the final design of the project works. In support of the design shown on the Exhibit L drawings, Licensee shall submit soils test data, stability analyses, hydraulic transient and governing stability studies; and shall file with the Commission's Regional Engineer and Chief, Bureau of Power, one copy each of reduced size contract drawings and specifications and a quality assurance plan for earth dam construction as soon as available. The Chief, Bureau of Power, may require appropriate changes in the plans and specifications so as to assure a safe and adequate project.

Article 26. The Licensee shall install appropriate instrumentations and other devices to monitor seepage, uplift, and performance of the project structures and reservoir slopes. A plan of instrumentation and a schedule for recording instrument readings shall be filed with the Chief, Bureau of Power prior to the initial filling of the upper reservoir. The Licensee shall furnish periodically to the Chief, Bureau of Power, as may be requested, a report and analysis of instrument readings.

Article 27. Licensee shall file with the Commission, implement, and modify when appropriate, an emergency action plan designed to provide an early warning to upstream and/or downstream inhabitants and property owners if there should be an impending or actual sudden release of water caused by an accident to, or failure of, project structures. Such plan, to be submitted prior to initial filling of the project reservoir(s), shall include, but not be limited to, instructions to be provided on a continuing basis to operators and attendants for actions they are to take in the event of an emergency; detailed and documented plans for notifying law enforcement agents, appropriate Federal, State, and local agencies, operators of water-related facilities, and those residents and owners of properties that could be endangered; actions that would be taken to reduce the inflow to the reservoir, if such is possible, by limiting the outflow from upstream dams or control structures; and actions to reduce downstream flows by controlling the outflow from dams located on tributaries to the stream on which the project is located. Licensee shall also submit a summary of the study used as a basis for determining the areas that may be affected by such emergency occurrence, including criteria and assumptions used. Licensee shall monitor any changes in upstream or downstream conditions which may influence possible flows or affect areas susceptible to damage, and shall promptly make and file with the Commission appropriate changes in such emergency action plan.

Article 28. The Licensee shall retain a Board of three or more qualified, independent engineering consultants to review the design, specifications, and construction of the project for safety and adequacy. The names and qualifications of the Board members shall be submitted to Chief, Bureau of Power, for approval. Among other things, the Board shall assess the geology of the project site and surroundings; the design, specifications and construction of the dikes, dam, powerhouse, electrical and mechanical equipment involved in water control, and emergency power supply; instrumentation; the filling schedule for the upper reservoir and plans for surveillance during the initial filling; the construction inspection program; and construction procedures and progress. The Licensee shall submit to the Commission copies of the Board's report on each meeting. Reports reviewing each portion of the project shall be submitted prior to or simultaneously with the submission of the corresponding Exhibit L final design drawings. The Licensee shall also submit a final report of the Board upon completion of the project. The final report shall contain a statement indicating the Board's satisfaction with the construction, safety, and adequacy of the project structures.

Article 29. The Licensee shall pay the United States the following annual charge, effective as of the first day of the month in which this license is issued:

(a) For the purpose of reimbursing the United States for the cost of administration of Part I of the Act, a reasonable annual charge as determined by the Commission in accordance with the provisions of its Regulations, in effect from time to time. The authorized installed capacity for such purposes is 1,333,000 horsepower.

Article 30. Pursuant to Section 10(d) of the Act, after the first 20 years of operation of the project under the license, the rate as computed below shall be the specified rate of return on the net investment in the project for determining surplus earnings of the project for the establishment and maintenance of amortization reserves. One-half of the project surplus earnings, if any, accumulated after the first 20 years of operation under the license, in excess of the specified rate of return per annum on the net investment, shall be set aside in a project amortization reserve account as of the end of each fiscal year: *Provided,* that, if and to the extent that there is a deficiency of project earnings below the specified rate of return per annum for any fiscal year or years after the first 20 years of operation under the license, the amount of any surplus earnings accumulated thereafter until absorbed, and one-half of the remaining surplus earnings, if any, thus cumulatively computed, shall be set aside in the project amortization reserve account; and the amounts thus established in the project amortization reserve account shall be maintained until further order of the Commission.

The annual specified reasonable rate of return shall be the sum of the weighted cost components of long-term debt, preferred stock, and the cost of common equity, as defined herein. The weighted cost component for each element of the reasonable rate of return is the product of its capital ratios and cost rate. The current capital ratios for each of the above elements of the rate of return shall be calculated annually based on an average of 13 monthly balances of amounts properly includable in the Licensee's long-term debt and proprietary capital accounts as listed in the Commission's Uniform System of Accounts. The cost rates for such ratios shall be the weighted average cost of long-term debt and preferred stock for the year, and the cost of common equity shall be the interest rate on 10-year government bonds (reported as the Treasury Department's 10-year constant maturity series) computed on the monthly average for the year in question plus four percentage points (400 basis points).

Article 31. The Licensee shall, within two years from the date of this order, file for Commission approval an amendment to Exhibit R which shall include:

(a) Maps, drawings, and related data on the 31-mile central segment of the Foothills Trails to be developed by the Applicant, to indicate: (1) the specific locations of the proposed trail route and public shelters; (2) detailed plans for parking at highway access points; (3) provisions for hikers to cross streams along the trail; (4) evidence of consultation with the U.S. Forest Service of the Department of Agriculture, and the South Carolina Department of Parks, Recreation and Tourism in determining the route of Applicant's segment of the Foothills Trails; and

(b) A management plan for the Applicant's proposed trail segment and related facilities, including programs for solid waste disposal, annual clearing of the trail route, periodic trash removal, and placement of appropriate signs and other markers along the Applicant's trail and at major access points.

(c) Licensee shall, during the term of the license, consult and cooperate with the appropriate Federal, State, and local agencies in developing and maintaining a hiking trail; and *Provided, further,* that, should it be necessary and in the public interest to relocate or permanently close a significant segment of the trail, Licensee shall advise the Commission of the location of the affected area, and the reasons for taking such action.

Article 32. Licensee shall, within one year from the date of issuance of the license, file a revised Exhibit S for Commission approval, prepared pursuant to Section 4.41 of the Commission's Rules and Regulations. In addition to the information contained in the Exhibit S filed with the Commission as part of the license application for Project No. 2740, the revised Exhibit S shall include the following:

(a) A detailed wildlife mitigation plan, as appropriate, to avoid or to mitigate adverse impacts on wildlife, including an implementation schedule and a description of locations and acreages of lands to be managed for wildlife. Licensee shall also include a map of the project area showing those areas that will be revegetated for wildlife purposes, and the vegetation selected for planting;

(b) An outline of the studies to be conducted to assess the effect of project operation; (1) on entrainment and any resultant mortality of fish; (2) on the coldwater fish habitat in Lake Jocassee; and (3) on trout migration, spawning, and rearing in impacted streams. These studies shall be initiated at the beginning of project operation and the results shall be filed with the Commission three years after commencement of project operation; and

(c) A detailed mitigation plan with proposed measures to be taken by the Licensee to mitigate the adverse impacts of project operations on Lake Jocassee and stream fisheries. Such plan shall include, but not be limited to, those measures agreed upon between the Licensee and South Carolina Wildlife and Marine Resources Department as set forth by Licensee in its letter dated January 10, 1977, to the Secretary, Federal Power Commission.

Article 33. The Licensee shall prepare a comprehensive plan to avoid or minimize damage to the environment and to protect and enhance the visual, cultural and related natural resource values of areas that would be affected by the proposed transmission facilities. The Licensee shall, not later than one year prior to beginning construction of the transmission facilities, file with the Commission its comprehensive plan which shall include, but not be limited to, detailed design, construction, and maintenance specifications of the proposed transmission facilities, specifications and information on access roads, major linear topographic features affected, tower types, conductors, visual design characteristics, coloring and texture, average number of structures per mile over the entire length, or as appropriate, and schedules, cost estimates, and other pertinent data as needed. The plan shall show how the existing rights-of-way are to be utilized, shall include such data as widths, lengths, and acreages, and information on possible future use of the rights-of-way for additional transmission facilities. The plan shall consider Commission Order No. 414, issued November 27, 1970 (44 FPC 1491, 35 F.R. 18585), other recognized engineering and landscape design methods, and shall be prepared after consultation and in cooperation with the South Carolina State Land Resources Commission, and any other appropriate Federal, State, or local agencies having an interest in the proposed action. The Commission reserves the right, after notice and the opportunity for hearing, to prescribe any changes in the plan as the public interest may warrant.

Article 34. For the purpose of assessing the impact of construction and operation on water quality and the aquatic environment, the Licensee shall, in cooperation with the South Carolina Wildlife and Marine Resources Department, the South Carolina Department of Health and Environmental Control, and the Fish and Wildlife Service of the U.S. Department of the Interior:

(a) Continue its pre-construction water quality studies in the Howard Creek basin and the monitoring in Lake Jocassee until the project becomes operational. Samples shall be taken on a monthly basis and shall include, but not be limited to, measurements of dissolved oxygen, temperature, pH, specific conductance, turbidity (or suspended solids), inorganic and total phosphorus and nitrogen, total hardness, alkalinity, total and fecal coliforms, BOD, and streamflow;

(b) Conduct a post-operational water quality monitoring study in Howard Creek basin and Lake Jocassee for a period of five years from the commencement date of project operation using the same sampling frequency and parameters as stated in (a) above; and

(c) File with the Commission annual study reports and, within one year following conclusion of the overall study, file a final report containing the results and conclusions, together with recommendations for any further studies or proposed changes in the operation of the project deemed necessary to protect and enhance the aquatic environment and related resources.

The Commission reserves the right, after notice and opportunity for hearing, to require additional studies and require such reasonable changes in the project and its operation as may be found necessary or appropriate to maintain or improve the aquatic environment.

Article 35. Licensee shall consult and cooperate with the U.S. Environmental Protection Agency, local and county health departments, and the South Carolina Department of Health and Environmental Control in complying with Federal, State and local regulations in the construction, operation, and maintenance of sanitary facilities used during construction of the project facilities, and for sanitary waste disposal during operation.

Article 36. The Licensee shall, to the satisfaction of the Commission's authorized representative, install and operate signs, lights, sirens, or other devices at the project outlet structure in Lake Jocassee to warn the public of significant fluctuations in flows from the project.

Article 37. Licensee shall consult with the South Carolina Department of Health and Environmental Control, and local and county health departments, and provide for measures to control vectors at the project.

Article 38. Licensee, in coordination with the South Carolina Wildlife and Marine Resources Department and the U.S. Fish and Wildlife Service of the Department of the Interior, shall arrange for a preconstruction survey of endangered and threatened plant and animal species in areas to be disturbed and not previously surveyed. If endangered or threatened species are found, the Licensee shall implement appropriate measures to protect the associated habitat and the individual specimens. A proposal of any protective measures to be undertaken shall be filed with the Commission 30 days prior to any disturbances in areas not previously surveyed.

Article 39. Licensee, in cooperation and consultation with the South Carolina Wildlife and Marine Resources Department and the U.S. Fish and Wildlife Service of the Department of the Interior, shall: assess the desirability and feasibility of: (a) providing storm-flow augmentation through the stream diversion structure in the Bad Creek Dam to facilitate sediment removal in Howard Creek following construction; (b) providing flow to Howard Creek from the Bad Creek augmentation system, and determine the minimum flows to be maintained through use of the augmentation system in the Bad Creek Dam. This analysis shall include such seepage as may occur through project dams. Licensee shall file, within one year after the project becomes operational, the results of these evaluations, proposals, and schedules for the implementation of flow augmentation to Howard Creek.

Article 40. The Licensee shall consult and cooperate with appropriate Federal, State, and local agencies, including the South Carolina State Highway Department, in determining construction procedures and final realignment of a 0.4-mile section of Highway S–171, in the construction of transmission lines where they cross state roads and highways, and in the construction of access road(s) that connect to Highway S–171. Efforts shall be made to protect visual resources and to minimize erosion and the deposition of silt into Howard Creek from the construction of roads.

Article 41. The Licensee shall conduct, or cause to be conducted, archeological surveys along the transmission line corridor. The report of these archeological surveys shall be filed with the Commission and the State Historic Preservation Officer. If archeological sites are discovered, they shall be evaluated for possible inclusion in the National Register of Historic Places prior to selecting the final location of project facilities. All reasonable efforts shall be made to avoid impacting significant sites, but where this is impossible such sites shall be salvaged after consultation with the State Historic Preservation Officer, and the Atlanta Regional Office of the National Park Service's Interagency Archeological Services Division.

Article 42. The Licensee shall file within two years of the date of issuance of this license a revised Exhibit F and, for Commission approval, revised Exhibits J, K, and M to reflect the transmission facilities found to be primary transmission facilities by this order as a part of the licensed project works under this license. The project boundary on Exhibit K shall be drawn to include within the project boundary both the 100-kV Jocassee-Bad Creek transmission line right-of-way and the 525-kV Oconee-Bad Creek transmission line right-of-way.

Article 43. The Licensee shall enter into a reservoir filling agreement with the authorized representative of the Chief of Engineers, Department of the Army prior to initial filling of the reservoir to insure either sufficient releases to the downstream Federal Hartwell and Clark Hill projects consistent with the portion of the watershed affected by Project No. 2740 or take other acceptable measures to assure the firm power capacity of the Hartwell and Clark Hill projects which would have been available in the absence of Project No. 2740. A copy of the agreement shall be filed with the Commission. If agreement cannot be reached within six months prior to the proposed initiation of filling of the reservoir, the Commission will prescribe the reservoir filling schedule, after notice and opportunity for hearing and upon a finding based on substantial evidence that such schedule is necessary and desirable and consistent with the provisions of the Act.

Article 44. The Licensee shall consult with the authorized representative of the Chief of Engineers, Department of the Army, for the purpose of determining whether the operating agreement reached under the auspices of Article No. 32 of the FPC license for Keowee-Toxaway Project No. 2503 requires modification as a result of construction of Bad Creek Pumped Storage Project No. 2740. If such a modification to the agreement is required, a copy of the agreement shall be filed with the Commission. If agreement cannot be reached within six months prior to the proposed date of operation of the project, the Commission will prescribe the method of operation, after notice and opportunity for hearing and upon a finding based on substantial evidence that such method is necessary and desirable and consistent with the provisions of the Act.

Article 45. Licensee shall, prior to the start of construction, supplement its erosion and sediment pollution control plan which was submitted to the Commission by letter dated August 21, 1976. The supplement to the plan shall be prepared after consultation and in cooperation with the South Carolina Department of Health and Environmental Control, State Land Resources Commission, and any other appropriate Federal, State and local agencies; shall include the suspended solids limit to be maintained for effluent from proposed settlement traps and sediment control structures emptying into Howard Creek and other waters in the project area; shall include all erosion and sediment control measures described in the application, but not included in the previously filed plan; shall include a schedule and description of methods by which the entire plan will be implemented and supervised to ensure adequate and continual protection of the environment; and shall include any other plans, proposals, and recommendations for protecting the aquatic environment.

Article 46. The Licensee shall operate the project reservoir during flood periods so as not to cause peak discharges downstream greater than those which would have occurred in the absence of Project No. 2740.

Article 47. The Licensee shall furnish the authorized representative of the Chief of Engineers, Department of the Army such information on the operation of the Bad Creek Project as he may need for forecasting flows downstream from the project.

Article 48. Licensee is authorized to use the reservoir of Project No. 2503 in the operation of Project No. 2740 and shall coordinate the operation of the project with that of Project No. 2503.

Article 49. In the event that the ownership or control of Project No. 2503 and Project No. 2740 becomes vested in different entities, either through transfer of license, surrender of license, issuance of license to another Licensee, Federal takeover, or any other reason, the separate owners or Licensees of the projects shall negotiate an agreement to be submitted to the Commission for its approval, providing for compensation, if any, to be paid by the Licensee or owner of Project No. 2740 to the Licensee or owner of Project No. 2503, for the former's use of Jocassee reservoir. If such an agreement cannot be reached, the Commission reserves the right to establish such compensation, after notice and opportunity for hearing.

(E) The license for the Keowee-Toxaway Project (FPC Project No. 2503) is hereby amended by the addition of Article Nos. 47 and 48 thereto, to be identical to Article Nos. 48 and 49 of the license for Project No. 2740.

(F) This order shall become final 30 days from the date of its issuance unless application for rehearing shall be filed as provided in Section 313(a) of the Act, and failure to file such an application shall constitute acceptance of this license and license amendment. In acknowledgment of the acceptance of this license and license amendment it shall be signed for the Licensee and returned to the Commission within 60 days from the date of issuance of this order.

MOTION TO REOPEN RECORD (DENIED)

Before Commissioners: Richard L. Dunham, Chairman; Don S. Smith and John H. Holloman III.

EL PASO NATURAL GAS COMPANY, DOCKET NO. CP75-362

ORDER DENYING PETITION TO REOPEN PROCEEDING AND DEFER FINAL DECISION

(Issued August 1, 1977)

On July 15, 1977, the People of the State of California and the Public Utilities Commission of the State of California (CPUC), pursuant to Section 1.33(c) of the Commission's Rules of Practice and Procedure, filed a petition requesting the Commission to reopen the above-referenced proceeding. In addition, CPUC also requested that the final decision in this proceeding be deferred.

El Paso Natural Gas Company (El Paso) filed an application on June 11, 1975, for permission to abandon certain mainline transmission pipeline, compression and right-of way tap facilities. These facilities would then be converted to the transmission of crude oil.

On May 23, 1977, the Law Judge issued a partial decision in this proceeding dealing with non-environmental issues. On May 26, 1977, the Commission ordered expedited procedures on the environmental issues with hearings

DUKE POWER COMPANY

P. O. BOX 2178

GENERAL OFFICES

422 SOUTH CHURCH STREET

CHARLOTTE, N. C. 28242

TELEPHONE: AREA 704
373-4011

February 28, 1978

Office of Electric Power Regulation
Federal Energy Regulatory Commission
Room 9310
825 North Capital Street, NE
Washington, D.C. 20426

Gentlemen:

Re: Bad Creek Pumped Storage Project
FERC (FPC) Project 2740
File No. BK-1410.02

In accordance with Articles 32, 33, 34, 38, and 39 of Bad Creek License 2740, we are enclosing fifteen copies each of the following:

1. Article 32
   Information on Wildlife and Fisheries Mitigation for review prior to submitting revised Exhibit S in August, 1978.

2. Article 33
   Comprehensive Construction Plan for Transmission Facilities

3. Article 34
   Water Quality Study Plan

4. Article 38
   Pre-construction survey of endangered and threatened plant and animal species

5. Article 39
   Stream flow augmentation analysis

Articles 32, 34, 38, and 39 have been reviewed by appropriate Federal and State Agencies. Letters of approval from the agencies are enclosed.

Reports required in Articles 32b, 34c, 38, and 39 will be submitted at the appropriate time.

L. C. Dail, Chief Engineer
Civil-Environmental Division

S B Hager

By: S. B. Hager
Principal Engineer

SBH/dhl

Enclosures

cc W. L. Porter without enclosures

DUKE POWER COMPANY
BAD CREEK PROJECT
OCONEE COUNTY, SOUTH CAROLINA
FEB 28 1978

Outline of Plans for Environmental Mitigation and Monitoring
(FPC License Articles 32, 34, 38, 39)

Table of Contents

FPC LICENSE ARTICLE 32

1.0 Wildlife Mitigation

Duke will revegetate approximately half the land that will be disturbed during construction of the Bad Creek Project. Approximately 495 acres of the revegetated land will represent openings in early stages of secondary succession within a dense expansive woodland. The creation of such openings is a standard wildlife management technique for increasing the habitat-carrying capacity for upland game. Thus the revegetated areas will serve as mitigation for the permanently disturbed areas.

Revegetated lands will consist of approximately 420 acres of transmission corridor and 75 acres of construction yard. An additional 65 acres will be revegetated around the reservoir, if it is cleared during earthwork operations

The transmission corridor will be revegetated and maintained with low-growing species including grasses and Lespedeza sp. (Reference: Comprehensive Construction Plan for Transmission Facilities, Sec. 3.2.3).

Revegetation species for the construction yard and reservoir area have not been determined at this time, but will be selected in consultation with the South Carolina Wildlife and Marine Resources Department and the South Carolina Land Resources Conservation Commission and planted when use of these areas is complete.

2.0 Studies of the Effects of Operations on Fishes and Their Habitat

2.1 Studies of Entrainment and Resultant Mortality - The "state of the art" for doing such studies at pumped storage facilities is still in the early development stage. Therefore, it is not feasible to provide a detailed outline at this time. However, we will continue to examine the methodology available and will implement a program to determine if large numbers of fish are being affected. Duke will consult with the South Carolina Wildlife and Marine Resources Department regarding plans for this work.

2.2 Studies of Coldwater Fish Habitat in Lake Jocassee - To determine any changes in coldwater fish (trout) habitat in Lake Jocassee, we will monitor the vertical profiles of water temperature and dissolved oxygen during the first three years of project operations. Data will be collected monthly at stations generally similar to those used in the preconstruction period.

2.3 Studies of Trout Migration, Spawning, and Rearing in Impacted Streams - Duke will monitor the trout population in those portions of the Howard Creek drainage that may be impacted during the construction of the Bad Creek Project. These studies will involve the native population and the Lake Jocassee trout that migrate into the lower part of the drainage during winter. Sampling stations will be located above and below the project area. Data analysis will include population density, size frequency distribution, and the growth rate of first-year trout. Following construction, Duke will consult with the South Carolina Wildlife and Marine Resources Department regarding the need for additional studies of these populations.

3.0 Fisheries Mitigation

3.1 Land Usage - Duke will restrict its usage of a tract of land along the Whitewater River for the duration of the construction period plus an additional two years. The terms of restrictions are contained in an Agreement signed by Duke, Crescent Land and Timber Corporation, and the South Carolina Wildlife and Marine Resources Department.

3.2 Erosion Control - Duke will implement and maintain a detailed erosion control program during project construction. (Reference: Article 45).

3.3 Howard Creek Monitoring - Duke will monitor Howard Creek during project construction and the early operation period in consultation with the South Carolina Wildlife and Marine Resources Department and the South Carolina Department of Health and Environmental Control. Monitoring will include studies on water quality, sediment accumulation, benthos, and fishes. Sampling stations will be located above and below the project area. Data obtained will include:

Water Quality: Parameters studied will be:

A. temperature, dissolved oxygen, pH, specific conductance, alkalinity, total suspended solids, turbidity, flow rate, BOD, fecal coliforms.

B. ammonia, nitrate-nitrite, orthophosphate, total phosphorus.

Sampling Frequency:

Beginning a minimum of one year prior to construction, and continuing through the construction period, the parameters under A above will be sampled monthly and those under B above will be sampled quarterly.

Following construction the data will be analyzed and a appropriate water quality monitoring program will be designed, as necessary, in consultation with the South Carolina Department of Health and Environmental Control and the South

Carolina Wildlife and Marine Resources Department.

Sediment Accumulation:

Duke will establish permanent monitoring stations above and below the project area to determine major changes in sediment accumulation in Howard Creek.

Benthos: Samples will be take quarterly or semiannually (to be determined by consultation with the South Carolina Wildlife and Marine Resources Department). Organisms will be identified to phylum, class, order, or family, depending on the taxa. Data analysis will include the number of individuals/m^2 and the biomass/m^2.

Trout: See Item 2.3.

3.4 Flow Augumentation - Duke will provide storm flow and base flow augumentation systems for Howard Creek, and will use these systems on the advice of the South Carolina Wildlife and Marine Resources Department.

3.5 Stocking - Duke will provide for the stocking of trout in Howard Creek during the construction period.

FPC LICENSE ARTICLE 34

1.0 Water Quality Studies - Construction Operation Phases

1.1 HOWARD CREEK

1.1.1 Sampling stations will be located above and below the project area. The initial location of these stations, and any recommended changes during the study will be determined in consultation with the South Carolina Department of Health and Environmental Control and the South Carolina Wildlife and Marine Resources Department.

1.1.2 Parameters will include:

A		B
temperature	alkalinity	ammonia
dissolved oxygen	total suspended solids	nitrate-nitrite
pH	turbidity	orthophosphate
specific conductance	flow rate	total phosphorus
BOD	fecal coliforms	

1.1.3 Sampling Frequency:

1. Beginning a minimum of one year prior to construction, and continuing through the construction period, the parameters under column A above will be sampled monthly, and those in column B will be sampled quarterly.

2. Following construction, the data will be analyzed, and an appropriate water quality program will be designed in consultation with the South Carolina Department of Health and Environmental Control and the South Carolina Wildlife and Marine Resources Department.

2.1 LAKE JOCASSEE

2.1.1 Sampling Stations: Approximately 8 sampling stations, located in strategic areas, will be utilized. The initial location of these stations, and any recommended changes during the study, will be determined in consultation with the South Carolina Department of Health and Environmental Control and the South Carolina Wildlife and Marine Resources Department.

2.1.2 *Parameters will include:*

In-situ: Vertical profiles at sufficient depths to characterize the water column for temperature, dissolved oxygen, pH, and specific conductance.

2.1.3 Lab Analysis: Samples taken at 10 m intervals to 40 m, then at 60 m and 80 m, and analyzed for alkalinity, ammonia, calcium, magnesium, nitrate-nitrite, orthophosphate, total phosphorus, turbidity.

BOD will be sampled at 0.5 m depth and fecal coliforms will be sampled at the surface.

2.1.4 Sampling Frequency:

1. Beginning one year prior to project construction, and continuing until one year prior to project operations, the above parameters will be sampled quarterly.
2. Beginning one year prior to operations, and continuing until three years after operations begin, the samples will be taken monthly.
3. Following the above period, the data will be analyzed and an appropriate water quality program will be implemented in consultation with the South Carolina Department of Health and Environmental Control and the South Carolina Wildlife and Marine Resources Department.

FPC LICENSE ARTICLE 38

1.0 Endangered Species

Duke has completed studies of the flora of the reservoir area and transmission corridor, and the fauna of the reservoir area. The results of this work have been reviewed by the South Carolina Wildlife and Marine Resources Department and the U.S. Fish and Wildlife Service. Duke is presently completing a survey to determine if any endangered or threatened animals occur in the transmission corridor. This report is a part of the Comprehensive Construction Plan for the Bad Creek Pumped Storage Transmission Facilities. Reference Article 33.

FPC LICENSE ARTICLE 39

1.0 Flow Augumentation Analysis

1.1 Storm Flow Augumentation - Duke will make provisions for releasing storm size flows to flush possible sediment accumulations in Howard Creek following construction of the project. Duke will consult with the South Carolina Wildlife and Marine Resources Department on the desirability of providing storm flow augumentation.

1.2 Base Flow Augumentation - Duke will construct a base flow augumentation system as described in the License Application. During the first year of operation Duke will consult with the South Carolina Wildlife and Marine Resources Department regarding the desirability of using the system.

South Carolina
Wildlife & Marine
Resources Department

James A. Timmerman, Jr., Ph.D.
Executive Director

December 1, 1977

Mr. L. C. Dail
Chief Engineer, Civil-Environmental Division
Duke Power Company
Post Office Box 2178
Charlotte, North Carolina 28242

RE: Bad Creek Project
FPC License Requirements
File No. BK-1410.02

Dear Mr. Dail:

Personnel of this Department have reviewed the document which you submitted on November 18, concerning plans for environmental mitigation and monitoring to meet the requirements of the FPC license, articles 32, 34, 38, and 39. Based on this review, I concur that the plans are adequate to meet the provisions of the stated license articles.

The documents have been forwarded to the U.S. Fish & Wildlife Service for its review, and by carbon of this letter I am requesting that they respond directly to you.

It is my understanding that Mr. S. B. Hager should be our contact for soil erosion matters.

Please advise me if we can be of further assistance.

Sincerely,

James A. Timmerman, Jr.
Executive Director

JATjr/jlm

cc: Mr. Roger Banks, Field Supervisor
U.S. Fish & Wildlife Service
P.O. Box 12559
Charleston, S.C. 29412

P.O. Box 167 □ Dutch Plaza □ Building D □ Columbia, South Carolina 29202 □ Telephone: 803 - 758-6536

United States Department of the Interior

FISH AND WILDLIFE SERVICE
P.O. Box 12559
Charleston, South Carolina 29412

CAH

December 5, 1977

Mr. L.C. Dail
Chief Engineer
Duke Power Co.
Charlotte, N.C. 28242

Dear Mr. Dail:

This responds to your letter of November 18, 1977 requesting the South Carolina Wildlife and Marine Resources Department to obtain our comments on recent additions and changes to the environmental mitigation and monitoring plan for the Bad Creek Project in Oconee County, South Carolina. The U.S. Fish and Wildlife Service concurs with your proposed responses to articles 32, 34, 38, and 39 of the Bad Creek F.P.C. license. We recommend that Duke Power contact Dr. Harold Wahlquist, our Regional Activities Leader for Power Plant Siting, with regard to the methodology for studies of entrainment and resultant mortality of fishes and other organisms.

Sincerely yours,

Roger Banks
Field Supervisor

cc:

Dr. James A. Timmerman

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL

Albert G. Randall, M.D., M.P.H.
Commissioner

Sims Aycock Buildings
2600 Bull Street, Columbia, SC 29201

December 1, 1977

Mr. L. C. Dail, Chief Engineer
Civil-Environmental Division
Duke Power Company
P. O. Box 2178
Charlotte, N. C. 28242

Re: Water Quality Monitoring
Bad Creek Project
Oconee County

Dear Mr. Dail:

This office has reviewed your proposed water quality monitoring program for Howard Creek and Lake Jocassee. You may consider this letter as approval for the monitoring program described in your letter of November 21, 1977. This program will provide this Agency with a great deal of useful information.

Sincerely,

Charles R. Jeter, P.E., Chief
Bureau of Wastewater & Stream Quality Control

CRJ:JWP:bc

Document Content(s)

Duke Power Company
Legal Department
422 South Church Street
Charlotte, NC 28242-0001

(704) 382-8134
DUKE POWER

ORIGINAL

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OFFICE OF THE SECRETARY
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FEDERAL ENERGY
REGULATORY COMMISSION

(704)382-8137 Fax

STEVE C. GRIFFITH, JR.
ELLEN T. RUFF
W. EDWARD POE, JR.
WILLIAM LARRY PORTER
PETER C. BUCK
JOHN E. LANSCHE
WILLIAM J. BOWMAN, JR.
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MARY LYNNE GRIGG
SALLY G. Helweg
LEISL N. MUST

December 6, 1996

Ms. Lois D. Cashell
Secretary
Federal Energy Regulatory Commission
Dockets Room, Room 1A
888 First Street, N.E.
Washington, DC 20426

038

RE: Project No. 2740 - South Carolina
Bad Creek Pumped Storage Project
License Article 32(b)(1) (Fish Entrainment)
Duke Power Company

Dear Secretary Cashell:

Enclosed for filing with the Commission for its approval are an original and eight copies of a Memorandum of Understanding ("MOU") and Ten Year Work Plan ("Plan") between Duke Power Company ("Duke") and the South Carolina Department of Natural Resources ("SCDNR") concerning the Keowee-Toxaway area fishery resources. This MOU and Plan were prepared to fulfill the requirements of Article 32(b)(1) of the license for Project No. 2740 (Bad Creek Project). This article requires Duke to consult with the SCDNR and the United States Fish and Wildlife Service ("USFWS") concerning fish entrainment losses and a comprehensive management plan for the fishery. By letter dated September 12, 1996 from J. Mark Robinson, Director, Division of Project Compliance and Administration, the Commission extended the filing date for the Plan until December 6, 1996 to complete agency consultation.

The MOU contains the parties' agreement that there is a need to continue their cooperative efforts to maintain and enhance the high quality fishery resources in these reservoirs and their tributaries in light of the increased pressure placed upon these fisheries by angling and other factors. The Plan sets forth specific studies, habitat protection/enhancement measures, and other activities which will be conducted and which are considered important to the long-term effective management of the Keowee-Toxaway fishery resources. The Plan includes activities which have been ongoing for years and new

sub PER
S. Edmondson (OHL)

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activities which are expected to provide new types of information that will help sustain these fisheries.

In a letter dated December 2, 1996 (copy attached), the USFWS indicated its concurrence, in general, with the Plan and recommended three modifications to the Plan. The first two recommendations are to add language that includes the USFWS in consultation for the specified events. The third recommendation is the examination of maintaining streamside buffer zones with more stringent controls than the current state forestry best management practices. Duke agrees to incorporate all three of the USFWS' recommendations into the Plan.

Also attached are the following letters: (1) Dr. James A. Timmerman, Jr., SCDNR, to Mr. Jim Hendricks, Duke Power Company, dated December 3, 1996: and (2) Mr. Jim Hendricks, Duke Power Company, to Dr. James A. Timmerman, SCDNR, dated November 19, 1996. These letters indicate SCDNR's and Duke's agreement with the MOU and the Plan and recognition of their partnering effort to manage the fishery resources of Keowee-Toxaway.

Both the MOU and Plan refer to proposed upgrades of the Jocassee units. Duke is not planning to perform any upgrades at Jocassee at this time. However, should those plans change, the MOU and Plan will govern that activity.

Please contact the undersigned if you have any questions concerning this filing.

Sincerely,

Karol P. Mack (SJR)

Karol P. Mack
Assistant General Counsel

KPM/sjr
Enclosure
CC: Ed Bruce

United States Fish and Wildlife Service
South Carolina Department of Natural Resources

Duke Power Company
Electric System Support
[illegible]
13339 Hagers Ferry Road
Huntersville, NC 28078

[illegible]
General Manager
Environmental Division
(704) 875-5928
(704) 875-5038 Fax

DUKE POWER

November 19, 1996

Dr. James A. Timmerman, Jr., Director
S. C. Dept. Natural Resources
P. O. Box 167
Columbia, S. C. 29202

SUBJECT: BAD CREEK PROJECT
FERC LICENSE ARTICLE 32B(1) - FISH ENTRAINMENT
FILE NOS: BK-1444.00, BK-1410.02

Dear Dr. Timmerman:

Enclosed for your review and signature are copies of the "*Memorandum of Understanding: Keowee-Toxaway Fisheries Resources*", and its attached "Ten-Year Work Plan: January 1996 - December 2005". In addition to providing mitigation for fish losses associated with pumped-storage operations, this plan will also provide for continued management of the important and unique fisheries in this area. We are glad to be entering this agreement with SCDNR, and look forward to working cooperatively with your staff on the work plan activities M. D. McIntosh has signed for Duke Power. I would like to ask for your signature and then return the document to me. I will then sign it and provide copies to FERC, your office, and to the Charleston office of USFWS.

Please call me (704-875-5928) or John Garton (704-875-5932) if you have any questions.

Sincerely,

Jim Hendricks

JRH/am

Enclosures

cc: R. E. Duncan (SCDNR-Charleston)
J. S. Garton (Duke)

United States Department of the Interior

FISH AND WILDLIFE SERVICE
P.O. Box 12559
217 Fort Johnson Road
Charleston, South Carolina 29422-2559

December 2, 1996

Mr. J. S. Garton
Senior Scientist
Environmental Division
Duke Power Company
13339 Hagers Ferry Road
Huntersville, NC 28078-7929

Re: Bad Creek Project, FERC #2740, License Article 32B(1), Mitigation for Entrainment and Mortality of Fish

Dear Mr. Garton:

The U.S. Fish and Wildlife Service (Service) has reviewed the Keowee-Toxaway Fishery Resources Ten Year Work Plan prepared by Duke Power Company (DPC) and the South Carolina Department of Natural Resources (SCDNR). We have also reviewed the associated Memorandum of Understanding between DPC and SCDNR on Keowee-Toxaway Fishery Resources. It is our understanding that DPC intends on submitting these documents to the FERC in fulfillment of License Article 32B(1) of the Bad Creek License.

In general, The Service concurs with the Ten Year Plan and the adequacy of its work elements to satisfy entrainment and mortality mitigation requirements. We do recommend the following modifications to the Ten Year Plan.

Page 3. Agreement on Fish Entrainment at Jocassee Pumped Storage Station. The last bullet should be modified to read:

> Following unit upgrades, if any significant changes are observed in fish entrainment, Duke will consult with SCDNR ***and the U.S. Fish and Wildlife Service*** to determine if any additional measures should be initiated.

Page 4. Agreement on Minimizing Fish Entrainment via Bad Creek Pumped Storage Project. The second sentence of the last bullet should be modified to read:

> If the pool elevation is projected to remain below 335 m (1099 ft) MSL for a total of 60 consecutive days, Duke will initiate consultation with the SCDNR ***and the U.S. Fish and Wildlife Service*** to determine if further monitoring of entrainment impacts and/or measures to minimize these impacts are appropriate.

Page 17. Erosion Control Work. The first bullet should be modified to read:

> Duke and Crescent Resources, Inc. will develop a team to review erosion control needs in pertinent areas related to forestry work on DPC and CRI lands. ***Included in the review will be the examination of maintaining streamside buffer zones with more stringent controls than suggested in the current State forestry Best Management Practices.***

Provided the above modifications are incorporated into the Plan, the Service endorses the Plan as satisfying License Article 32B(1) requirements. We appreciate this opportunity to review and comment on the subject matter.

Sincerely yours,

Roger Banks

Roger L. Banks
Field Supervisor

RLB/SG

South Carolina Department of
Natural Resources

James A. Timmerman, Jr., Ph.D.
Director

December 3, 1996

Mr. Jim Hendricks
General Manager
Environmental Division
Duke Power Company
13339 Hagers Ferry Road
Huntersville, NC 28078

Dear Jim:

Please find enclosed signed copies of the "Memorandum of Understanding: Keowee-Toxaway Fisheries Resources" and the "Ten-Year Work Plan." It is with great pleasure that I return these executed documents.

The finalization of this cooperative agreement represents another major milestone in the partnering effort between Duke and the DNR to conserve our precious natural resources. I want to thank you and your staff for your vision and support of this unique agreement to insure the maintenance and enhancement of the Keowee-Toxaway fishery resources for future generations.

Sincerely,

James A. Timmerman, Jr.
Director

JATjr:rms
Enclosure
CC: Mr. Roger Banks
Mr. Ed Duncan
Mr. Brock Conrad
Mr. Val Nash

Rembert C. Dennis Building • 1000 Assembly St • P.O. Box 167 • Columbia, S.C. 29202 • Telephone: 803/734-4007

Memorandum of Understanding

Keowee-Toxaway Fishery Resources

South Carolina Department of Natural Resources
Duke Power Company

Since the filling of Lakes Keowee and Jocassee in the early 1970s, the South Carolina Department of Natural Resources (SCDNR) and Duke Power Company (DPC) have worked cooperatively on many items related to the fisheries of these reservoirs and their tributaries. While much of this work has been associated with license requirements, it has helped the SCDNR in their efforts to develop the high quality and diverse fisheries now present in these waterbodies.

Today many of DPC's license required efforts are being completed, while at the same time angling and other factors are exerting increased pressures on these fisheries. With these increased pressures there is a need to maintain and/or expand management activities to enhance the quality of the fisheries. Because both SCDNR and DPC have as an objective the existence of high quality fisheries in these reservoirs and streams, both parties recognize that cooperative efforts should continue.

Therefore, it is agreed that:

1) DPC and SCDNR will continue to cooperate through a framework that will be based on joint planning and management efforts.
2) The planning and management efforts will be directed toward the objective of assisting SCDNR in the management of fisheries in Lakes Keowee and Jocassee, and in those tributaries flowing through lands owned by DPC, or its subsidiary Crescent Resources.
3) Planning and management activities will be based on ten year work plans jointly developed by SCDNR and DPC personnel. In addition to these written plans, routine communications will continue through working channels, and there will be an annual meeting to review the status of ongoing activities.

4) Cooperative activities under this Memorandum may include, but are not necessarily restricted to:

   a) research on fish populations
   b) water quality studies
   c) trout habitat studies in Lake Jocassee
   d) stream surveys
   e) creel surveys
   f) fish culture/stocking work
   g) fish and habitat management work
   h) development of bank fishing areas
   i) development of handicapped accessible facilities
   j) angler access areas along streams
   k) youth fishing events
   l) stream protection/enhancement work
   m) impact assessments

5) A log of major programs/activities conducted under this Memorandum will be kept to provide a record of the activities and their contribution to the objective.

6) This agreement is intended to provide full mitigation for known fish losses associated with the operation of the Bad Creek Pumped Storage Station, and for the anticipated fish losses associated with the present, and proposed upgraded operation status, of the Jocassee Pumped Storage Station.

7) This agreement is intended to remain in effect for the duration of the present Bad Creek FERC License period (through the year 2027). However, it can be amended at any time through the mutual consent of the parties.

Dr. J. A. Timmerman, Jr. Director SC Dept. Natural Resources	M. D. McIntosh Vice President Fossil/Hydro Generation	J. R. Hendricks General Manager Environmental Division Duke Power Company
12/2/96 Date	Nov-18, 1996 Date	12/4/96 Date

KEOWEE-TOXAWAY FISHERY RESOURCES

TEN YEAR WORK PLAN
JANUARY 1996 - DECEMBER 2005

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES
AND
DUKE POWER COMPANY

Dr. J. A. Timmerman, Jr. Director SC Dept. Natural Resources	M. D. McIntosh Vice President Fossil/Hydro Generation	J. R. Hendricks General Manager Environmental Division Duke Power Company
12/2/96 Date	Mar 18, 1996 Date	12/2/96 Date

KEOWEE-TOXAWAY FISHERIES RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

INTRODUCTION

The following studies, habitat protection/enhancements, and other activities are considered important to the long-term effective management of the Keowee-Toxaway Fishery Resources. Many of the activities (monitoring trout habitat, creel surveys) have been ongoing for years and have been the basis of establishing high quality and unique fisheries for the state of South Carolina. Other activities (telemetry and bass habitat studies) will provide new types of information that will help sustain these fisheries as they are subjected to increased angler pressure.

The studies and other activities in this plan will all be jointly planned by the SCDNR/DPC team that has worked cooperatively over the years on the Keowee-Toxaway fishery resources. This team will coordinate and carry out the needed activities, involve third parties as needed (i.e., Clemson University, others), plan activities, and schedule and carry out an annual review meeting on the status of activities.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Agreement on Fish Entrainment at Jocassee Pumped Storage Station

- The complete extent of fish entrainment at Jocassee is not currently documented. However, observations and experience at this project indicate that entrainment damages are not in excess of that which would be mitigated by this agreement. It is not anticipated that the proposed upgrade of Jocassee units will result in any significant change in fish entrainment.

- Duke and SCDNR will continue to cooperatively monitor the lake fishery at Jocassee and pumped storage operations.

- Following unit upgrades, if any significant changes are observed in fish entrainment, Duke will consult with SCDNR to determine if any additional measures should be initiated.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Agreement on Minimizing Fish Entrainment via Bad Creek Pumped Storage Project

- DPC and SCDNR have worked cooperatively on a three-year study to evaluate fish entrainment at the Bad Creek hydro. Results indicate that fish entrainment was relatively low when Lake Jocassee was near full pool [338.3 m (1110 ft) MSL]. However, entrainment of thread-fin shad and blue-back herring increased substantially on days when Lake Jocassee water surface elevations were below 334 m (1096 ft) MSL [4.3 m (14 ft) below full pool].

- During this ten-year plan period, Duke will operate its facilities so as to minimize, to the extent possible, the period during which Lake Jocassee pool elevation is below 335 m (1099 ft) MSL.

- If the pool elevation in Lake Jocassee falls below 335 m (1099 ft) MSL and is projected to remain below this level for 30 consecutive days, Duke will notify the SCDNR. If the pool elevation is projected to remain below 335 m (1099 ft) MSL for a total of 60 consecutive days, Duke will initiate consultation with the SCDNR to determine if further monitoring of entrainment impacts and/or measures to minimize these impacts are appropriate.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Cost Share Agreement for Stocking of Trout in Lake Jocassee

- Duke Power and SCDNR will equally cost share the providing of trout for stocking in Lake Jocassee. The total annual cost is $102,250. Thus, the annual cost to DPC will be $51,125 (plus any inflation adjusted annually based on the consumer price index), or the actual cost of their share of the fish, whichever is less.

- Ten-Year Plan: Trout are currently produced at the Walhalla State Hatchery for stocking in Lake Jocassee.

- Function: Help ensure trout are available for maintaining the quality, and high demand, fishery in Lake Jocassee.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Agreement on Maintaining Adequate Pelagic Trout Habitat in Lake Jocassee

- DPC and SCDNR have worked cooperatively since 1973 to obtain a continuous and systematic database on trout habitat in Lake Jocassee and the factors that influence its horizontal and vertical distribution. A detailed understanding of habitat factors, including the roles of pumped storage operations and winter stored oxygen, have been gained.

- During this 10-year plan period, Duke will continue to work actively and in cooperation with SCDNR to help ensure the presence of trout habitat in Lake Jocassee.

- Duke will continue to carry out appropriate field studies on the vertical and horizontal distribution of trout habitat in Lake Jocassee. Study details will be determined jointly with SCDNR.

- Based on field data, and the Jocassee model, Duke and SCDNR will work to protect trout habitat in Lake Jocassee. Activities will include:

  A) To help prevent operations from causing degradation, efforts will focus on precluding depletion of water cooler than 20° C (68° F) at elevations lower than 305 m (1000.7 ft) MSL (this is the lower level reached in past years). These efforts may include switching "Jocassee operations" to other available peaking facilities, when needed to meet the non-depletion goal.

  B) To help prevent an unusual DO depletion from causing degradation by resulting in too narrow a band of trout habitat, Duke will use the Jocassee model to help ensure a 10 m (32.8 ft) band of adequate habitat exists at all times. These efforts may include switching "Jocassee operations" to other available peaking facilities, when needed to meet the "minimum band" goal.

  C) The general goal of these efforts will therefore be to maintain, at a minimum, a layer of adequate trout habitat at least 10 m (32.8 ft) in thickness, and with its upper layer no lower than elevation 305 m (1000.7 ft) MSL. However, in no event will any operations occur if the habitat thickness decreases to 5 m (16.4 ft), unless mutually agreed by both parties.

- Ten-Year Plan: Data will be obtained routinely throughout the 10-year period through a jointly planned sampling program. The data, and any operational modifications, will be reviewed annually with the SCDNR Regional Office fisheries personnel.

- Function: This effort will provide an active and cooperative system that will help ensure that adequate habitat is maintained for this highly popular Lake Jocassee fishery.

Item: Jocassee Creel Survey

- Duke will provide funding up to $30,000/yr.

- SCDNR will administer and implement the study and data presentation.

- Ten-Year Plan: Survey is scheduled to be done annually throughout the period.

- Function:
  - ⇒ Provides vital information on fishing effort, catch and harvest of sportfish as well as socioeconomic data.

  - ⇒ This is the most important sampling tool available to monitor the sport fishery. The Jocassee fishery is impossible to manage effectively without this monitoring tool because most traditional fishery sampling tools (i.e., electrofishing) are not effective on Jocassee.

  - ⇒ Used to formulate stocking strategies, size and creel limits, and to monitor the impacts of commercial uses of the reservoir (i.e., power production) on the fishery.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Keowee Creel Survey

- Duke will provide funding up to $30,000/yr.
- SCDNR will administer.
- Clemson University fisheries scientists will implement and summarize data.
- Ten-Year Plan: This survey is scheduled for every third year, except it will occur for three consecutive years following installation of upgraded runners at the Jocassee Station.
- Function:
  - ⇒ Provides vital information on fishing effort, catch and harvest of sportfish as well as socioeconomic data.
  - ⇒ Will provide effective monitoring of the fishery to assure there are no major impacts immediately after a runner upgrade takes place, hence the three year annual creel following upgrade.
  - ⇒ Long term monitoring also needs to be conducted. Creel survey on every third year thereafter should be sufficient.

Item: Gill-Netting Studies (Jocassee)

- Duke will furnish the nets at a cost up to $1,200/yr.

- SCDNR will conduct the sampling.

- Ten-Year Plan: Sampling is scheduled annually throughout the period.

- Function:
  - ⇒ Provides the longest database on the Jocassee fishery. Gill net data has been collected since 1975 (prior to development of the creel survey or hydroacoustic technique).

  - ⇒ Provides vital "hands on" data on the trout fishery to assess trout stocking practices and population monitoring.

  - ⇒ Data on trout densities, species and strain performance, year class strength, growth, "carry-over," survival, etc. are collected. This data is used to formulate stocking and management decisions such as creel and size limits.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Jocassee Water Quality Monitoring for Trout Habitat

- Duke will provide funding and implement.

- Projections for late summer habitat will be reviewed with SCDNR Regional Office fisheries personnel in May, based on the Jocassee model. Actual late summer data will be reported by October of each year.

- Ten-Year Plan: Data will be obtained routinely over the study period.

- Function:
  - ⇒ Provides information on a critical element in the Jocassee coldwater fishery.
  - ⇒ Allows biologist to factor in the impacts of environmental and operational events into the management of the fishery.
  - ⇒ Lake Jocassee maintains a very low narrow band of coldwater habitat in late summer and this is the only way to assess the quantity of, and future maintenance of, this critical habitat.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Hydroacoustic Monitoring of Small Pelagic Fish (Jocassee, Keowee)

- Duke will provide funding and conduct this monitoring work.
- Ten-Year Plan: This monitoring is scheduled to occur annually (spring and fall) throughout the planning period.
- Function:
  - ⇒ This data allows effective monitoring of the status of shad populations in the reservoirs. Shad are the most important food source of trout and other game fish in Lake Jocassee and Lake Keowee.
  - ⇒ This is "cutting edge" technology that will be extremely important in the future as more traditional sampling procedures that require mortality of fish are more closely scrutinized by the public (i.e., cove rotenones).

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: <u>Telemetry Study of Trout</u> (Jocassee)

- Duke will provide funding for this study (up to $18,000) which will be conducted during 1997.

- SCDNR will administer the project.

- Clemson University fisheries personnel will conduct the study.

- <u>Ten-Year Plan</u>: During the remainder of this 10-year agreement, if there is a period of minimal trout habitat, a 1-year follow-up study may be necessary. Duke will provide funding (up to $18,000) if an additional 1-year study is deemed necessary by Duke and SCDNR.

- <u>Function</u>:
  - ⇒ Provide important back-up information, and "ground truth" data, for hydroacoustic plots of vertical distribution of trout in Lake Jocassee.
  - ⇒ Develop habitat criteria (Temp., D.O.) that is based on the fish and their ecology in this specific system.
  - ⇒ This study will also help validate and or calibrate hydroacoustic estimation techniques with which SCDNR and Duke Power have been experimenting.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Study of Black Bass Populations Electrofishing (Keowee, Jocassee)

- Duke will provide support (as in previous years) for electrofishing studies and collection of black bass for population analysis and age-and-growth studies.
- SCDNR will provide overall coordination of the work.
- Ten-Year Plan: These electrofishing efforts are scheduled to occur every third year during this planning period.
- Function:
  - ⇒ Black bass (largemouth, spotted, smallmouth bass) are the most sought after species in both lakes.
  - ⇒ Electrofishing and other sampling techniques allows the biologist to collect "hands on" data such as condition factors, health assessments, size structures, age and growth, etc.
  - ⇒ This sampling is necessary to make proper recommendations for creel and size limits for the long-term maintenance of the bass fishery given increasing public use.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Black Bass Habitat Study (Keowee)

- Duke will provide funding for this study up to $18,000/yr.
- SCDNR will administer the project.
- Clemson University fisheries personnel will conduct the study.
- Ten-Year Plan: This effort will be scheduled for a 3-year period during the planning period.
- Function: Provide important data for bass management in Lake Keowee. Black bass (largemouth and spotted bass) are the two most sought after gamefish in Lake Keowee. The recent development of the spotted bass fishery makes the obtaining of this data an important management need.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Stream Surveys

- Duke will assist SCDNR in their ongoing efforts to survey fish populations in tributaries of Lakes Jocassee and Keowee.
- SCDNR will coordinate the effort.
- Ten-Year Plan: One or more streams will be surveyed each year, as determined by SCDNR.
- Function: Maintain a database on headwater stream fish populations (such as Whitewater River), and document any impacts or management efforts that need attention.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Erosion Control Work

- Duke and Crescent Resources, Inc. will develop a team to review erosion control needs in pertinent road areas related to forestry work on DPC and CRI lands.
- Plans will be developed and implemented to take needed corrective erosion control actions in a timely manner.
- SCDNR will participate in this team effort.
- Ten-Year Plan: The review will begin in 1996.
- Function: Protec' 'enhance water quality and habitat factors in headwater trout streams at Keowee-Toxaway.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Lower Eastatoe Creek Management and Angler Access

- Duke will provide and maintain adequate access for the hatchery truck on DPC lands along Eastatoe.
- Duke will provide and maintain an angler parking area on its Eastatoe property, including needed signage, trails, etc.
- SCDNR will coordinate the overall plan.
- Ten-Year Plan: The access area will be developed in 1996 and maintained throughout the planning period.
- Function: Cooperatively provide access for anglers to a major SC stream, in a manner compatible with the resources.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

Item: Agreement to Prohibit Development Around Lake Jocassee

- Duke's Land Use Plan, in effect since 1983, prohibits development of company lands around Lake Jocassee.

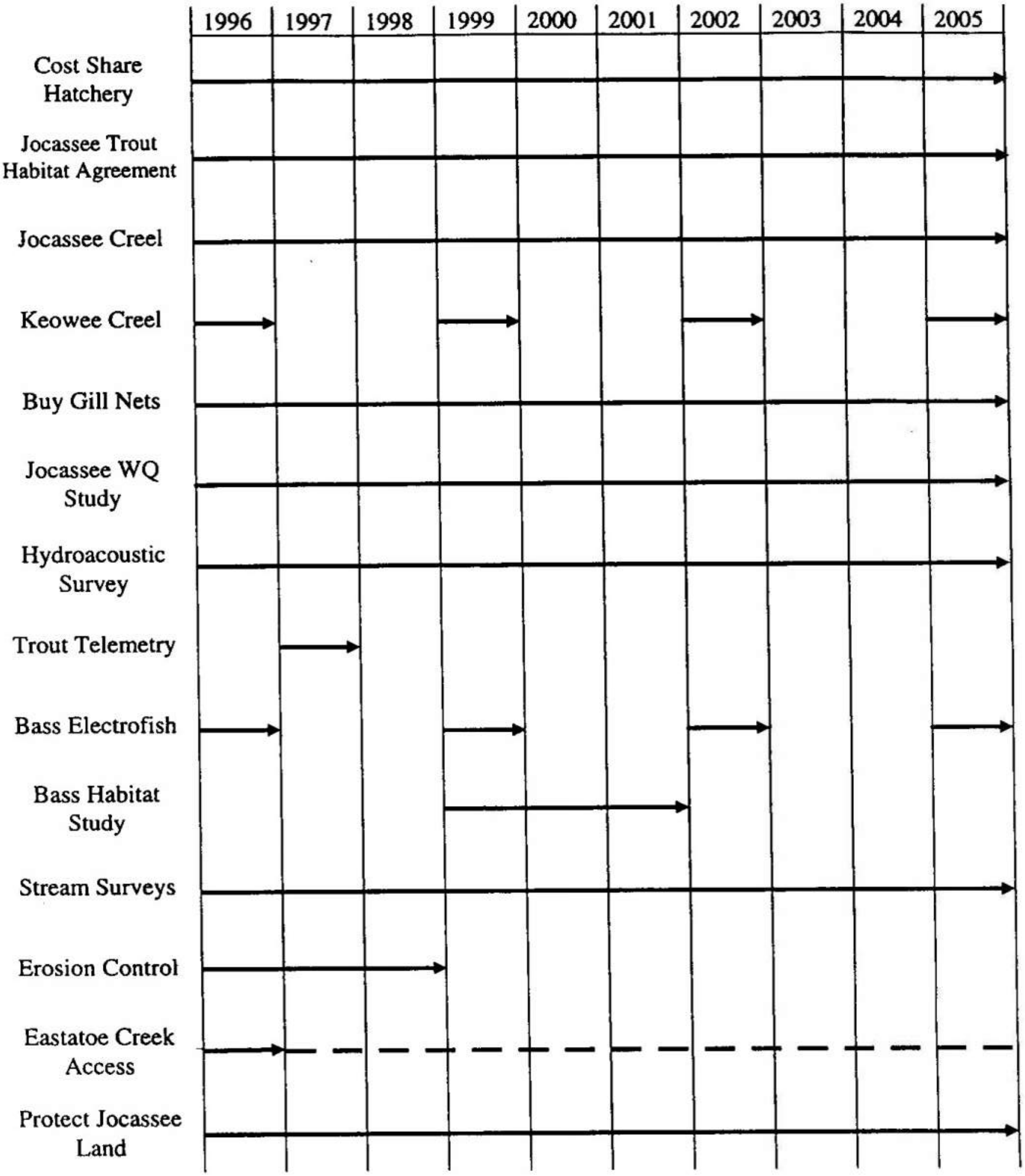
- Duke has reviewed this plan closely with the SCDNR and made the commitment that Duke will not change this "non-development" aspect of the Land Use Plan without SCDNR review.

- In recent years, and months, Duke has maintained (and is maintaining) a close dialogue with SCDNR on this subject, and will continue to do so.

- Ten-Year Plan: Duke will maintain close contact wit[illegible] [illegible]DNR on its Jocassee lands throughout the planning period.

- Function: To ensure protection of significant resources related to biodiversity, aesthetics, and water quality.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC



BAD CREEK PROJECT
SUMMARY OF FERC LICENSING ACTIVITIES

Article 32(b)(1): Fish Entrainment

Status: Required 3-yr study was completed and reviewed with SCDNR and USFWS. Upon their concurrence, it was filed with FERC October 27, 1994.

Commitments: Duke has agreed to further consultation with SCDNR and USFWS on several items contained in the final report. On November 9, 1995 we advised FERC on the status of these consultations and committed to provide them results by July 1, 1996.

Activities: Duke is working with SCDNR and USFWS to develop a comprehensive management plan for the Keowee-Toxaway fisheries.

Article 32(b)(2): Lake Jocassee Trout Habitat Study

Status: The required 15-yr summary report (which included 3 years of data taken after Bad Creek became operational) was completed and reviewed with SCDNR and USFWS. Upon their concurrence, it was Filed with FERC October 27, 1995. On December 5, 1995, Duke received a letter from FERC stating that the Article 32(b)(2) requirements had been fulfilled.

Commitments: Continue to monitor trout habitat for an additional 5 years in consultation with SCDNR and USFWS. Annual reports will be provided to SCDNR and USFWS and a 5-yr summary report will be prepared for FERC.

Activities: Coordinate with WJ Foris.

Article 32(b)(3): Howard Creek Trout Study

Status: Required 15-yr summary report was completed and reviewed with SCDNR and USFWS. Upon their concurrence, it was filed with FERC July 27, 1995. An order from FERC was received October 2, 1995 and they concurred that the Howard Creek trout population has fully recovered to pre-project levels.

Commitments: Agreement with SCDNR that Duke will gather additional data when needed and as determined in consultation with their regional fisheries biologist. Based on initial consultation, plans are to sample Howard Creek trout populations every three years and provide the data to the SCDNR regional office every three years. In the future, if it is felt that any station related impacts are occurring, they will be reviewed and a written record, including recommendations, will be provided to FERC. If this sampling program is altered, Duke will advise FERC and other appropriate agencies.

In FERC's order, they stated "additional monitoring of trout in Howard Creek to measure project related impacts is not warranted and therefore will not be required. This order constitutes final agency action."

Activities: Coordinate with DH Barwick.

Article 32(c): Howard Creek Macroinvertebrate Study

Status: Required 15-yr summary report was completed and is being reviewed by SCDNR and USFWS. Both SCDNR and USFWS have concurred with Duke's recommendations and a submittal was filed with FERC January 23, 1996. To date, a response letter from FERC has not been received.

Commitments: Concurrent with fisheries sampling (approximately every 3 years) a macroinvertebrate bioassessment will be done at stations 576.0 (control station H9) and 571.5 (most downstream impacted station H1). These data will be provided to SCDNR and USFWS regional offices.

Activities: Coordinate with TW Bowen.

Article 34: Howard Creek Water Quality Study

Status: Required 15-yr summary report was completed and reviewed with SCDNR, USFWS, and SCDHEC. Upon their concurrence, it was filed with FERC February 24, 1995. To date, a response letter from FERC has not been received.

Commitments: Duke will conduct twice yearly (i.e., once during the summer and once during the winter) monitoring of the seepage flows (W1, B1, and H7) for Total Alkalinity, Total Hardness, and Specific Conductance through the year 1997. Data will be reviewed with the consulting resource agencies as called for.

Activities: Coordinate with WJ Foris. Need to begin taking required samples starting winter 1996.

Article 34: Lake Jocassee Water Quality Study

Status: Required 15-yr summary report was completed and reviewed with SCDNR, USFWS, and SCDHEC. Upon their concurrence, the report was filed with FERC July 27, 1995. An order was received from FERC on September 26, 1995 that confirmed the project is having no discernible negative impact on Lake Jocassee Water Quality.

Commitments: Duke will conduct quarterly monitoring of temperature and DO profiles for a period of 5 years. Annual data reports will be provided to SCDNR, USFWS, and SCDHEC. In addition, a 5-yr summary will be provided along with conclusions and recommendations to FERC.

Activities: Coordinate with WJ Foris.

Article 39(a): Stormflow Augmentation in Howard Creek

Status: Required study was completed and reviewed with SCDNR and USFWS. Upon their concurrence, it was filed with FERC May 27, 1994. On February 14, 1995, Duke received an order from FERC approving our recommendations for Article 39(a).

Commitments: None

Activities: None

Article 39(b): Baseflow Augmentation in Howard Creek

Status: Required study was completed and reviewed with SCDNR and USFWS. Upon their concurrence, it was filed with FERC on June 9, 1995. After some follow up questions from FERC were addressed, they agreed (July 20, 1995) with the conclusions and recommendations contained in June 9, 1995 submittal.

Commitments: Duke will monitor dam seepage flowrates into Howard Creek and will notify USFWS and SCDNR anytime the combined seepage flows of Bad and West Bad Creeks drop below 2.0 cfs or exceed 3.5 cfs for two consecutive biweekly flume recordings. It was also agreed that there are no current plans to use the baseflow augmentation system.

Activities: Coordinate with Alan Nicholson at Bad Creek. A process needs to be developed that will ensure biweekly flume recordings are taken, recorded, and properly reported.

KEOWEE-TOXAWAY FISHERY RESOURCES
TEN-YEAR WORK PLAN (JANUARY 1996 - DECEMBER 2005)
SCDNR/DPC

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cost Share Hatchery	$0	$51,125	$51,125	$51,125	$51,125	$51,125	$51,125	$51,125	$51,125	$51,125
Jocassee Trout Habitat Agreement	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Jocassee Creel Survey	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000
Keowee Creel Survey	$30,000			$30,000			$30,000			$30,000
Buy Gill Nets	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200
Jocassee WQ Study for Trout Habitat	$25,920	$25,920	$25,920	$25,920	$25,920	$25,920	$25,920	$25,920	$25,920	$25,920
Hydroacoustic Survey (Jocassee & Keowee)	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000
Jocassee Trout Telemetry		$49,500 R&D								
Black Bass Electrofish (Jocassee & Keowee)	$34,000			$34,000			$34,000			$34,000
Bass Habitat Study (Keowee)				$18,000	$18,000	$18,000				
Stream Surveys	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000
Erosion Control										
Eastatoe Creek Access										
Protect Jocassee Land	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL $	173,120	209,745	160,245	242,245	178,245	178,245	224,245	160,245	160,245	224,245

DUKE ENERGY.

WATER STRATEGY, HYDRO LICENSING AND LAKE SERVICES

Duke Energy Corporation
526 South Church Street
Charlotte, NC 28202

Mailing Address:
EC12Y/P.O. Box 1006

February 26, 2016

The Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street N.E.
Washington, DC 20426

Re: Duke Energy Carolinas, LLC
Bad Creek Hydroelectric Project - Docket No. 2740-047
Final Report on the Keowee-Toxaway Ten-Year Fishery Resources Work Plan

Dear Secretary Bose:

Duke Energy Carolinas, LLC (Duke Energy) is required by the Keowee-Toxaway Ten-Year Fishery Resources Work Plan (Plan) pursuant to the Memorandum of Understanding (MOU) required by Article 32(b)1 of the Federal Energy Regulatory Commission (FERC) License for the Bad Creek Hydroelectric Project (Project), to file a final Ten-Year Fishery Resources Work Plan Report (Report) by December 1, 2015. Due to circumstances beyond the control of Duke Energy affecting data collections in 2015, we requested an Extension of Time to file the report to March 1, 2016 and were granted that request by FERC Order on January 13, 2016.

The FERC Order Modifying and Approving the Plan (Order) specifically requires Duke Energy to file a final Report regarding the summary status of the Plan and include any resource agency comments on the final Report. The attached final Report was drafted and submitted to the United States Fish and Wildlife Service and the South Carolina Department of Natural Resources as required and their comments on the Report appear in Appendix A. All comments from both agencies were incorporated into the final Report.

Duke Energy believes submittal of the attached Report satisfies the filing requirements per the MOU and Order. Please contact Alan Stuart at (980) 373-2079 (Alan.Stuart@duke-energy.com) if you have questions or require additional information.

Sincerely,

Jeff L

Jeffrey G. Lineberger, P.E.
Director, Water Strategy and Hydro Licensing
Duke Energy
Enclosure

cc: w/enclosure: Bill Marshall, SCDNR
Bryan Tompkins, USFWS
Phil Fragapane, Duke Energy

KEOWEE-TOXAWAY FISHERY RESOURCES WORK PLAN
JANUARY 2006 – DECEMBER 2015
SUMMARY REPORT

BAD CREEK PUMPED STORAGE PROJECT
(FERC NO. 2740)

February 2016

DUKE ENERGY®

Introduction

Duke Energy and the South Carolina Department of Natural Resources (SCDNR) continued to cooperatively monitor the fishery in Lake Jocassee and Lake Keowee via cost-share during 2006 – 2015. The Keowee-Toxaway Fishery Resources Work Plan (Plan; Appendix B) included a list of multiple items that required studies, habitat protection/enhancements, and other activities considered important to the successful management of the Keowee-Toxaway fishery resources.

Item 1: Agreement on fish entrainment at the Jocassee Pumped Storage Station

The Plan (signed December 2005) refers to a lack of documentation of the extent of entrainment at Jocassee Pumped Storage Station (JPSS). The Plan also acknowledged a lack of any population-level problems with a requirement for continued monitoring via other items in the Plan and the potential for a more thorough study conducted concurrent with relicensing of the JPSS.

On January 27, 2012, approximately six years after signing of the Plan, the Federal Energy Regulatory Commission (FERC) issued a Study Plan Determination during the relicensing of the Keowee-Toxaway Hydroelectric Project (FERC Project No. 2503). The FERC directed Duke Energy to determine the effect of project operations at the JPSS on the fisheries in Lake Jocassee and Lake Keowee and directed the specific methodology, in addition to that already proposed by Duke Energy, to accomplish the objective. The FERC recommended methodology included:

1. Use of hydroacoustic monitoring near the intakes to estimate numbers of fish entrained under the range of project operations to provide critical data to be used in estimating entrainment-related fish mortality;
2. Use of an Acoustic Doppler Current Profiler to describe current velocities around the intakes across operational scenarios to allow Duke Energy to relate velocity data to historical generation and pumping rates; and
3. Desktop entrainment mortality estimation, based on pump-turbine characteristics and the species and sizes of fish being entrained, to provide a mortality rate for entrained fish.

Duke Energy (2013a; Appendix C) completed the fish entrainment study and reported that fish mortality associated with entrainment minimally impacted forage fish populations in Lake Jocassee and Lake Keowee. Fish entrainment during the twelve-month study period was conservatively estimated (i.e., overestimated) to be a total of 13,253 (conventional generation) and 24,328 (pump back operations) fish susceptible to turbine-induced mortality with non-game species (i.e., blueback herring and threadfin shad) comprising the bulk of fish affected by entrainment. These entrainment levels represented approximately 0.15 % and 0.74 % of the forage fish populations present in Lake Jocassee and Lake Keowee, respectively, based on 2012 fall and 2013 spring population estimates. Based upon study results, the Relicensing Agreement

(Appendix D) specifies a hydro unit start-up sequence, to the extent practicable, and lighting modifications to further minimize fish entrainment.

Item 2: Agreement on minimizing fish entrainment via Bad Creek Pumped Storage Project

A low water-level condition at Lake Jocassee (pool elevation below 1099[1] ft. Above Mean Sea Level (AMSL)) is used to trigger operational protocols for the Bad Creek Pumped Storage Project (BCPSP; FERC Project No. 2740) to minimize fish entrainment. During the 10-year Plan period, Lake Jocassee experienced 16 low water-level events due to drought (Table 2-1). Extended droughts caused long-term events of low water levels in 2007 – 2009 and again in 2011 – 2013 (events lasting 673 days and 638 days, respectively). Additionally, shorter low water-level events occurred over the 10-year period ranging from 1 to 191 days.

Table 2-1. Number of consecutive days in 2006 – 2015 that Lake Jocassee pool elevation was below 1099 ft. AMSL.

Event start date	Event end date	Event duration (days)
8/1/2006	2/7/2007	191
2/17/2007	2/28/2007	12
6/30/2007	6/30/2007	1
7/8/2007	5/10/2009	673
5/14/2009	5/15/2009	2
5/21/2009	5/23/2009	3
7/25/2009	9/28/2009	66
10/5/2009	10/21/2009	17
10/23/2009	10/23/2009	1
9/27/2010	9/29/2010	3
10/2/2010	12/27/2010	87
1/13/2011	3/8/2011	55
8/2/2011	8/4/2011	3
8/6/2011	5/4/2013	638
9/30/2014	10/23/2014	24
10/25/2014	12/7/2014	44

There was a total of seven low water-level events longer than 30 days and five low water-level events longer than 60 days. Duke Energy consulted with the SCDNR as required and, based on those efforts, no additional measures were determined necessary or implemented to minimize fish entrainment over the 10-year period.

[1] Fish entrainment at the BCPSP can increase when the Lake Jocassee pool elevation reaches 1096 ft. AMSL (the allowable lower pool limit per the Normal Operating Range for Lake Jocassee contained in the Relicensing Agreement). Therefore, when the Lake Jocassee pool elevation reaches 1099 ft. AMSL, this provided a three ft. buffer and notification alerting Duke Energy to begin consulting with resource agencies to evaluate modifications to minimize entrainment as required by the Plan.

Item 3: Cost-share for fishery enhancements and studies

Funding was provided by Duke Energy for activities implemented by the SCDNR including the following:

- 2006 – 2015 Annual trout stocking (Table 3-1)
- Jocassee creel survey once every three years beginning in 2006 (i.e., 2006, 2009, 2012, and 2015; Figure 3-1a provided by SCDNR). Data reflect creel surveys through 2012. The 2015 data will be analyzed in early 2016.
- Keowee creel survey once every three years beginning in 2008 (i.e., 2008, 2011, and 2014; Figure 3-1b from Rankin et al. 2015)
- 2012 Bioenergetics study (Taylor and Bulak 2011; Appendix E)
- 2014 Redeye bass study (Leitner and Kanczuzewski 2015)[2]
- 2015 Eastern brook trout restoration efforts (Appendices F and G)

Table 3-1. Annual funding for trout stocking and creel surveys, 2006 – 2015.

Year	Trout stocking costs	Fish monitoring, research, and restoration costs	Total
2006	$80,000	$110,000	$190,000
2007	$80,000	$135,000	$215,000
2008	$88,200	$127,746	$215,946
2009	-	-	$238,104[1]
2010	$95,030	$143,992	$239,022
2011	$95,030	$143,992	$239,022
2012	$81,829	$160,046	$241,875
2013	$75,900	$166,000	$241,900
2014	$78,891	$168,109	$247,000
2015	$80,054	$170,630	$250,684
Total	$754,934	$1,325,515	$2,318,553

[1]itemization not provided by SCDNR

[2] The SCDNR is in the process of drafting the referenced report and therefore Duke Energy has not included it in this summary report.

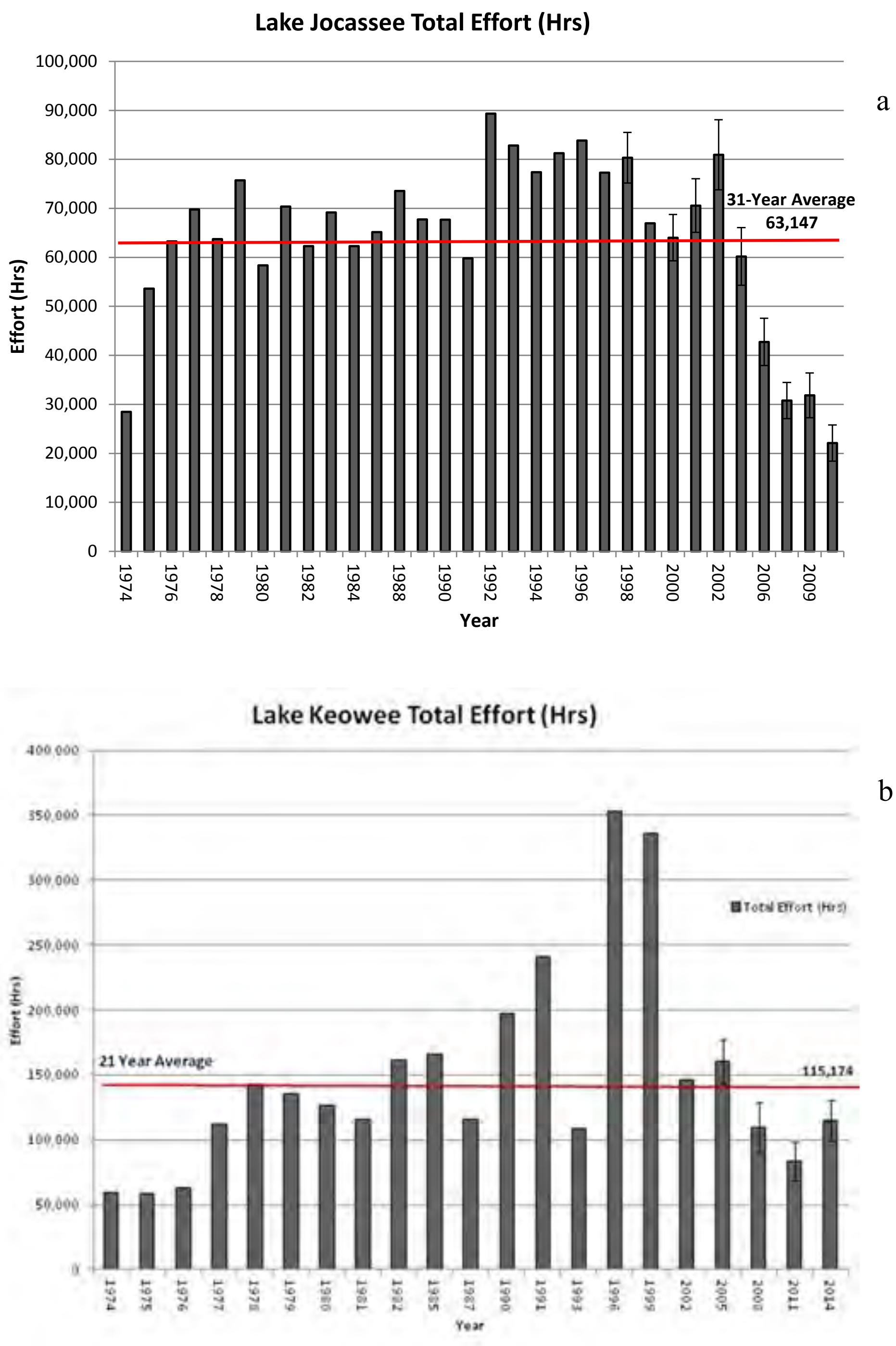


Figure 3-1. Recreational fishing effort on Lake Jocassee (a) and Lake Keowee (b) during 1974 – 2014 (with 95% Confidence Intervals for estimates from 2005 to 2014).

Item 4: Agreement on Maintaining Adequate Pelagic Habitat in Lake Jocassee

Monitoring and reporting were performed by Duke Energy personnel during 2006 – 2015 as required. Monthly temperature and dissolved oxygen (DO) profiles, used to determine pelagic trout habitat, were made at 10 locations in Lake Jocassee. Trout habitat was defined as ≤20 °C containing ≥5 mg/L DO. Profile data allowed Duke Energy to model and predict late summer (September) trout habitat thickness, verify the accuracy of the late summer model prediction, and evaluate the vertical and horizontal distribution of trout habitat throughout the calendar year. Pelagic habitat predictions were developed using “the Jocassee model”, a model developed by Duke Energy to predict late summer trout habitat thickness in the main body of the reservoir (Foris 1991). Field study results were presented to the SCDNR during annual Plan meetings and in project annual summary reports (Foris 2006 – 2014) which included study methodology and detailed study results.

The Jocassee model accurately predicted late summer habitat thickness during the Plan period of 2006 – 2015 (Figure 4-1). Habitat thickness was never predicted to be ≤10 m (the lowest predicted habitat thickness was 20 m in 2012). As such, additional monitoring requirements and modifications to hydropower operations to ensure habitat did not decrease to ≤5 m were not required. Measured late summer main body trout habitat thickness ranged from 17 m to 73 m, which indicated sufficient habitat availability in the reservoir to support a robust trout population (Figure 4-2).

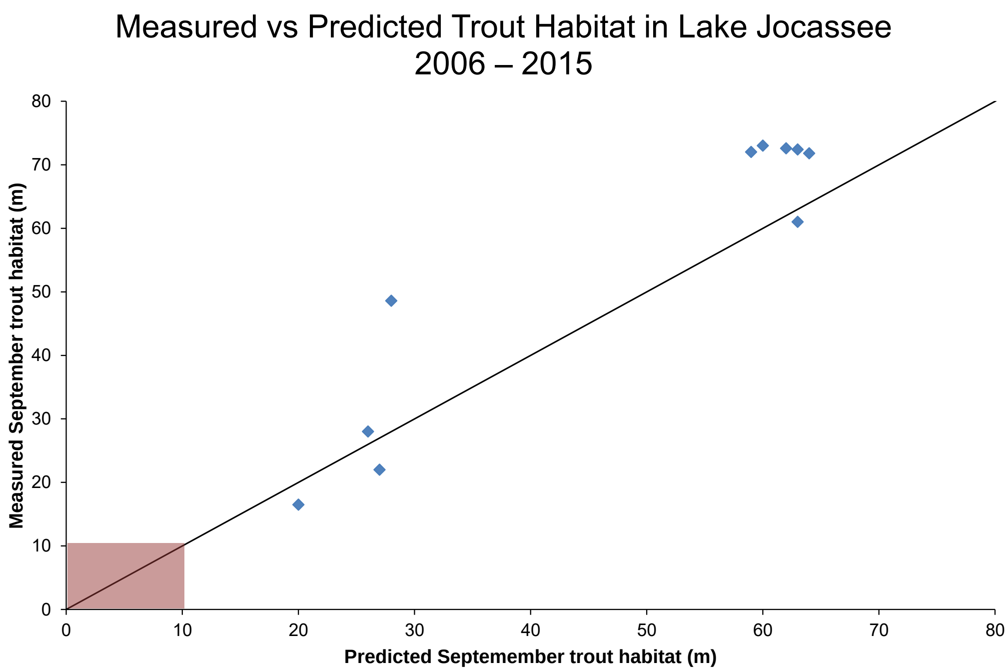


Figure 4-1. September measured vs. Jocassee model predicted trout habitat thickness during the Plan period of 2006 – 2015. Shaded box represents habitat thickness ≤10 m.

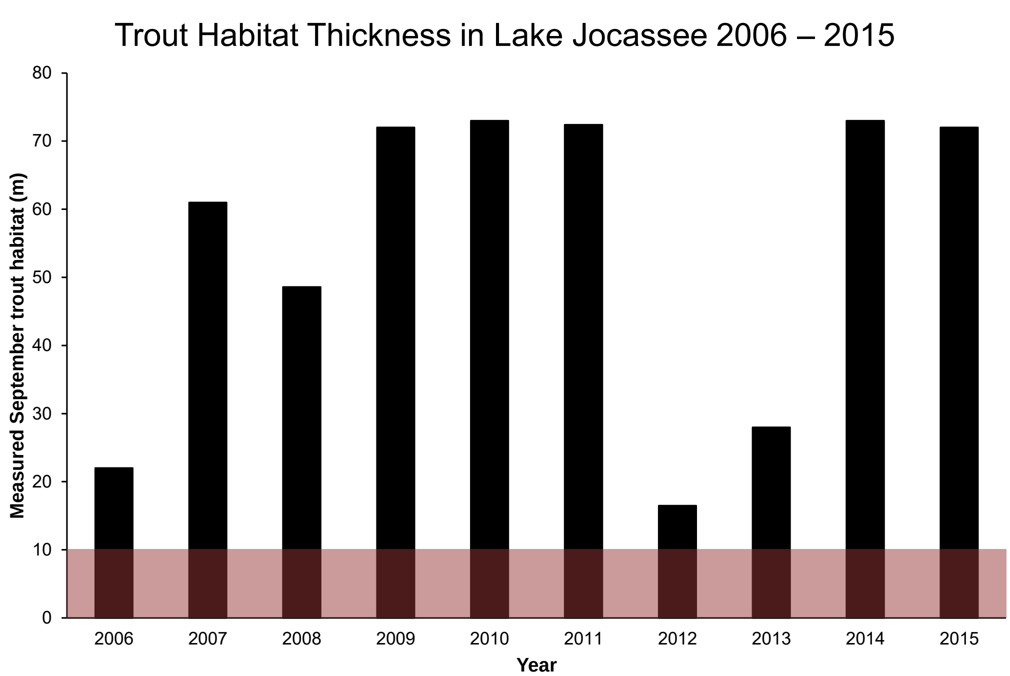


Figure 4-2. September measured trout habitat thickness in Lake Jocassee during the Plan period of 2006 – 2015. Shaded box represents habitat thickness ≤10 m.

Item 5: Keowee and Jocassee creel surveys following Jocassee runner upgrade

Creel surveys have been conducted by the SCDNR on Lake Jocassee and Lake Keowee since the development of the lakes to assess angler fishing success, fishing pressure, and socioeconomic effects of fishing on the region (Rankin et al. 2015; recreational fishing effort data are summarized in Figure 3-1). The SCDNR presented creel survey results at annual meetings and produced survey reports according to the Plan.

Creel surveys specific to the 2007 – 2011 runner upgrades were not required due to completion of the fish community assessment study (Duke Energy 2013a; also see Item 1). The FERC was notified of the agreed upon modification via letter dated March 28, 2012.

Item 6: Hydroacoustic monitoring of small pelagic fish (Jocassee, Keowee)

Bi-annual mobile hydroacoustic surveys of Lake Jocassee and Lake Keowee were performed by Duke Energy personnel in early spring and late fall 2006 – 2015 according to the Plan. Estimated abundance of pelagic forage fish (fish/ha) were provided to SCDNR at annual meetings (Figures 6-1 and 6-2). Forage fish densities were consistently highest in the upper Toxaway River arm (Zone 4) during the 10-year study period and exhibited considerable variability both spatially and temporally.

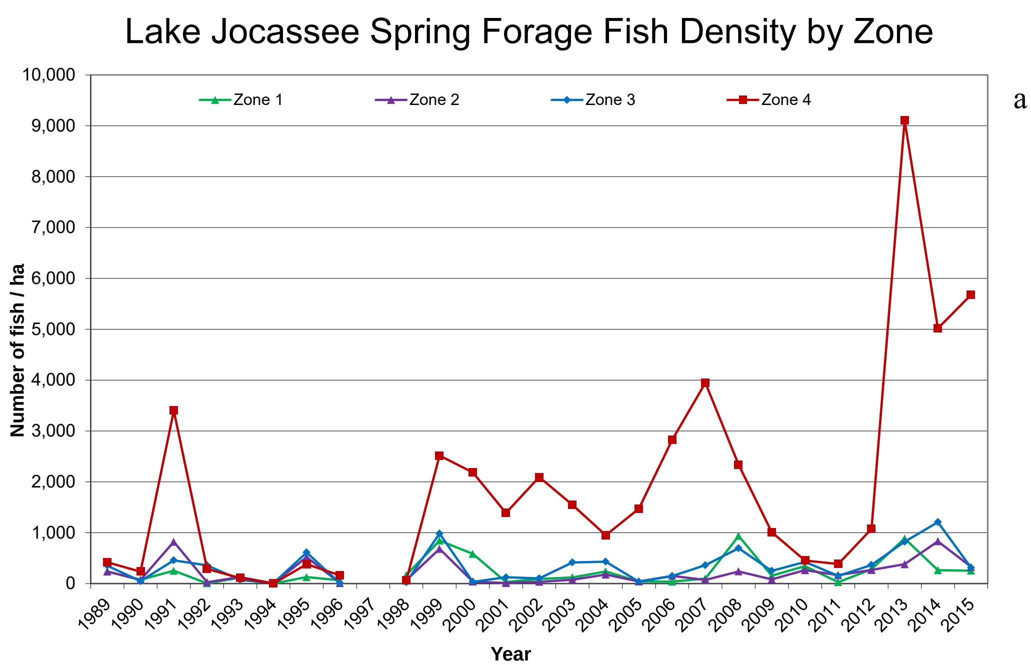
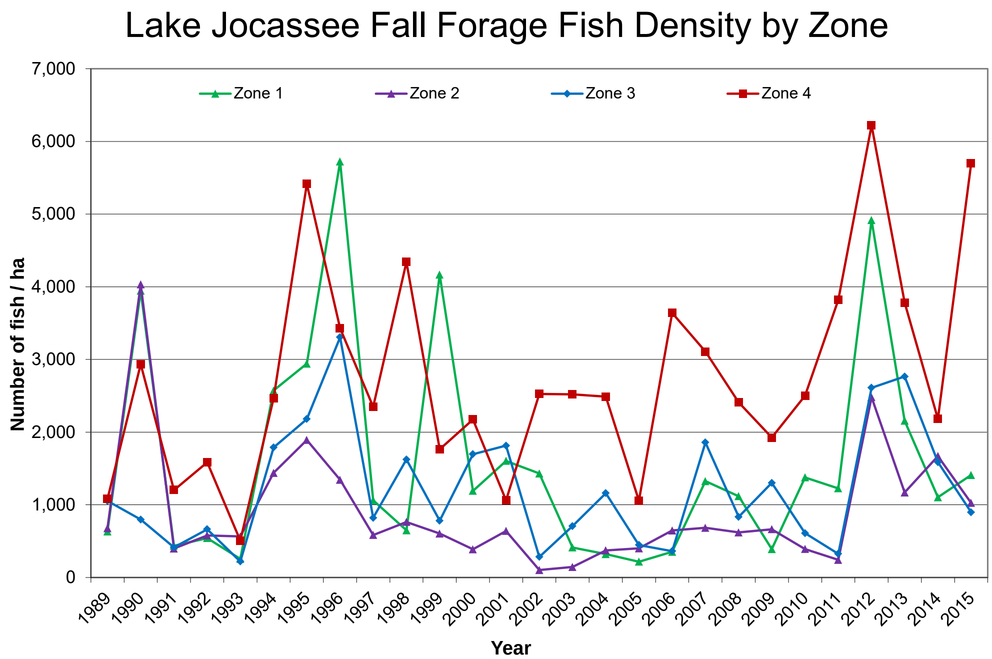


Figure 6-1a. Lake Jocassee forage fish density (fish/ha) by zone during mobile hydroacoustic surveys in spring 1989 – 2015.



b

Figure 6-1b. Lake Jocassee forage fish density (fish/ha) by zone during mobile hydroacoustic surveys in fall 1989 – 2015.

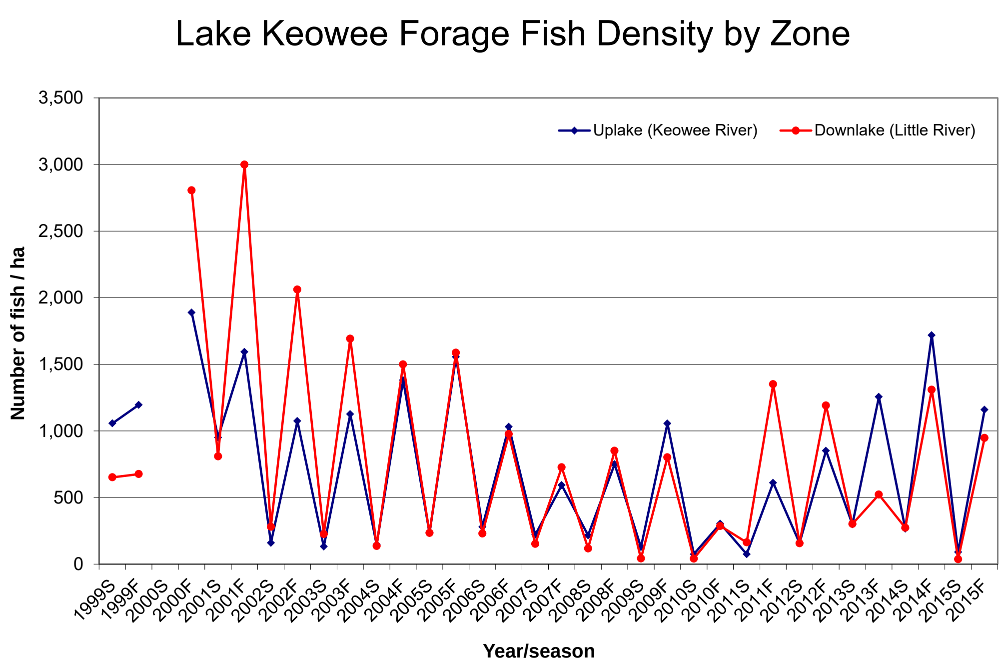


Figure 6-2. Lake Keowee forage fish density (fish/ha) by zone during mobile hydroacoustic surveys in spring and fall 1999 – 2015.

Item 7: Electrofishing of littoral fish populations (Jocassee and Keowee)

Littoral electrofishing surveys were performed as required by Duke Energy personnel once every three years in spring 2006 – 2015 (i.e., 2008, 2011, and 2014). Results were provided to SCDNR at annual meetings (Tables 7-1 and 7-2). Results from Lake Keowee were also submitted in periodic reports as part of Oconee Nuclear Station (ONS) permit applications (Tables 7-3 and 7-4; Duke Energy 2007 and 2013b). The littoral fish populations of Lake Jocassee and Lake Keowee exhibited considerable variability during the 10-year study period, both spatially and temporally.

Table 7-1. Number of individuals of fish collected from electrofishing ten 300-m transects each, at two areas (Lower and Upper) in Lake Jocassee, spring 2008, 2011, and 2014.

	Lower			Upper		
Species	2008	2011	2014	2008	2011	2014
Blackbanded darter	1	1			2	1
Blueback herring	81	31	45	71	23	168
Bluegill	370	221	251	702	273	244
Brassy jumprock					4	
Common carp			3	1		
Flat bullhead	3	1	12	4	8	10
Golden shiner	1			1	1	
Green sunfish	42	58	47	53	134	67
Hybrid black bass	6	1		1		6
Hybrid sunfish	6	3	5	3	5	4
Largemouth bass	8	9	2	58	41	34
Redbreast sunfish	415	239	500	354	357	251
Redear sunfish		1	1			
Redeye bass	23	56	77	87	87	115
Smallmouth bass	4	3	7	1	5	2
Snail bullhead	6	13	2	4	3	1
Spotted bass	4		5	1	2	1
Striped jumprock		1				
Warmouth	12	11	1	13	17	3
Whitefin shiner	253	65	31	75	16	16
Yellow perch						2

Table 7-2. Weight (g) of fish collected from electrofishing ten 300-m transects each, at two areas (Lower and Upper) in Lake Jocassee, spring 2008, 2011, and 2014.

	Lower			Upper		
Species	2008	2011	2014	2008	2011	2014
Blackbanded darter	1	4			5	2
Blueback herring	1,102	222	329	693	150	1,233
Bluegill	2,786	3,033	4,275	2,830	3,156	3,426
Brassy jumprock					1,313	
Common carp			5,476	1,072		
Flat bullhead	170	64	1,163	160	564	778
Golden shiner	9			2	9	
Green sunfish	468	680	876	638	2,721	2,210
Hybrid black bass	1,416	146		191		943
Hybrid sunfish	83	91	246	116	207	78
Largemouth bass	3,843	3,055	852	19,881	6,115	18,585
Redbreast sunfish	4,636	4,747	10,269	4,879	5,381	6,500
Redear sunfish		28	6			
Redeye bass	2,296	6,228	12,425	11,904	10,017	13,413
Smallmouth bass	372	493	1,347	1,148	1,426	98
Snail bullhead	212	732	104	168	245	53
Spotted bass	1,051		2,770	368	30	189
Striped jumprock		2				
Warmouth	61	89	9	114	355	148
Whitefin shiner	442	249	110	318	84	84
Yellow perch						36

Table 7-3. Number of individuals of fish collected from electrofishing ten 300-m transects each, at three areas (Lower, ONS, and Upper) in Lake Keowee, spring 2008, 2011, and 2014.

	Lower			ONS			Upper		
Species	2008	2011	2014	2008	2011	2014	2008	2011	2014
Black crappie		2			1				
Blackbanded darter					2		7	8	4
Blueback herring	169		94			1	1	106	
Bluegill	1105	2542	770	795	1945	1110	888	1062	790
Brassy jumprock							5	4	
Brown trout								1	
Channel catfish	4	1	5	6	3	5			
Common carp	7	5	4	1		1			2
Eastern mosquitofish	1					2			
Flat bullhead		3			1		5	6	5
Flathead catfish		1	1						
Golden shiner				1			3		
Green sunfish	159	254	262	92	189	155	61	125	129
Hybrid black bass			1			1	2	8	
Hybrid sunfish	35	84	51	62	61	87	24	37	55
Largemouth bass	15	18	10	18	12	16	36	29	7
Northern hog sucker				1					
Redbreast sunfish	219	350	145	218	308	223	390	462	436
Redear sunfish	9	40	12	57	84	121	20	47	16
Redeye bass								8	3
Smallmouth bass							3	1	2
Snail bullhead	2			2			27	8	1
Spottail shiner	23		15	153	26	194			
Spotted bass	74	87	76	17	28	28	30	24	13
Threadfin shad	1		2				1		
Warmouth	62	107	67	33	48	91	87	88	83
Whitefin shiner	96	132	52	11	45	43	23	51	9

Table 7-4. Weight (g) of fish collected from electrofishing ten 300-m transects each, at three areas (Lower, ONS, and Upper) in Lake Keowee, spring 2008, 2011, and 2014.

	Lower			ONS			Upper		
Species	2008	2011	2014	2008	2011	2014	2008	2011	2014
Black crappie		974			64				
Blackbanded darter					8		22	22	15
Blueback herring	607		634			7	4	837	
Bluegill	6,314	15,168	6,891	3,486	10,474	7,928	4,994	6,702	6,247
Brassy jumprock							486	893	
Brown trout								86	
Channel catfish	3,215	522	3,838	2,470	1,167	2,731			
Common carp	11,798	8,324	6,900	1,331		2,248			4,430
Eastern mosquitofish	1					4			
Flat bullhead		179			77		323	385	157
Flathead catfish		142	107						
Golden shiner				2			7		
Green sunfish	1,404	2,725	5,099	341	1,574	1,845	638	1,457	2,694
Hybrid black bass			257			366	91	263	
Hybrid sunfish	776	1,104	1,698	618	1,245	1,919	643	720	1,183
Largemouth bass	7,615	10,963	1,590	8,757	4,064	10,629	7,609	2,806	1,572
Northern hog sucker				183					
Redbreast sunfish	1,387	3,490	2,428	1,733	3,027	3,600	5,143	6,031	5,096
Redear sunfish	516	1,177	581	683	1,397	1,381	473	790	282
Redeye bass								769	111
Smallmouth bass							112	128	471
Snail bullhead	123			49			1,494	645	67
Spottail shiner	133		95	1,173	166	1,200			
Spotted bass	10,553	9,883	10,447	823	4,943	3,414	3,970	3,126	3,577
Threadfin shad	2		9				4		
Warmouth	618	814	831	151	341	776	1,130	947	1,201
Whitefin shiner	306	290	280	37	174	188	114	186	33

Item 8: Stream Surveys

Electrofishing surveys of fish populations in tributaries flowing into Lake Keowee were performed as required by Duke Energy personnel in 2008. The streams sampled included Cornhouse Creek, Cane Creek, Mile Creek and Crow Creek. Data were provided to the SCDNR (Coughlan 2011) with the following conclusion:

> Fish collections, per SCDNR stream fish sampling methods, occurred in October 2008 in four Lake Keowee tributaries yielding a total of 28 species representing seven families. The most numerous individuals typically belonged to a cyprinid or centrarchid species. The fish species found are consistent with those expected from distribution maps for the SC portion of the upper Savannah River drainage and none were federally or state listed as threatened or endangered. Seven of the collected species have received conservation concern in the latest SCDNR Comprehensive Wildlife Conservation Strategy (SCDNR 2005). External abnormalities, principally black spot, were only a concern in Cornhouse Creek and may be related to upstream nutrient inputs in the watershed. Excessive percentages of what are typically considered pollution tolerant individuals, principally green sunfish, redbreast sunfish, and eastern mosquitofish, were only collected in Mile Creek. No species considered intolerant of pollution were collected in Cornhouse Creek and this was the only stream where none were collected. Fish community metrics based on trophic relationships appeared inconclusive as an indicator of impairment. Measured hardness and specific conductance in the three Piedmont streams exceeded that of the soft water in Cane Creek draining the Blue Ridge province. Of the three Piedmont streams, nutrient concentrations in Cornhouse Creek were about twice as high as measured in the other two. Keowee tributary streams have diverse fish populations that are affected by watershed inputs and the underlying geology of the physiographic province. Natural barriers to fish migration were frequently observed in Keowee tributary streams and may place additional constraints on observed fish assemblages.

Item 9: Erosion control work

Duke Energy continues to maintain roads in the Jocassee Gorges area and are in compliance with the Jocassee Gorges Road MOA (July 2005) and South Carolina Department of Health and Environmental Control requirements. Duke Energy and SCDNR consult annually to review and discuss road maintenance to control erosion.

Item 10: Lower Eastatoe Creek management and angler access

Duke Energy provided enhancements to the Upper Powerline Parking Area and Dug Mountain Access Area and continues to maintain access to the Eastatoe Creek for hatchery trucks and anglers.

The Upper Powerline Parking Area was maintained over the 10-year period per the Plan. Periodic placement of gravel and vegetation control measures have been implemented as recommended.

The Dug Mountain Angler Access Area was developed through consultation with SCDNR and construction completed in March 2008 (Figure 10-1).

Figure 10-1. Images of the Dug Mountain Access Area

Item 11: Agreement to manage property around Lake Jocassee

Duke Energy implemented the Jocassee Shoreline Management Plan (SMP) on December 2, 2008 and received the FERC approval on February 4, 2013. The SMP is consistent with protecting and enhancing the scenic, recreational, and environmental values within the FERC project boundary. Duke Energy has since developed an updated SMP as part of the application for New License filed on August 27, 2014 and is currently awaiting the FERC approval of the revised SMP.

Literature cited

Coughlan, DJ. 2011. Fish communities in Lake Keowee tributary streams: 2008. Duke Energy Corporation, Huntersville, NC.

Duke Energy. 2007. Oconee Nuclear Station, 316(a) demonstration report. Duke Energy Corporation, Charlotte, NC.

Duke Energy. 2013a. Fish community assessment study: FERC required fish entrainment modification, Keowee-Toxaway hydroelectric project FERC No. 2503. Duke Energy Corporation, Charlotte, NC.

Duke Energy. 2013b. Oconee Nuclear Station, 316(a) demonstration report. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 1991. Temporal and spatial variability in pelagic trout habitat in a southeastern pumped-storage reservoir. Paper presented at NALMS, November 1991. Denver, CO.

Foris, WJ. 2006. Jocassee Reservoir pelagic trout habitat-2005, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2007. Jocassee Reservoir pelagic trout habitat-2006, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2008. Jocassee Reservoir pelagic trout habitat-2007, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2009. Jocassee Reservoir pelagic trout habitat-2008, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

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Foris, WJ. 2011. Jocassee Reservoir pelagic trout habitat-2010, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2012. Jocassee Reservoir pelagic trout habitat-2011, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2013. Jocassee Reservoir pelagic trout habitat-2012, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2014. Jocassee Reservoir pelagic trout habitat-2013, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Leitner, J and K Kanczuzewski. 2015. Assessing introgressive hybridization within and habitat requirements of native South Carolina redeye bass-Freshwater Fisheries Section, Draft Annual Progress Report, South Carolina Department of Natural Resources, Columbia, SC.

Rankin, D., AB Chastain, and WE Houck. 2015. Fisheries investigations in lakes and streams: annual progress report (draft) F-63-20, July 1, 2014 – June 30, 2015. South Carolina Department of Natural Resources, Columbia, SC.

Taylor, T and J Bulak. 2011. Forage requirements of brown trout in Lake Jocassee, study completion report. South Carolina Department of Natural Resources, Columbia, SC.

Appendix A

Agency Consultation

Stuart, Alan Witten

From:	Tompkins, Bryan <bryan_tompkins@fws.gov>
Sent:	Monday, February 01, 2016 2:21 PM
To:	Stuart, Alan Witten
Subject:	Re: Keowee-Toxaway Ten-Year Fisheries Work Plan Draft Report
Attachments:	Bad Creek MOU Work Plan 2006 - 2015 summary - BTEdits.docx

Good afternoon Alan. Hope you are well. I have completed my review of the draft Keowee-Toxaway Ten-Year Fisheries Work Plan Summary Report that you provided to me via e-mail on January 15, 2016. I believe the report is concise and adequate for its intended use. However, there are a few sections of the report that need attention. The inclusion of my comments might make the report more cumbersome than intended but if the additional information can be included it would be more useful to others that might be working in the area. Attached is the report with my edits in track changes. Let me know if you have any questions or if my comments didn't make sense. I appreciate the opportunity to review the report.

Bryan Tompkins
US Fish and Wildlife Service
160 Zillicoa Street
Asheville, North Carolina 28801
828/258-3939 ext.240

On Fri, Jan 15, 2016 at 1:55 PM, Stuart, Alan Witten <Alan.Stuart@duke-energy.com> wrote:

Bill/Bryan,

Attached for your review and comment is the draft Keowee-Toxaway Ten-Year Work Plan Summary Report. We must file the final report, including agency correspondence, with the FERC by March 1, 2016. Please review the attached report and provide any comments and edits by February 19, 2016. This should allow sufficient time for us to incorporate any changes and file with the FERC by the due date. As always, if you can get us your comments sooner we would certainly welcome that.

We appreciate your working with us on this document. If you have any questions please don't hesitate to give me a call.

Thanks !

Alan

DUKE ENERGY.

Alan W. Stuart

Senior Project Manager

Duke Energy Carolinas, LLC

Water Strategy, Hydro Licensing and Lake Services

526 S. Church Street, - EC12Y | Charlotte, NC 28202

Office 980-373-2079 | Cell 803-640-8765

KEOWEE-TOXAWAY TEN- YEAR FISHERIES WORK PLAN SUMMARY REPORT

BAD CREEK HYDROELECTRIC PROJECT
(FERC No. 2740)

January 2016

DUKE ENERGY

Duke Energy and South Carolina Department of Natural Resources (SC DNR) continued to cooperatively monitor the fishery in lakes Jocassee and Keowee via cost share during 2006 – 2015. The Keowee-Toxaway Fishery Resources Ten-Work Plan (Work Plan) included a list of multiple items that required studies, habitat protection/enhancements, and other activities considered important to the successful management of the Keowee-Toxaway fishery resources. The Work Plan is presented in Appendix A.

Item 1: Agreement on fish entrainment at the Jocassee pumped storage station

Comment [TB1]: Appendix A does not have the information as indicated here

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¶

The Work Plan (signed December 2005) refers to a lack of documentation of the extent of entrainment at Jocassee Pumped Storage Station (JPSS). The Work Plan also acknowledged a lack of any population-level problems with a requirement for continued monitoring via other items in the Work Plan and the potential for a more thorough study conducted concurrent with relicensing of the JPSS.

On January 27, 2012, approximately six years after signing of the Work Plan, the Federal Energy Regulatory Commission (FERC) issued a Study Plan Determination for the Keowee-Toxaway Hydroelectric Project that directed Duke Energy to determine the effect of project operations at the JPSS on the fisheries in Lake Jocassee and Lake Keowee and directed the specific methodology, in addition to that already proposed by Duke Energy, to accomplish the objective. The FERC recommended methodology included:

1. Use of hydroacoustic monitoring near the intakes to estimate numbers of fish entrained under the range of project operations to provide critical data to be used in estimating entrainment-related fish mortality;
2. Use of an Acoustic Doppler Current Profiler to describe current velocities around the intakes across operational scenarios to allow Duke Energy to relate velocity data to historical generation and pumping rates; and
3. Desktop entrainment mortality estimation, based on pump-turbine characteristics and the species and sizes of fish being entrained, to provide a mortality rate for entrained fish.

Duke Energy (2013a) completed the study and reported that fish mortality associated with entrainment minimally impacted forage fish populations in Lakes Jocassee and Keowee. Observed fish kills associated with JPSS operations were rare and the abundance of forage fish in both Lake Jocassee and Lake Keowee was similar to estimates noted in other nearby conventional hydroelectric reservoirs with similar levels of fertility.

Comment [TB2]: I have reviewed the information that came from the fish entrainment studies. I recommend including some of the detailed information from the study to support the final conclusion issued in Item 1. The conclusion in the draft report matches the conclusion in the recent EA for FERC license P-2503 but no details are provided here. Other studies reviewed in the report included supporting documentation and I believe it should be included in this section also. I also recommend including the estimates of fish kill in "other nearby conventional hydroelectric reservoirs" for quick comparison.

Item 2: Agreement on minimizing fish entrainment via Bad Creek pump storage project

Lake Jocassee experienced lower than expected water conditions due to extended droughts in 2007 – 2009 and again in 2011 – 2013 (673 days and 638 days, respectively). Additionally, shorter periods of lower than expected water levels occurred over the 10 year period ranging from 1 to 191 days.

Number of consecutive days in 2006 – 2015 that Lake Jocassee was less than elevation 1099.

Event start date	Event end date	Event duration (days)
8/1/2006	2/7/2007	191
2/17/2007	2/28/2007	12
6/30/2007	6/30/2007	1
7/8/2007	5/10/2009	673
5/14/2009	5/15/2009	2
5/21/2009	5/23/2009	3
7/25/2009	9/28/2009	66
10/5/2009	10/21/2009	17
10/23/2009	10/23/2009	1
9/27/2010	9/29/2010	3
10/2/2010	12/27/2010	87
1/13/2011	3/8/2011	55
8/2/2011	8/4/2011	3
8/6/2011	5/4/2013	638
9/30/2014	10/23/2014	24
10/25/2014	12/7/2014	44

There was a total of seven events longer than 30 days and five events longer than 60 days. Duke Energy consulted with the SC DNR as required and, based on those efforts, no additional measures were determined necessary or implemented to minimize fish entrainment over the 10-year period.

Item 3: Cost share for fishery enhancements and studies

Funding was provided by Duke Energy for the following activities implemented by the SC DNR:

- Jocassee creel survey once every three years beginning in 2006 (i.e., 2006, 2009, 2012, and 2015)
- Keowee creel survey once every three years beginning in 2008 (i.e., 2008, 2011, and 2014)
- 2006 – 2015 Annual trout stocking
- 2007 Special creel survey requested and performed by SCDNR. Citations needed
- 2010 and 2011 Tributary studies (Coughlan 2011) SCDNR citation needed
- 2011 and 2012 Redeye bass studies citations needed
- 2012 Bioenergetics study (Taylor and Bulak 2011).

Comment [AWS3]: SCDNR can you provide the requested citations ?

Annual funding for trout stocking and creel surveys, 2006 – 2015

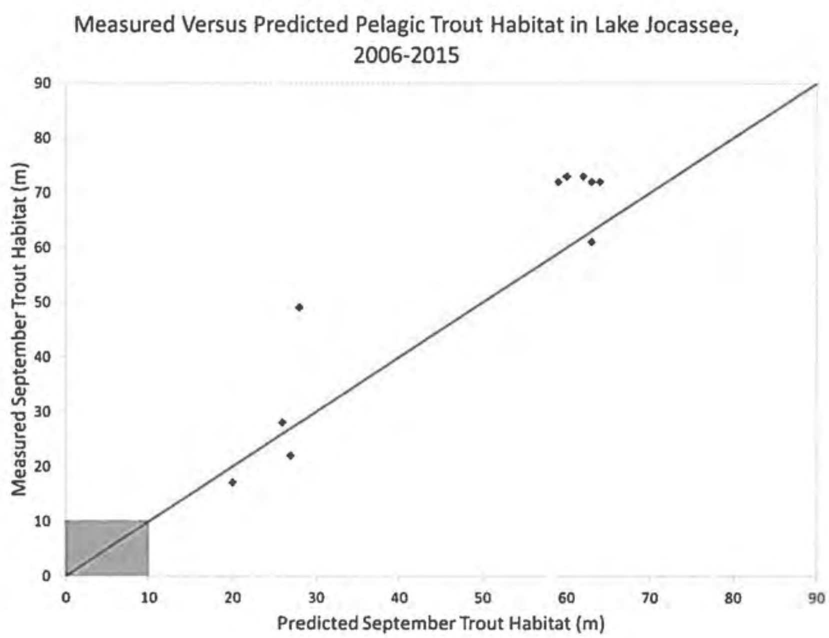
Year	Trout Stocking Costs	Creel Survey Costs	Total
2006	$ 80,000	$110,000	$ 190,000
2007	$ 80,000	$135,000	$ 215,000
2008	$ 88,200	$127,746	$ 215,946
2009			$ 238,104
2010	$ 95,030	$143,992	$ 239,022
2011	$ 95,030	$143,992	$ 239,022
2012	$ 81,829	$160,046	$ 241,875
2013			$ -
2014			$ -
2015			$ -
Total	$520,089	$820,776	$1,578,969

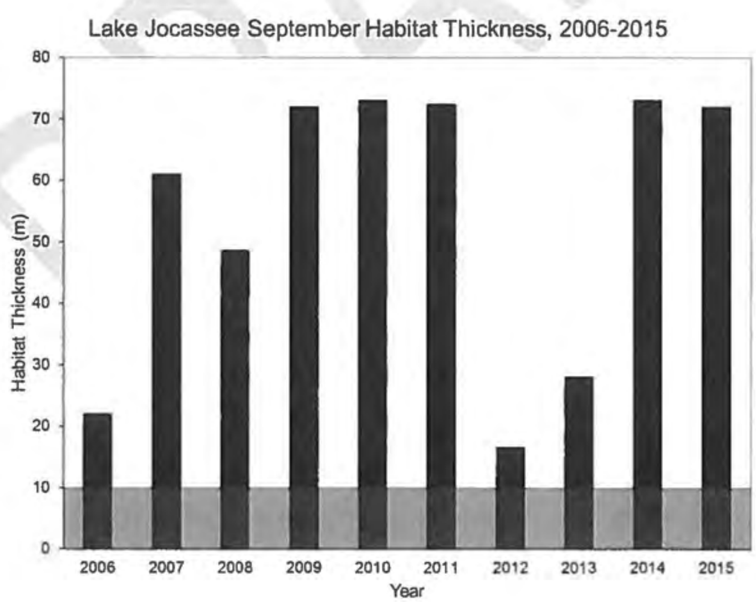
Comment [AWS4]: SCDNR is currently researching this information. If possible, please provide a breakdown of the 2009 costs and provide the costs for 2013-2015 ? In discussions with Dan Rankin he believes the Creel Survey costs listed may include costs for other fishery sponsored projects. If we need to include a another column to make everything balance we can once we get the numbers. Alternatively, we can make the column header "Creel Survey and Fishery Study Costs"

Item 4: Agreement on Maintaining Adequate Pelagic Habitat in Lake Jocassee

Monitoring and reporting were performed by Duke Energy personnel during 2006 – 2015 as required. Monthly temperature and dissolved oxygen (DO) profiles, used to determine pelagic trout habitat, were made at 10 locations in Lake Jocassee. Trout habitat was defined as ≤20 °C containing ≥5 mg/L DO. Profile data allowed Duke Energy to model and predict late summer (September) trout habitat thickness, verify the accuracy of the late summer model prediction, and evaluate the vertical and horizontal distribution of trout habitat throughout the calendar year. Pelagic habitat predictions were developed using "the Jocassee model", a model developed by Duke Energy to predict late summer trout habitat thickness in the main body of the reservoir (Foris, 1991). Field study results were presented to the SC DNR during annual Work Plan meetings and in project annual summary reports (Foris 2006 – 2014) which included study methodology and detailed study results.

The Jocassee model accurately predicted late summer habitat thickness during the Work Plan period of 2006 – 2010. Habitat thickness was never predicted to be ≤10 m (the lowest predicted habitat thickness was 20 m in 2012). As such, additional monitoring requirements and modifications to hydropower operations to ensure habitat did not decrease to ≤5 m were not required. Measured late summer main body trout habitat thickness ranged from 17 m to 73 m, which indicated sufficient habitat availability in the reservoir to support a robust trout population.


Measured Versus Predicted Pelagic Trout Habitat in Lake Jocassee, 2006-2015
Measured September Trout Habitat (m)
Predicted September Trout Habitat (m)
0
10
20
30
40
50
60
70
80
90


Lake Jocassee September Habitat Thickness, 2006-2015
Habitat Thickness (m)
Year
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
0
10
20
30
40
50
60
70
80

Item 5: Keowee and Jocassee creel surveys following Jocassee runner upgrade

Creel surveys have been conducted by the SC DNR on lakes Jocassee and Keowee since the development of the lakes to assess angler fishing success, fishing pressure, and socioeconomic effects of fishing on the region (see Item 3). The SC DNR presented results and produced survey reports according to the Work Plan. Creel surveys specific to the 2007 – 2011 runner upgrades were not required due to completion of the fish community assessment study (Duke Energy 2013a; also see Item 1). The FERC was notified of the agreed upon modification via letter dated March 28, 2012.

Comment [TB5]: Same comments as Item 1. It would be nice to see summary of data from creel surveys.

Item 6: Hydroacoustic monitoring of small pelagic fish (Jocassee, Keowee)

Bi-annual mobile hydroacoustic surveys of lakes Jocassee and Keowee were performed by Duke Energy personnel in early spring and late fall 2006 – 2015 according to the Work Plan. Estimated abundance of pelagic forage fish (fish/ha) were provided to SC DNR at annual meetings and are presented below. Forage fish densities were consistently highest in the upper Toxaway arm (Zone 4) during the 10 year study period and exhibited considerable variability both spatially and temporally.

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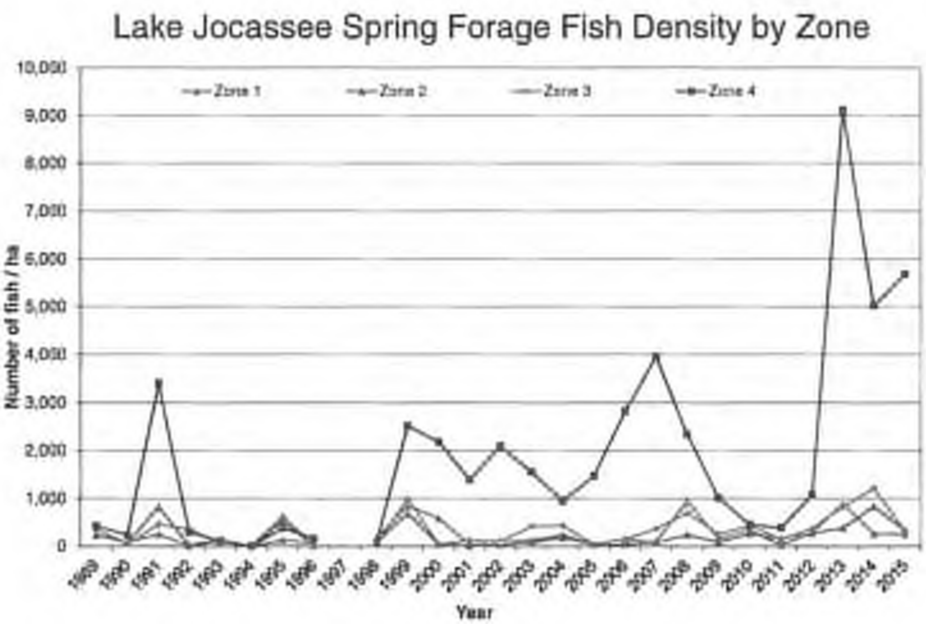

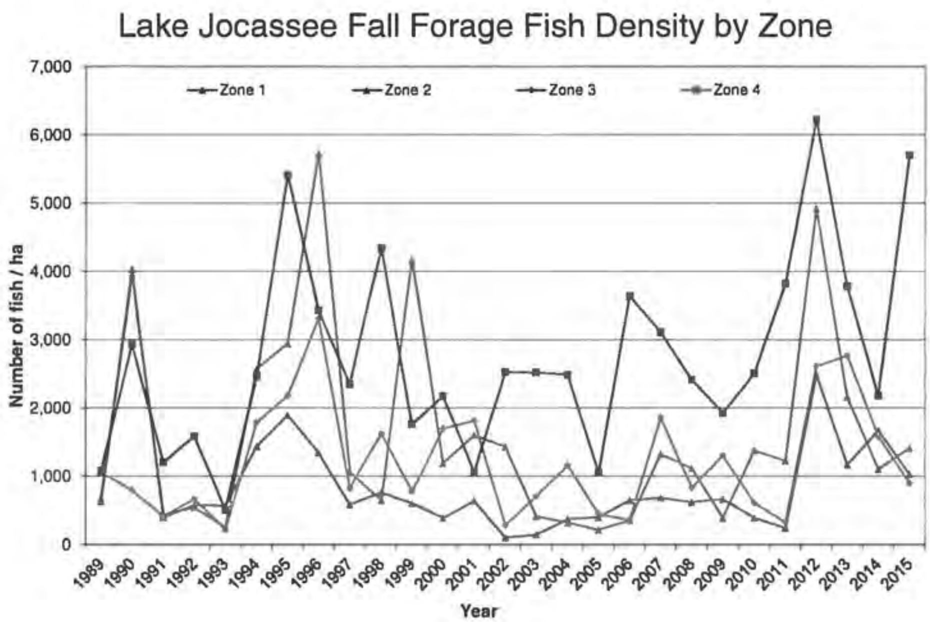
Lake Jocassee Fall Forage Fish Density by Zone
Zone 1
Zone 2
Zone 3
Zone 4
Number of fish / ha
Year
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
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2011
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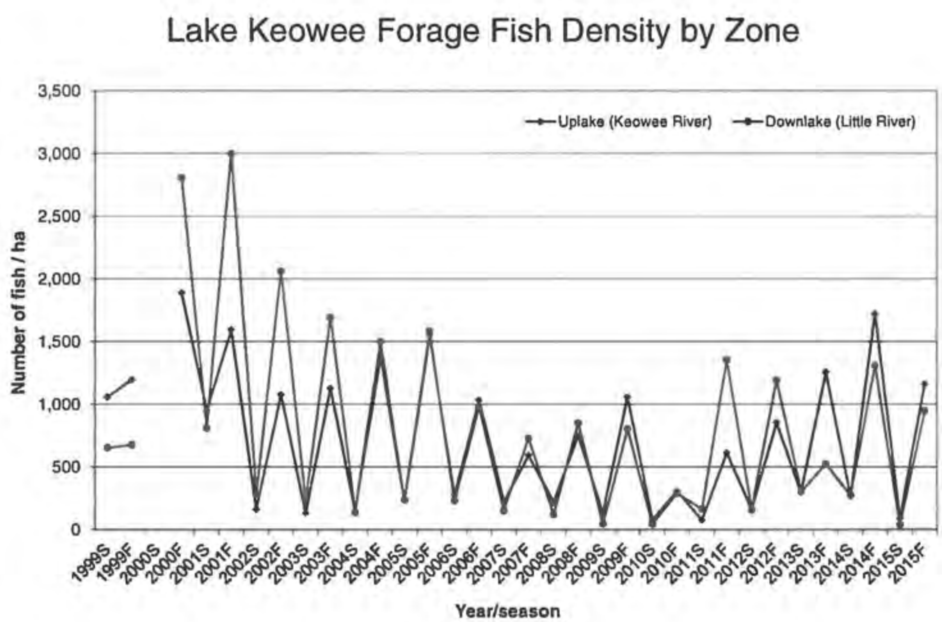
2014
2015


Lake Keowee Forage Fish Density by Zone
Uplake (Keowee River)
Downlake (Little River)
Number of fish / ha
Year/season
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1999S
1999F
2000S
2000F
2001S
2001F
2002S
2002F
2003S
2003F
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Item 7: Electrofishing of littoral fish populations (Jocassee and Keowee)

Electrofishing surveys were performed as required by Duke Energy personnel once every three years in spring 2006 – 2015 (2008, 2011, and 2014). Results were provided to SC DNR at annual meetings and are presented below. Results from Lake Keowee were also submitted in periodic reports as part of Oconee Nuclear Station (ONS) permit applications (Duke Energy 2007 and 2013b). The littoral fish populations of Jocassee and Keowee exhibited considerable variability during the 10 year study period, both spatially and temporally.

Number of individuals of fish collected from electrofishing ten 300-m transects each, at two areas (Lower and Upper) in Lake Jocassee, spring 2008, 2011, and 2014.

Comment [TB6]: All of the tables are formatted differently. Not a problem but if it can be fixed easily it would clean up the document.

	Lower			Upper		
Species	2008	2011	2014	2008	2011	2014
Blackbanded darter	1	1			2	1
Blueback herring	81	31	45	71	23	168
Bluegill	370	221	251	702	273	244
Brassy jumprock					4	
Common carp			3	1		
Flat bullhead	3	1	12	4	8	10
Golden shiner	1			1	1	
Green sunfish	42	58	47	53	134	67
Hybrid black bass	6	1		1		6
Hybrid sunfish	6	3	5	3	5	4
Largemouth bass	8	9	2	58	41	34
Redbreast sunfish	415	239	500	354	357	251
Redear sunfish		1	1			
Redeye bass	23	56	77	87	87	115
Smallmouth bass	4	3	7	1	5	2
Snail bullhead	6	13	2	4	3	1
Spotted bass	4		5	1	2	1
Striped jumprock		1				
Warmouth	12	11	1	13	17	3
Whitefin shiner	253	65	31	75	16	16
Yellow perch						2

Weight (g) of fish collected from electrofishing ten 300-m transects each, at two areas (Lower and Upper) in Lake Jocassee, spring 2008, 2011, and 2014.

	Lower			Upper		
Species	2008	2011	2014	2008	2011	2014
Blackbanded darter	1	4			5	2
Blueback herring	1,102	222	329	693	150	1,233
Bluegill	2,786	3,033	4,275	2,830	3,156	3,426
Brassy jumprock					1,313	
Common carp			5,476	1,072		
Flat bullhead	170	64	1,163	160	564	778
Golden shiner	9			2	9	
Green sunfish	468	680	876	638	2,721	2,210
Hybrid black bass	1,416	146		191		943
Hybrid sunfish	83	91	246	116	207	78
Largemouth bass	3,843	3,055	852	19,881	6,115	18,585
Redbreast sunfish	4,636	4,747	10,269	4,879	5,381	6,500
Redear sunfish		28	6			
Redeye bass	2,296	6,228	12,425	11,904	10,017	13,413
Smallmouth bass	372	493	1,347	1,148	1,426	98
Snail bullhead	212	732	104	168	245	53
Spotted bass	1,051		2,770	368	30	189
Striped jumprock		2				
Warmouth	61	89	9	114	355	148
Whitefin shiner	442	249	110	318	84	84
Yellow perch						36

Number of individuals of fish collected from electrofishing ten 300-m transects each, at three areas (Lower, ONS, and Upper) in Lake Keowee, spring 2001, 2011, and 2014.

Comment [TB7]: This doesn't match the survey year in the charts below for Lake Keowee.

	Lower			ONS			Upper		
Species	2008	2011	2014	2008	2011	2014	2008	2011	2014
Black crappie		2			1				
Blackbanded darter					2		7	8	4
Blueback herring	169		94			1	1	106	
Bluegill	1105	2542	770	795	1945	1110	888	1062	790
Brassy jumprock							5	4	
Brown trout								1	
Channel catfish	4	1	5	6	3	5			
Common carp	7	5	4	1		1			2
Eastern mosquitofish	1					2			
Flat bullhead		3			1		5	6	5
Flathead catfish		1	1						
Golden shiner				1			3		
Green sunfish	159	254	262	92	189	155	61	125	129
Hybrid black bass			1			1	2	8	
Hybrid sunfish	35	84	51	62	61	87	24	37	55
Largemouth bass	15	18	10	18	12	16	36	29	7
Northern hog sucker				1					
Redbreast sunfish	219	350	145	218	308	223	390	462	436
Redear sunfish	9	40	12	57	84	121	20	47	16
Redeye bass								8	3
Smallmouth bass							3	1	2
Snail bullhead	2			2			27	8	1
Spottail shiner	23		15	153	26	194			
Spotted bass	74	87	76	17	28	28	30	24	13
Threadfin shad	1		2				1		
Warmouth	62	107	67	33	48	91	87	88	83
Whitefin shiner	96	132	52	11	45	43	23	51	9

Weight (g) of fish collected from electrofishing ten 300-m transects each, at three areas (Lower, ONS, and Upper) in Lake Keowee, spring 2001, 2011, and 2014.

Comment [TB8]: See above comment

	Lower			ONS			Upper		
Species	2008	2011	2014	2008	2011	2014	2008	2011	2014
Black crappie		974			64				
Blackbanded darter					8		22	22	15
Blueback herring	607		634			7	4	837	
Bluegill	6,314	15,168	6,891	3,486	10,474	7,928	4,994	6,702	6,247
Brassy jumprock							486	893	
Brown trout								86	
Channel catfish	3,215	522	3,838	2,470	1,167	2,731			
Common carp	11,798	8,324	6,900	1,331		2,248			4,430
Eastern mosquitofish	1					4			
Flat bullhead		179			77		323	385	157
Flathead catfish		142	107						
Golden shiner				2			7		
Green sunfish	1,404	2,725	5,099	341	1,574	1,845	638	1,457	2,694
Hybrid black bass			257			366	91	263	
Hybrid sunfish	776	1,104	1,698	618	1,245	1,919	643	720	1,183
Largemouth bass	7,615	10,963	1,590	8,757	4,064	10,629	7,609	2,806	1,572
Northern hog sucker				183					
Redbreast sunfish	1,387	3,490	2,428	1,733	3,027	3,600	5,143	6,031	5,096
Redear sunfish	516	1,177	581	683	1,397	1,381	473	790	282
Redeye bass								769	111
Smallmouth bass							112	128	471
Snail bullhead	123			49			1,494	645	67
Spottail shiner	133		95	1,173	166	1,200			
Spotted bass	10,553	9,883	10,447	823	4,943	3,414	3,970	3,126	3,577
Threadfin shad	2		9				4		
Warmouth	618	814	831	151	341	776	1,130	947	1,201
Whitefin shiner	306	290	280	37	174	188	114	186	33

Item 8: Stream Surveys

Electrofishing surveys of fish populations in tributaries flowing into Lake Keowee were performed as required by Duke Energy personnel in 2008. The streams sampled included Cornhouse Creek, Crane Creek, Mile Creek and Crow Creek. Data were provided to the SC DNR (Coughlan 2011) with the following conclusion:

> Fish collections, per SCDNR stream fish sampling methods occurred in October 2008 in four tributaries to Lake Keowee, yielded a total of 28 species representing seven families. The most numerous individuals typically belonged to a cyprinid or centrarchid species. The fish species found are consistent with those expected from distribution maps for the SC portion of the upper Savannah River drainage and none were federally or state listed as threatened or endangered. Seven of the collected species have received conservation concern in the latest SCDNR Comprehensive Wildlife Conservation Strategy (SCDNR 2005). External abnormalities, principally black spot, were only a concern in Cornhouse Creek and may be related to upstream nutrient inputs in the watershed. Excessive percentages of what are typically considered pollution tolerant individuals, principally green sunfish, redbreast sunfish, and eastern mosquitofish, were only collected in Mile Creek. No species considered intolerant of pollution were collected in Cornhouse Creek and this was the only stream where none were collected. Fish community metrics based on trophic relationships appeared inconclusive as an indicator of impairment. Measured hardness and specific conductance in the three Piedmont streams exceeded that of the soft water in Cane Creek draining the Blue Ridge province. Of the three Piedmont streams, nutrient concentrations in Cornhouse Creek were about twice as high as measured in the other two. Keowee tributary streams have diverse fish populations that are affected by watershed inputs and the underlying geology of the physiographic province. Natural barriers to fish migration were frequently observed in Keowee tributary streams and may place additional constraints on observed fish assemblages.

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Comment [TB9]: It would be useful to see the collection data here too. I think it's important mainly for others working in the area in the future.

Item 9: Erosion control work

Duke Energy continues to maintain roads in the Jocassee Gorges area and are in compliance with the Jocassee Gorges Road MOA (July 2005) and South Carolina Department of Health and Environmental Control requirements. Duke Energy and SCDNR consult annually to review and discuss road maintenance to control erosion.

Item 10: Lower Eastatoe Creek management and angler access

Duke Energy provided enhancements to the Upper Powerline Parking Area and Dug Mountain Access Area and continues to maintain access to the Eastatoe Creek for hatchery trucks and anglers.

The Upper Powerline Parking Area was maintained over the 10 year period per the agreement. Periodic placement of gravel and vegetation control measures have been implemented as required.

Images of the Dug Creek Access Area developed and completed in March 2008.

Item 11: Agreement to manage property around Lake Jocassee

Duke Energy implemented the Jocassee Shoreline Management Plan (SMP) on December 2, 2008 and received the FERC approval on February 4, 2013. The SMP is consistent with protecting and enhancing the scenic, recreational, and environmental values within the FERC project boundary. Duke Energy has since developed an updated SMP as part of the application for New License filed on August 27, 2014 and is currently awaiting the FERC approval of the revised SMP.

Literature cited

Coughlan, DJ. 2011. Fish communities in Lake Keowee tributary streams: 2008. Duke Energy Corporation, Huntersville, NC.

Duke Energy. 2007. Oconee Nuclear Station, 316(a) demonstration report. Duke Energy Corporation, Charlotte, NC.

Duke Energy. 2013a. Fish community assessment study: FERC required fish entrainment modification, Keowee-Toxaway hydroelectric project FERC No. 2503. Duke Energy Corporation, Charlotte, NC.

Duke Energy. 2013b. Oconee Nuclear Station, 316(a) demonstration report. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 1991. Temporal and spatial variability in pelagic trout habitat in a southeastern pumped-storage reservoir. Paper presented at NALMS, November 1991. Denver, CO.

Foris, WJ. 2006. Jocassee Reservoir pelagic trout habitat-2005, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2007. Jocassee Reservoir pelagic trout habitat-2006, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2008. Jocassee Reservoir pelagic trout habitat-2007, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2009. Jocassee Reservoir pelagic trout habitat-2008, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

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Foris, WJ. 2011. Jocassee Reservoir pelagic trout habitat-2010, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2012. Jocassee Reservoir pelagic trout habitat-2011, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2013. Jocassee Reservoir pelagic trout habitat-2012, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Foris, WJ. 2014. Jocassee Reservoir pelagic trout habitat-2013, Bad Creek Project. Duke Energy Corporation, Charlotte, NC.

Taylor, T and J Bulak. 2011. Forage requirements of brown trout in Lake Jocassee, final report draft. South Carolina Department of Natural Resources, Columbia, SC.

Appendix A

Keowee-Toxaway Fisheries Ten-Year Work Plan

Comment [TB10]: Will this be completed with upcoming coordination with SCDNR?

Stuart, Alan Witten

From: Bill Marshall <MarshallB@dnr.sc.gov>
Sent: Wednesday, February 03, 2016 11:42 AM
To: Stuart, Alan Witten
Subject: RE: Keowee-Toxaway Ten-Year Fisheries Work Plan Draft Report
Attachments: Bad Creek MOU Work Plan 2006 - 2015 (wdm-dc-edits).docx

Hey Alan, attached is the report with suggested edits provided by me and Dick Christie.

I'm thinking you have received from Dan the citations needed from DNR under Item 3 and you are still waiting for the additional cost figures. -- Is this correct?

Thanks,
Bill

From: Stuart, Alan Witten [mailto:Alan.Stuart@duke-energy.com]
Sent: Wednesday, February 03, 2016 11:21 AM
To: Bill Marshall <MarshallB@dnr.sc.gov>
Subject: RE: Keowee-Toxaway Ten-Year Fisheries Work Plan Draft Report

Hi Bill,

I agree with you. We are going to try and minimally introduce some additional information from existing sources but definitely not overload. Our thoughts were to Append the DNR reports Dan provided and state in the applicable summary section that more detailed information can be found in those documents. I think the information Dan provide can be very useful to others and would like to show the studies were good products. If you have other thoughts please let me know.

If you have any comments ready, please feel free to pass them along. I'm meeting with our environmental folks on Friday to begin getting this report and comments addressed so we can meet the March 1 filing deadline.
Thanks !
Alan

From: Bill Marshall [mailto:MarshallB@dnr.sc.gov]
Sent: Wednesday, February 03, 2016 11:14 AM
To: Stuart, Alan Witten
Subject: RE: Keowee-Toxaway Ten-Year Fisheries Work Plan Draft Report

Alan,
I've looked over Bryan's comments. I agree that some additional summary info of data collected under the BC-MOU would make the report more useful but it may not be necessary to satisfy the FERC... Do you have what is needed to meet his suggestions -- in other words, can it be extracted from existing reports you have? The recent emailed report from Dan provides several summary graphs for some of the Keowee creel survey data (years 1974-2014), which could be appropriate to add to this work-plan report.

Regarding DNR comments on the report, I'm waiting to hear from Dan, but currently have ready a few suggested edits from me and Dick, which I can go ahead and send you if you're wanting them sooner than later. Just let me know.

Thanks,
Bill

From: Stuart, Alan Witten [mailto:Alan.Stuart@duke-energy.com]
Sent: Tuesday, February 02, 2016 7:37 AM
To: Bill Marshall <MarshallB@dnr.sc.gov>
Cc: Tompkins, Bryan <bryan_tompkins@fws.gov>
Subject: FW: Keowee-Toxaway Ten-Year Fisheries Work Plan Draft Report

Bill,

As an FYI, attached are Bryan Tompkin's comments on the KT MOU Summary report.

Thanks !
Alan

From: Tompkins, Bryan [mailto:bryan_tompkins@fws.gov]
Sent: Monday, February 01, 2016 2:21 PM
To: Stuart, Alan Witten
Subject: Re: Keowee-Toxaway Ten-Year Fisheries Work Plan Draft Report

Good afternoon Alan. Hope you are well. I have completed my review of the draft Keowee-Toxaway Ten-Year Fisheries Work Plan Summary Report that you provided to me via e-mail on January 15, 2016. I believe the report is concise and adequate for its intended use. However, there are a few sections of the report that need attention. The inclusion of my comments might make the report more cumbersome than intended but if the additional information can be included it would be more useful to others that might be working in the area. Attached is the report with my edits in track changes. Let me know if you have any questions or if my comments didn't make sense. I appreciate the opportunity to review the report.

Bryan Tompkins
US Fish and Wildlife Service
160 Zillicoa Street
Asheville, North Carolina 28801
828/258-3939 ext.240

On Fri, Jan 15, 2016 at 1:55 PM, Stuart, Alan Witten <Alan.Stuart@duke-energy.com> wrote:

Bill/Bryan,

Attached for your review and comment is the draft Keowee-Toxaway Ten-Year Work Plan Summary Report. We must file the final report, including agency correspondence, with the FERC by March 1, 2016. Please review the attached report and provide any comments and edits by February 19, 2016. This should allow sufficient time for us to incorporate any changes and file with the FERC by the due date. As always, if you can get us your comments sooner we would certainly welcome that.

We appreciate your working with us on this document. If you have any questions please don't hesitate to give me a call.

Thanks !

Alan

DUKE ENERGY.

Alan W. Stuart

Senior Project Manager

Duke Energy Carolinas, LLC

Water Strategy, Hydro Licensing and Lake Services

526 S. Church Street, - EC12Y | Charlotte, NC 28202

Office 980-373-2079 | Cell 803-640-8765

KEOWEE-TOXAWAY TEN- YEAR FISHERIES WORK PLAN SUMMARY REPORT

BAD CREEK HYDROELECTRIC PROJECT
(FERC NO. 2740)

January 2016

DUKE ENERGY.

Duke Energy and South Carolina Department of Natural Resources (SCDNR) continued to cooperatively monitor the fishery in lakes Jocassee and Keowee via cost share during 2006 – 2015. The Keowee-Toxaway Fishery Resources Ten-Work Plan (Work Plan) included a list of multiple items that required studies, habitat protection/enhancements, and other activities considered important to the successful management of the Keowee-Toxaway fishery resources. The Work Plan is presented in Appendix A.

Comment [BM1]: Remove the space in "SC DNR" so it reads as "SCDNR"—and make change throughout document

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Item 1: Agreement on fish entrainment at the Jocassee pumped storage station

The Work Plan (signed December 2005) refers to a lack of documentation of the extent of entrainment at Jocassee Pumped Storage Station (JPSS). The Work Plan also acknowledged a lack of any population-level problems with a requirement for continued monitoring via other items in the Work Plan and the potential for a more thorough study conducted concurrent with relicensing of the JPSS.

During the relicensing of JPSS, a study of fish entrainment was conducted. On January 27, 2012, approximately six years after signing of the Work Plan, the Federal Energy Regulatory Commission (FERC) issued a Study Plan Determination for the Keowee-Toxaway Hydroelectric Project (FERC Project No. 2503) that directed Duke Energy to determine the effect of project operations at the JPSS on the fisheries in Lake Jocassee and Lake Keowee and directed the specific methodology, in addition to that already proposed by Duke Energy, to accomplish the objective. The FERC recommend methodology included:

1. Use of hydroacoustic monitoring near the intakes to estimate numbers of fish entrained under the range of project operations to provide critical data to be used in estimating entrainment-related fish mortality;
2. Use of an Acoustic Doppler Current Profiler to describe current velocities around the intakes across operational scenarios to allow Duke Energy to relate velocity data to historical generation and pumping rates; and
3. Desktop entrainment mortality estimation, based on pump-turbine characteristics and the species and sizes of fish being entrained, to provide a mortality rate for entrained fish.

Duke Energy (2013a) completed the study and reported that fish mortality associated with entrainment minimally impacted forage fish populations in Lakes Jocassee and Keowee. Study results suggest that changes in Project Operations (start-up sequence) could help to further minimize fish mortality. Observed fish kills associated with JPSS operations were rare and the abundance of forage fish in both Lake Jocassee and Lake Keowee was similar to estimates noted in other nearby conventional hydroelectric reservoirs with similar levels of fertility.

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Item 2: Agreement on minimizing fish entrainment via Bad Creek pump storage project

Pool elevation at Lake Jocassee (below 1099 ft. MSL) is used to trigger operational protocols for Bad Creek Station to minimize fish entrainment during pumping. During the 10-year period, Lake Jocassee experienced 16 events of low water-level conditions (less than 1099 ft.) due to drought. Extended droughts caused long-term events of low water levels in 2007 – 2009 and again in 2011 – 2013 (events lasting 673 days and 638 days, respectively). Additionally, shorter events of low water levels occurred over the 10 year period ranging from 1 to 191 days.

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Number of consecutive days in 2006 – 2015 that Lake Jocassee was less than elevation 1099.

Event start date	Event end date	Event duration (days)
8/1/2006	2/7/2007	191
2/17/2007	2/28/2007	12
6/30/2007	6/30/2007	1
7/8/2007	5/10/2009	673
5/14/2009	5/15/2009	2
5/21/2009	5/23/2009	3
7/25/2009	9/28/2009	66
10/5/2009	10/21/2009	17
10/23/2009	10/23/2009	1
9/27/2010	9/29/2010	3
10/2/2010	12/27/2010	87
1/13/2011	3/8/2011	55
8/2/2011	8/4/2011	3
8/6/2011	5/4/2013	638
9/30/2014	10/23/2014	24
10/25/2014	12/7/2014	44

There was a total of seven events longer than 30 days and five events longer than 60 days. Duke Energy consulted with the SCDNR as required and, based on those efforts, no additional measures were determined necessary or implemented to minimize fish entrainment over the 10-year period.

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Item 3: Cost share for fishery enhancements and studies

Funding was provided by Duke Energy for the following activities implemented by the SCDNR:

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- Jocassee creel survey once every three years beginning in 2006 (i.e., 2006, 2009, 2012, and 2015)
- Keowee creel survey once every three years beginning in 2008 (i.e., 2008, 2011, and 2014)
- 2006 – 2015 Annual trout stocking
- 2007 Special creel survey requested and performed by SCDNR. Citations needed
- 2010 and 2011 Tributary studies (Coughlan 2011) SCDNR citation needed
- 2011 and 2012 Redeye bass studies citations needed
- 2012 Bioenergetics study (Taylor and Bulak 2011).

Comment [AWS2]: SCDNR can you provide the requested citations ?

Annual funding for trout stocking and creel surveys, 2006 – 2015.

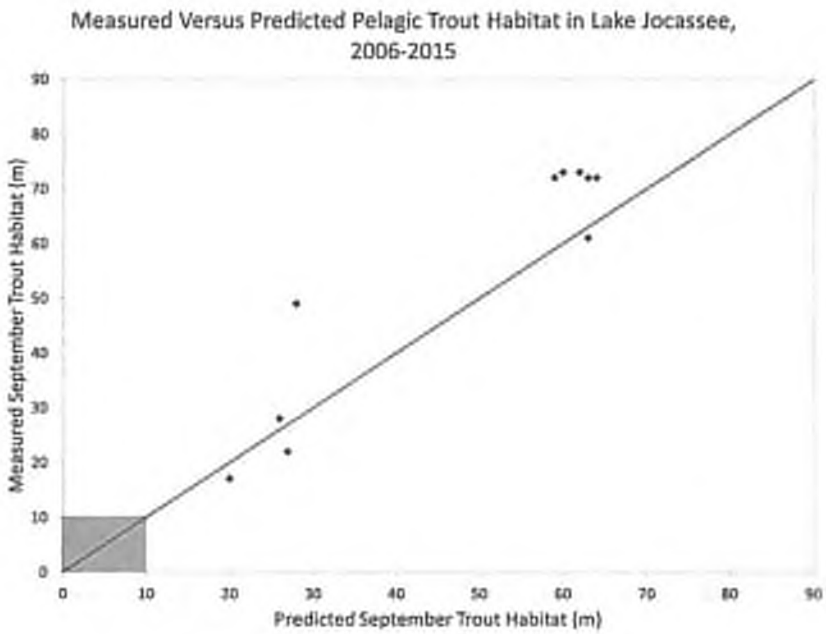
Year	Trout Stocking Costs	Creel Survey Costs	Total
2006	$ 80,000	$110,000	$ 190,000
2007	$ 80,000	$135,000	$ 215,000
2008	$ 88,200	$127,746	$ 215,946
2009			$ 238,104
2010	$ 95,030	$143,992	$ 239,022
2011	$ 95,030	$143,992	$ 239,022
2012	$ 81,829	$160,046	$ 241,875
2013			$ -
2014			$ -
2015			$ -
Total	$ 520,089	$ 820,776	$ 1,578,969

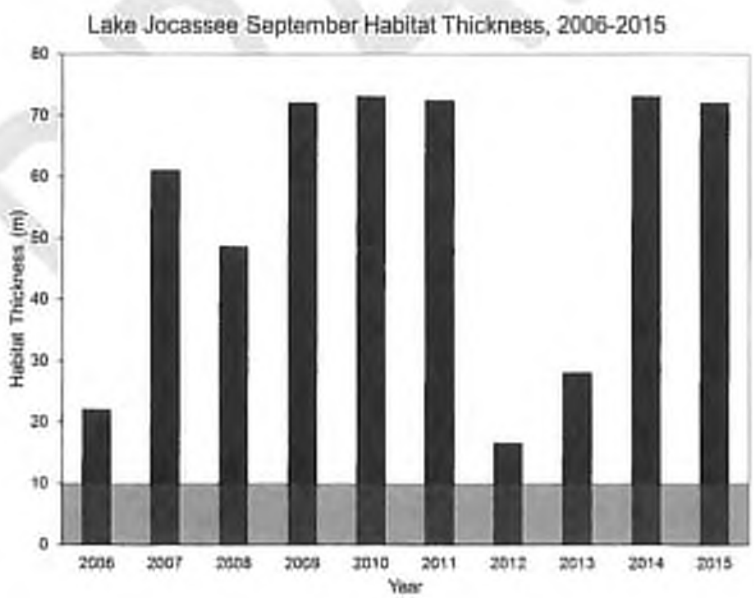
Comment [AWS3]: SCDNR is currently researching this information. If possible, please provide a breakdown of the 2009 costs and provide the costs for 2013-2015 ? In discussions with Dan Rankin he believes the Creel Survey costs listed may include costs for other fishery sponsored projects. If we need to include a another column to make everything balance we can once we get the numbers. Alternatively, we can make the column header "Creel Survey and Fishery Study Costs"

Item 4: Agreement on Maintaining Adequate Pelagic Habitat in Lake Jocassee

Monitoring and reporting were performed by Duke Energy personnel during 2006 – 2015 as required. Monthly temperature and dissolved oxygen (DO) profiles, used to determine pelagic trout habitat, were made at 10 locations in Lake Jocassee. Trout habitat was defined as ≤20 °C containing ≥5 mg/L DO. Profile data allowed Duke Energy to model and predict late summer (September) trout habitat thickness, verify the accuracy of the late summer model prediction, and evaluate the vertical and horizontal distribution of trout habitat throughout the calendar year. Pelagic habitat predictions were developed using "the Jocassee model", a model developed by Duke Energy to predict late summer trout habitat thickness in the main body of the reservoir (Foris, 1991). Field study results were presented to the SC-DNR during annual Work Plan meetings and in project annual summary reports (Foris 2006 – 2014) which included study methodology and detailed study results.

The Jocassee model accurately predicted late summer habitat thickness during the Work Plan period of 2006 – 2010. Habitat thickness was never predicted to be ≤10 m (the lowest predicted habitat thickness was 20 m in 2012). As such, additional monitoring requirements and modifications to hydropower operations to ensure habitat did not decrease to ≤5 m were not required. Measured late summer main body trout habitat thickness ranged from 17 m to 73 m, which indicated sufficient habitat availability in the reservoir to support a robust trout population.


Measured Versus Predicted Pelagic Trout Habitat in Lake Jocassee, 2006-2015
Measured September Trout Habitat (m)
Predicted September Trout Habitat (m)
0
10
20
30
40
50
60
70
80
90


Lake Jocassee September Habitat Thickness, 2006-2015
Habitat Thickness (m)
Year
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
0
10
20
30
40
50
60
70
80

Item 5: Keowee and Jocassee creel surveys following Jocassee runner upgrade

Creel surveys have been conducted by the SC-DNR on lakes Jocassee and Keowee since the development of the lakes to assess angler fishing success, fishing pressure, and socioeconomic effects of fishing on the region (see Item 3). The SC-DNR presented results and produced survey reports according to the Work Plan. Creel surveys specific to the 2007 – 2011 runner upgrades were not required due to completion of the fish community assessment study (Duke Energy 2013a; also see Item 1). The FERC was notified of the agreed upon modification via letter dated March 28, 2012.

Item 6: Hydroacoustic monitoring of small pelagic fish (Jocassee, Keowee)

Bi-annual mobile hydroacoustic surveys of lakes Jocassee and Keowee were performed by Duke Energy personnel in early spring and late fall 2006 – 2015 according to the Work Plan. Estimated abundance of pelagic forage fish (fish/ha) were provided to SCDNR at annual meetings and are presented below. Forage fish densities were consistently highest in the upper Toxaway arm (Zone 4) during the 10 year study period and exhibited considerable variability both spatially and temporally.

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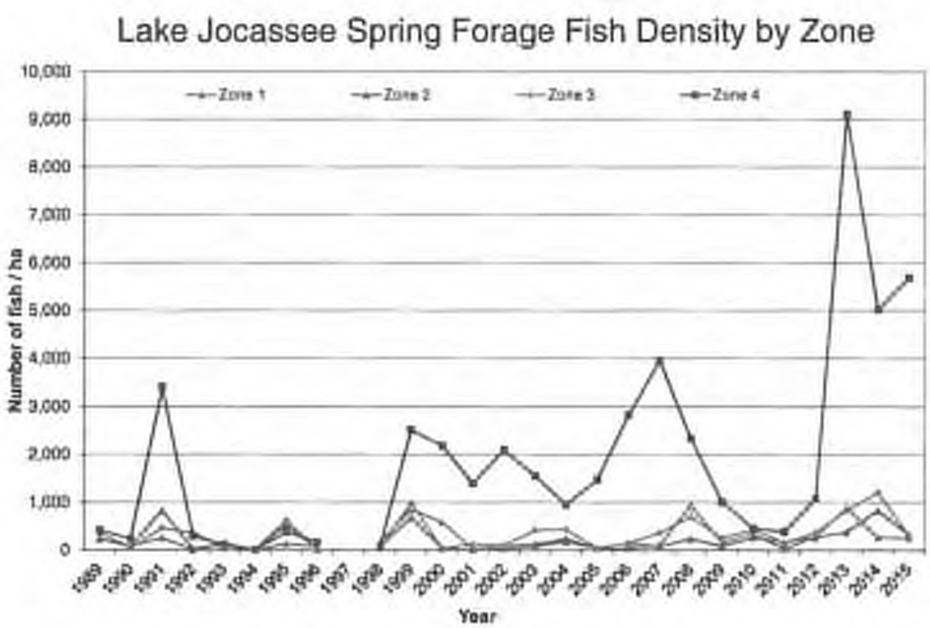

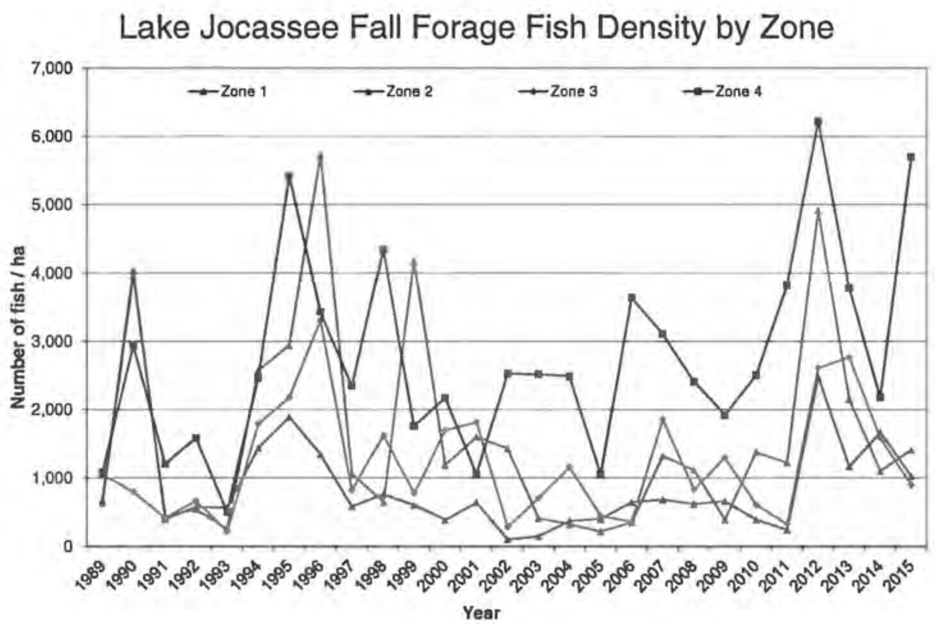
Lake Jocassee Fall Forage Fish Density by Zone
Zone 1
Zone 2
Zone 3
Zone 4
Number of fish / ha
Year
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
1989
1990
1991
1992
1993
1994
1995
1996
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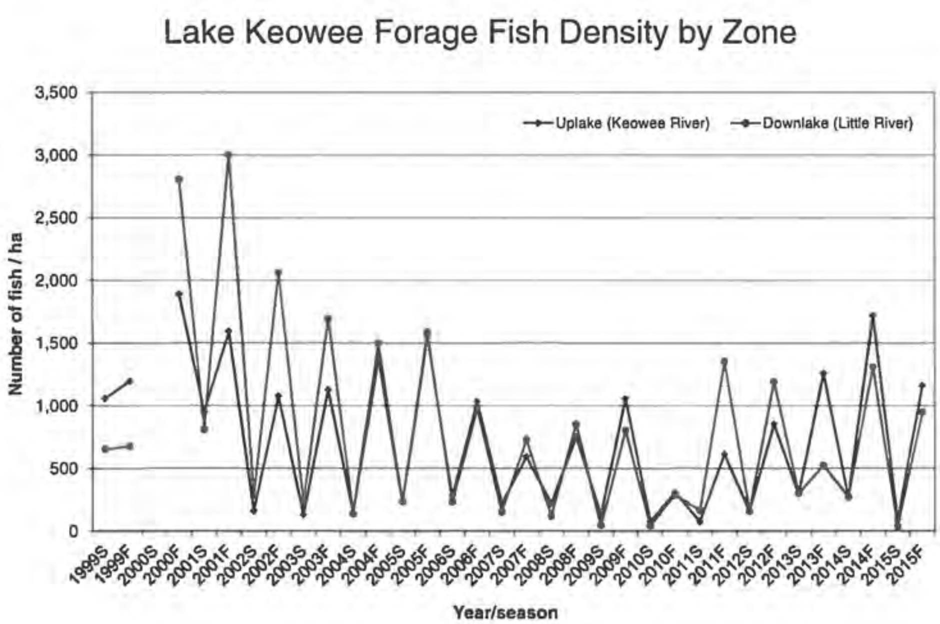
2015


Lake Keowee Forage Fish Density by Zone
Uplake (Keowee River)
Downlake (Little River)
Number of fish / ha
Year/season
0
500
1,000
1,500
2,000
2,500
3,000
3,500
1999S
1999F
2000S
2000F
2001S
2001F
2002S
2002F
2003S
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2015F

Item 7: Electrofishing of littoral fish populations (Jocassee and Keowee)

Electrofishing surveys were performed as required by Duke Energy personnel once every three years in spring 2006 – 2015 (2008, 2011, and 2014). Results were provided to SC DNR at annual meetings and are presented below. Results from Lake Keowee were also submitted in periodic reports as part of Oconee Nuclear Station (ONS) permit applications (Duke Energy 2007 and 2013b). The littoral fish populations of Jocassee and Keowee exhibited considerable variability during the 10 year study period, both spatially and temporally.

Number of individuals of fish collected from electrofishing ten 300-m transects each, at two areas (Lower and Upper) in Lake Jocassee, spring 2008, 2011, and 2014.

	Lower			Upper		
Species	2008	2011	2014	2008	2011	2014
Blackbanded darter	1	1			2	1
Blueback herring	81	31	45	71	23	168
Bluegill	370	221	251	702	273	244
Brassy jumprock					4	
Common carp			3	1		
Flat bullhead	3	1	12	4	8	10
Golden shiner	1			1	1	
Green sunfish	42	58	47	53	134	67
Hybrid black bass	6	1		1		6
Hybrid sunfish	6	3	5	3	5	4
Largemouth bass	8	9	2	58	41	34
Redbreast sunfish	415	239	500	354	357	251
Redear sunfish		1	1			
Redeye bass	23	56	77	87	87	115
Smallmouth bass	4	3	7	1	5	2
Snail bullhead	6	13	2	4	3	1
Spotted bass	4		5	1	2	1
Striped jumprock		1				
Warmouth	12	11	1	13	17	3
Whitefin shiner	253	65	31	75	16	16
Yellow perch						2

Weight (g) of fish collected from electrofishing ten 300-m transects each, at two areas (Lower and Upper) in Lake Jocassee, spring 2008, 2011, and 2014.

	Lower			Upper		
Species	2008	2011	2014	2008	2011	2014
Blackbanded darter	1	4			5	2
Blueback herring	1,102	222	329	693	150	1,233
Bluegill	2,786	3,033	4,275	2,830	3,156	3,426
Brassy jumprock					1,313	
Common carp			5,476	1,072		
Flat bullhead	170	64	1,163	160	564	778
Golden shiner	9			2	9	
Green sunfish	468	680	876	638	2,721	2,210
Hybrid black bass	1,416	146		191		943
Hybrid sunfish	83	91	246	116	207	78
Largemouth bass	3,843	3,055	852	19,881	6,115	18,585
Redbreast sunfish	4,636	4,747	10,269	4,879	5,381	6,500
Redear sunfish		28	6			
Redeye bass	2,296	6,228	12,425	11,904	10,017	13,413
Smallmouth bass	372	493	1,347	1,148	1,426	98
Snail bullhead	212	732	104	168	245	53
Spotted bass	1,051		2,770	368	30	189
Striped jumprock		2				
Warmouth	61	89	9	114	355	148
Whitefin shiner	442	249	110	318	84	84
Yellow perch						36

Number of individuals of fish collected from electrofishing ten 300-m transects each, at three areas (Lower, ONS, and Upper) in Lake Keowee, spring 2008, 2011, and 2014.

Deleted:

	Lower			ONS			Upper		
Species	2008	2011	2014	2008	2011	2014	2008	2011	2014
Black crappie		2			1				
Blackbanded darter					2		7	8	4
Blueback herring	169		94			1	1	106	
Bluegill	1105	2542	770	795	1945	1110	888	1062	790
Brassy jumprock							5	4	
Brown trout								1	
Channel catfish	4	1	5	6	3	5			
Common carp	7	5	4	1		1			2
Eastern mosquitofish	1					2			
Flat bullhead		3			1		5	6	5
Flathead catfish		1	1						
Golden shiner				1			3		
Green sunfish	159	254	262	92	189	155	61	125	129
Hybrid black bass			1			1	2	8	
Hybrid sunfish	35	84	51	62	61	87	24	37	55
Largemouth bass	15	18	10	18	12	16	36	29	7
Northern hog sucker				1					
Redbreast sunfish	219	350	145	218	308	223	390	462	436
Redear sunfish	9	40	12	57	84	121	20	47	16
Redeye bass								8	3
Smallmouth bass							3	1	2
Snail bullhead	2			2			27	8	1
Spottail shiner	23		15	153	26	194			
Spotted bass	74	87	76	17	28	28	30	24	13
Threadfin shad	1		2				1		
Warmouth	62	107	67	33	48	91	87	88	83
Whitefin shiner	96	132	52	11	45	43	23	51	9

Weight (g) of fish collected from electrofishing ten 300-m transects each, at three areas (Lower, ONS, and Upper) in Lake Keowee, spring 2008, 2011, and 2014.

Deleted:

	Lower			ONS			Upper		
Species	2008	2011	2014	2008	2011	2014	2008	2011	2014
Black crappie		974			64				
Blackbanded darter					8		22	22	15
Blueback herring	607		634			7	4	837	
Bluegill	6,314	15,168	6,891	3,486	10,474	7,928	4,994	6,702	6,247
Brassy jumprock							486	893	
Brown trout								86	
Channel catfish	3,215	522	3,838	2,470	1,167	2,731			
Common carp	11,798	8,324	6,900	1,331		2,248			4,430
Eastern mosquitofish	1					4			
Flat bullhead		179			77		323	385	157
Flathead catfish		142	107						
Golden shiner				2			7		
Green sunfish	1,404	2,725	5,099	341	1,574	1,845	638	1,457	2,694
Hybrid black bass			257			366	91	263	
Hybrid sunfish	776	1,104	1,698	618	1,245	1,919	643	720	1,183
Largemouth bass	7,615	10,963	1,590	8,757	4,064	10,629	7,609	2,806	1,572
Northern hog sucker				183					
Redbreast sunfish	1,387	3,490	2,428	1,733	3,027	3,600	5,143	6,031	5,096
Redear sunfish	516	1,177	581	683	1,397	1,381	473	790	282
Redeye bass								769	111
Smallmouth bass							112	128	471
Snail bullhead	123			49			1,494	645	67
Spottail shiner	133		95	1,173	166	1,200			
Spotted bass	10,553	9,883	10,447	823	4,943	3,414	3,970	3,126	3,577
Threadfin shad	2		9				4		
Warmouth	618	814	831	151	341	776	1,130	947	1,201
Whitefin shiner	306	290	280	37	174	188	114	186	33

Item 8: Stream Surveys

Electrofishing surveys of fish populations in tributaries flowing into Lake Keowee were performed as required by Duke Energy personnel in 2008. The streams sampled included Cornhouse Creek, Crane Creek, Mile Creek and Crow Creek. Data were provided to the SCDNR (Coughlan 2011) with the following conclusion:

Deleted:

> Fish collections per SCDNR stream fish sampling methods occurred October 2008 in four streams tributary to Lake Keowee and yielded a total of 28 species representing seven families. The most numerous individuals typically belonged to a cyprinid or centrarchid species. The fish species found are consistent with those expected from distribution maps for the SC portion of the upper Savannah River drainage and none were federally or state listed as threatened or endangered. Seven of the collected species have received conservation concern in the latest SCDNR Comprehensive Wildlife Conservation Strategy (SCDNR 2005). External abnormalities, principally black spot, were only a concern in Cornhouse Creek and may be related to upstream nutrient inputs in the watershed. Excessive percentages of what are typically considered pollution tolerant individuals, principally green sunfish, redbreast sunfish, and eastern mosquitofish, were only collected in Mile Creek. No species considered intolerant of pollution were collected in Cornhouse Creek and this was the only stream where none were collected. Fish community metrics based on trophic relationships appeared inconclusive as an indicator of impairment. Measured hardness and specific conductance in the three Piedmont streams exceeded that of the soft water in Cane Creek draining the Blue Ridge province. Of the three Piedmont streams, nutrient concentrations in Cornhouse Creek were about twice as high as measured in the other two. Keowee tributary streams have diverse fish populations that are affected by watershed inputs and the underlying geology of the physiographic province. Natural barriers to fish migration were frequently observed in Keowee tributary streams and may place additional constraints on observed fish assemblages.

Item 9: Erosion control work

Duke Energy continues to maintain roads in the Jocassee Gorges area and are in compliance with the Jocassee Gorges Road MOA (July 2005) and South Carolina Department of Health and Environmental Control requirements. Duke Energy and SCDNR consult annually to review and discuss road maintenance to control erosion.

Item 10: Lower Eastatoe Creek management and angler access

Duke Energy provided enhancements to the Upper Powerline Parking Area and Dug Mountain Access Area and continues to maintain access to the Eastatoe Creek for hatchery trucks and anglers.

The Upper Powerline Parking Area was maintained over the 10 year period per the agreement. Periodic placement of gravel and vegetation control measures have been implemented as required.

Images of the Dug Creek Access Area developed and completed in March 2008.

Item 11: Agreement to manage property around Lake Jocassee

Duke Energy implemented the Jocassee Shoreline Management Plan (SMP) on December 2, 2008 and received the FERC approval on February 4, 2013. The SMP is consistent with protecting and enhancing the scenic, recreational, and environmental values within the FERC project boundary. Duke Energy has since developed an updated SMP as part of the application for New License filed on August 27, 2014 and is currently awaiting the FERC approval of the revised SMP.

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Appendix A

Keowee-Toxaway Fisheries Ten-Year Work Plan

Appendix B

Keowee-Toxaway Fishery Resources Work Plan

January 2006 – December 2015

Bad Creek Hydroelectric Project

FERC No. 2740

Article 32(b)(1)

KEOWEE-TOXAWAY FISHERY RESOURCES WORK PLAN
JANUARY 2006 - DECEMBER 2015
SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES
AND
DUKE POWER, A DIVISION OF DUKE ENERGY CORPORATION

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

John E. Frampton, Director

Date: 12-16-05

DUKE POWER

William F. Hall, III

Vice-President – Fossil / Hydro Generation

Date: 12-21-05

KEOWEE-TOXAWAY FISHERIES RESOURCES
W0RK PLAN (JANUARY 2006 - DECEMBER 2015)
INTRODUCTION

The following studies, habitat protection/enhancements, and other activities are considered important to the successful management of the Keowee-Toxaway fishery resources. Many of the activities (e.g., trout habitat monitoring, gill-net surveys, electrofishing surveys, hydroacoustic surveys and creel surveys) have been ongoing for years and are the basis of establishing high quality and unique fisheries in South Carolina. Other activities will provide new types of information that will help manage these fisheries.

This work plan is the second to be developed under the Keowee-Toxaway Fishery Resources Memorandum of Understanding. The studies and other activities in this plan will all be jointly planned by the South Carolina Department of Natural Resources ("SCDNR") and Duke Power ("DP") team that have worked cooperatively over the years on the Keowee-Toxaway fishery resources. This team will coordinate and carry out these activities, involve third parties as needed, plan activities, and schedule and carry out an annual review of the status of activities.

All monetary values included in this MOU are based upon 2006 dollars. These amounts will be adjusted annually based upon the consumer price index.

Item 1: Agreement on Fish Entrainment at the Jocassee Pumped Storage Station

Lakes Jocassee and Keowee support robust fish populations. These populations were monitored by Duke Power and the SCDNR during the first ten-year work plan. While the extent of fish entrainment at the Jocassee Station is not currently documented, results of the monitoring have not identified any population level problems. The monitoring will continue in this work plan.

Work Plan

- DP and the SCDNR will continue to cooperatively monitor the fishery in lakes Jocassee and Keowee as described in Items 3, 5, 6 and 7.
- DP and SCDNR will annually review the results of the monitoring. If any significant changes are observed in fish populations in Lake Keowee or Lake Jocassee, DP and the SCDNR will meet to determine the cause of the changes and any necessary measures to correct them.

Function

DP and the SCDNR agree that these provisions should adequately protect the fisheries. A more thorough study of entrainment impacts may be conducted concurrent with relicensing of the Jocassee Pumped Storage Station.

Item 2: Agreement on Minimizing Fish Entrainment via Bad Creek Pumped Storage Project

DP and the SCDNR have worked cooperatively to evaluate fish entrainment at the Bad Creek Station. Site-specific studies provided information that identified operational periods associated with low and high entrainment rates, and this information was used to develop the operational guidelines presented in the work plan.

Work Plan

- During this work plan period, DP will operate its facilities to minimize, to the extent possible, the period during which Lake Jocassee pool elevations are below 335 m (1099 ft) MSL.
- When pool elevations in Lake Jocassee fall below 335 m (1099 ft) MSL [3.4 m (11) ft below full pool], DP will implement operational changes, based upon unit availability and other operational considerations, to minimize fish entrainment. These operational protocols were developed during the previous work plan and include turning off lights near the intake so as not to attract fish to the area and utilizing a unit startup and shutdown sequence that minimizes fish entrainment. These operational protocols may continue to evolve as additional information is gathered.
- If the pool elevation in Lake Jocassee falls below 335 m (1099 ft) MSL and is projected to remain below this level for 30 consecutive days, DP will notify the SCDNR. After such notification, DP will notify the SCDNR when the pool elevation rises above 335 m (1099 ft) for 7 consecutive days. No additional notifications to the SCDNR will be necessary if pool elevations fluctuate above and below 335 m (1099 ft) unless DP has previously notified the SCDNR the lake elevation rose above 335 m (1099 ft) for 7 consecutive days. If pool elevations are projected to remain below 335 m (1099 ft) MSL for 60 consecutive days, DP will initiate consultation with the SCDNR and the US Fish and Wildlife Service to determine if additional measures to minimize impacts are appropriate.

Function

- Minimize entrainment related to the operation of Bad Creek Hydroelectric Station during pump back operations.
- Establish communications protocols between DP and the SCDNR during low water periods.

Item 3: Cost Share for Fishery Enhancements and Studies

Both Lake Jocassee and Lake Keowee are recognized as important fisheries in the Upstate region. In addition, the SCDNR has established and manages a trout fishery in Lake Jocassee that is unique in South Carolina.

Work Plan

Depending on the specific activities proposed in the work schedule, DP will provide at least $190,000 and no more than $224,000/year to the SCDNR for use in enhancing fishery resources and conducting fishery studies in Lake Keowee, Lake Jocassee and tributaries to Lake Jocassee. This funding will provide for the following activities to be implemented by the SCDNR:

- Jocassee Creel Survey once every three years beginning in 2006 (i.e., 2006, 2009, 2012, and 2015);
- Keowee Creel Survey once every three years beginning in 2008 (i.e., 2008, 2011, and 2014);
- Annual trout stocking; and,
- At least two applied fishery research or monitoring studies or special management projects to be determined by the SCDNR in consultation with DP. Possible studies include but are not limited to the following:
    - Research study modeling historic water quality (habitat), environmental factors, hydro operations, etc. and relationships with fish population and fishery indices in Lake Jocassee;
    - Mortality studies of trout in Lake Jocassee and modeling of regulation scenarios;
    - Mortality studies of black bass in Lake Jocassee and Lake Keowee.

This funding may also be utilized for the purchase of supplies and equipment, special fishery research efforts and other activities identified by the SCDNR as beneficial to the fishery resources of Lake Jocassee and Lake Keowee. Funding for aforementioned work may be reallocated to address more pertinent or unforeseen fishery monitoring or management needs if mutually agreed upon by DP and the SCDNR. This funding may be used to hire SCDNR personnel to conduct or manage projects and for administrative support.

The creel survey schedule outlined above may be modified with the agreement of both the SCDNR and DP.

The SCDNR will provide DP copies of study reports prepared in conjunction with the annual funding.

Function

- Help ensure trout are available for maintaining the quality fishery in Lake Jocassee.
- Provide vital information on fishing effort, catch and harvest of sportfish as well as socioeconomic data.
- Use study data to formulate stocking strategies, size and creel limits, and to monitor potential impacts of commercial uses of the reservoir (i.e., power production) on the fishery.

Item 4: Agreement on Maintaining Adequate Pelagic Habitat in Lake Jocassee

DP and the SCDNR have worked cooperatively since 1973 to obtain a continuous and systematic database on trout habitat in Lake Jocassee and the factors that influence its horizontal and vertical distribution. A detailed understanding of habitat factors, including the roles of pumped storage operations and winter stored oxygen, has been gained. This understanding has led to the development of a model ("the Jocassee model") that can be used to predict late summer trout habitat thickness in the main body of the reservoir.

Work Plan

- During this work plan period, DP will continue to work in cooperation with the SCDNR to help ensure the presence of trout habitat in Lake Jocassee.
- DP will continue to carry out appropriate field studies on the vertical and horizontal distribution of trout habitat in Lake Jocassee. The program will include monthly measurements of temperature and dissolved oxygen profiles at 10 locations throughout the reservoir. If different or additional data are needed to refine the Jocassee model, these study details will be determined jointly with the SCDNR.
- Projections of late summer trout habitat thickness, defined as water ≤ 20 °C containing ≥ 5 mg/l DO, based on the Jocassee model will be reviewed with the SCDNR during the preceding May. Actual late summer data will be reported to the SCDNR in October of each year.
- Based on field data and the Jocassee model, DP and the SCDNR will work to protect trout habitat in Lake Jocassee. To help prevent operations from causing excessive habitat degradation, DP will do the following:
    - Employ the Jocassee trout habitat model and provide the September habitat prediction for the current year to the SCDNR and DP managers by 15 May.
    - If the model indicates a September habitat thickness of ≤ 10 m, DP will initiate bimonthly measurements of temperature and DO to monitor habitat conditions and update the actual rate of habitat depletion. These data will be shared with the SCDNR and DP managers in a timely manner.

The Jocassee model and additional monitoring will allow DP early notification and management flexibility, during rare critical habitat years, to ensure that hydro operations will not decrease trout habitat less than a 5-meter minimum thickness (habitat defined by temperatures ≤ 20° C and dissolved oxygen ≥ 5 mg/l criteria).

Function

This effort will provide an active and cooperative system that will help ensure the successful continuance of the trophy trout fishery in Lake Jocassee. Lake Jocassee provides the only trophy trout fishing and reservoir trout fishing opportunity in SC. These opportunities are also extremely limited across the southeast region. Monitoring and implementation of the DP habitat model will help ensure the continued compatibility of hydroelectric operations and maintenance of important fishery resources.

Item 5: Keowee and Jocassee Creel Surveys following Jocassee Runner Upgrade

Creel surveys have been conducted on Lake Jocasee and Lake Keowee since the development of the lakes. This long-term monitoring effort provided the means to assess angler fishing success, fishing pressure and socioeconomic effects of fishing on the region over a 20-year time period.

Work Plan

- DP will provide $54,000/year for additional creel surveys not identified in the schedule for Item 3 following completion of an upgrade of all four turbine runners at the Jocassee Station. Creel surveys on both lakes will be conducted for three consecutive years beginning the second full year after completion of the upgrade of all four runners. The creel survey methodology will be consistent with the other creel surveys conducted as part of this work plan.

  Following the three consecutive years of surveys, no creel surveys will be conducted for two years. Creel surveys will then be conducted on each lake once every three years with the first survey taking place on Lake Keowee.
- The SCDNR and DP will provide copies of study reports prepared in conjunction with this effort to one another.
- The SCDNR will administer the creel surveys if it chooses.

Function

- Provides vital information on angler success along with information on fishing effort, catch and harvest of sportfish as well as socioeconomic data.
- Will provide effective monitoring of the fishery to assess major impacts to the Lake Keowee and Lake Jocassee fisheries following runner upgrades.

Item 6: Hydroacoustic Monitoring of Small Pelagic Fish (Jocassee, Keowee)

During the first work plan period, hydroacoustic monitoring of fish populations was initiated to assess pelagic prey fish abundance and distribution in these reservoirs. As these fish provide prey for sportfish, understanding their relative abundance is important to assessing the overall quality of the fisheries in both lakes.

Work Plan

DP will provide funding and conduct this monitoring work. DP will provide the SCDNR copies of study reports prepared in conjunction with this activity.

This monitoring is scheduled annually (spring and fall) throughout the planning period.

Function

Based on the results of the Bad Creek entrainment study, entrainment impacts mostly small pelagic prey fish in these reservoirs. The collection of these data will allow effective on-going monitoring of these populations which are the primary food of trout and other predatory sport fish in Lake Jocassee and Lake Keowee.

Item 7: Electrofishing of Littoral Fish Populations (Jocassee and Keowee)

Electrofishing to assess the status of littoral fish populations in these reservoirs was conducted once every three years during the previous work plan period. Since littoral fish contribute significantly to the fisheries of these reservoirs, it is important to monitor their abundance, growth, and relative weight at regular intervals.

Work Plan

- DP will conduct this work.
- This monitoring is scheduled to occur once every three years (2008, 2011, and 2014) of the work plan period.
- DP will provide the SCDNR copies of study reports prepared in conjunction with this activity.

Function

Even though littoral fish are impacted less than pelagic fish, they are entrained and their spawning can be impacted by weekly water level fluctuations associated with pumped storage operations. These data allow effective monitoring of littoral sportfish populations (e.g., largemouth bass, spotted bass, smallmouth bass, redeye bass and bluegills) in these reservoirs.

Item 8: Stream Surveys

Streams flowing into Lake Jocassee and Lake Keowee provide critical habitat for a number of important fish species. DP and the SCDNR conducted stream surveys jointly during the previous work plan period.

Work Plan:

- One or more streams may be surveyed each year, as determined by the SCDNR.
- DP will assist the SCDNR in their ongoing efforts to survey fish populations in tributaries of lakes Jocassee and Keowee as staff availability allows.
- SCDNR will coordinate this effort.

Function

Maintain a database on tributary fish populations (e.g., Whitewater River) for use in developing future fish management strategies.

Item 9: Erosion Control Work

There are numerous unpaved roads within the Jocassee Gorges. Erosion from these roads can negatively impact the fishery.

During the first work plan period, many of these roads were owned by Duke Power. As a result of the Jocassee Gorges initiative, most of these roads are now owned by South Carolina and managed by the SCDNR. DP still needs to access portions of some of these roads in order to maintain the transmission lines and the Foothills Trail. The SCDNR maintains other roads for public access and property management activities. On-going maintenance of such roads is necessary to ensure that they meet the requirements of the South Carolina Department of Health and Environmental Control (SCDHEC).

Work Plan

- DP and the SCDNR will work together to develop an agreement regarding the management of roads in the Jocassee Gorges.
- This agreement will address management of roads such that they are in compliance with SCDHEC requirements.
- DP and the SCDNR will also work together to involve other property owners in cooperating on the management of roads within the Gorges.

Function

Protect/enhance water quality and habitat factors in headwater trout streams at Keowee-Toxaway.

Item 10: Lower Eastatoe Creek Management and Angler Access

The Lower Eastatoe Creek provides excellent fishing opportunities. The initial work plan called for DP and the SCDNR to work cooperatively to provide for angler access to the area and access for the hatchery trucks for stocking. The focus of this work plan period will be on enhancing the access facilities currently provided by DP. These areas are known as the "Upper Powerline Parking Area" and the "Dug Mountain Access Area."

Work Plan

- DP will provide and maintain access for the hatchery trucks at the Upper Powerline Parking Area and Dug Mountain Access Area.
- DP will ensure that the Upper Powerline Parking Area and the trail to the Eastatoe Creek are maintained.
- DP will enhance the existing parking lot at the Dug Mountain Access Area and construct a Handicapped Accessible Fishing Platform at the site by December 31, 2006.
- DP and the SCDNR will work cooperatively to involve additional partners in the planning and on-going management of the angler access areas. Potential partners include Trout Unlimited, homeowners groups and adjacent property owners.

Function

These activities will provide additional angler access to the Eastatoe Creek. Additionally, the development of partnerships to manage the sites will ensure that the sites have frequent on-site management activities.

Item 11: Agreement to Manage Property around Lake Jocassee

DP's Keowee-Toxaway Land Use Plan developed in 1983, prohibited development of company lands around Lake Jocassee. In keeping with that plan, DP and the SCDNR have worked cooperatively on the management of lands around Lake Jocassee. This cooperation led to the Jocassee Gorges Project which resulted in the transfer of more than 50,000 acres of property to the public. DP, consistent with its FERC license to operation the Keowee-Toxaway Project, which includes Lake Jocassee, is required to protect and enhance the scenic, recreational and environmental values of the project. Shoreline management planning addresses the management of lands within the FERC project boundary.

Work Plan

- Duke Power will develop a Shoreline Management Plan (SMP) for Lake Jocassee. Development of the SMP is targeted to be completed by the end of 2006.

- Duke Power will consult with the SCDNR, the USFWS and others during the development of the SMP to ensure that the plan is consistent with protecting and enhancing the scenic, recreational and environmental values of the project.

Function

Shoreline management planning at Lake Jocassee will provide for the protection of scenic, recreational and environmental values.

Appendix C

Fish community assessment study: FERC required fish entrainment modification, Keowee-Toxaway Hydroelectric Project FERC No. 2503

FISH COMMUNITY ASSESSMENT STUDY
FERC REQUIRED FISH ENTRAINMENT MODIFICATION

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT
FERC NO. 2503

October 2013

FISH COMMUNITY ASSESSMENT STUDY

FERC REQUIRED FISH ENTRAINMENT MODIFICATION

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APPENDICES

BACKGROUND

On January 27, 2012, the Federal Energy Regulatory Commission (FERC) issued Study Plan Determination for the Keowee-Toxaway Hydroelectric Project (Determination) that included Staff Recommendations on Proposed and Requested Study Modifications to Duke Energy's Keowee-Toxaway Hydroelectric Project's Revised Fish Community Assessment Study Plan (December 22, 2011). In this Determination, the FERC approved the revised Fish Community Assessment Study Plan with several modifications. The FERC directed Duke Energy to determine the effect of project operations at the Jocassee Pumped Storage Station (JPSS) on the fisheries in Lake Jocassee and Lake Keowee and directed the specific methodology, in addition to that proposed by Duke Energy, to accomplish this objective. The FERC recommend methodology included:

1. Use of hydroacoustic monitoring near the intakes to estimate numbers of fish entrained under the range of project operations to provide critical data to be used in estimating entrainment-related fish mortality;
2. Use of an Acoustic Doppler Current Profiler (ADCP) to describe current velocities around the intakes across operational scenarios to allow Duke Energy to relate velocity data to historical generation and pumping rates; and
3. Desktop entrainment mortality estimation, based on pump-turbine characteristics and the species and sizes of fish being entrained, to provide a mortality rate for entrained fish.

This report fulfills the FERC Staff Recommendations in Duke Energy's effort to determine the effect of JPSS's operations on the fishery resources in Lake Jocassee and Lake Keowee.

CHAPTER 1

FISH COMMUNITY ASSESSMENT STUDY PLAN – FISH ENTRAINMENT

KEOWEE-TOXAWAY PROJECT

FERC NO. 2503

Prepared by

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For

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July 26, 2013

CHAPTER ONE

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INTRODUCTION

This report fulfills the Federal Energy Regulatory Commission's request (January 27, 2012 Study Plan Determination for the Keowee-Toxaway Hydroelectric Project) for Duke Energy to use hydroacoustic monitoring near the Jocassee Pumped Storage Station (JPSS) intakes to estimate fish entrainment under the range of project operations to provide critical data to be used in estimating entrainment-related mortality.

METHODS

To estimate fish entrainment at the four-unit Jocassee Pumped Storage Station (JPSS), four Simrad 333-kHz frequency multiplexing sonar systems with four 7° circular split beam transducers each were deployed at the station, one system at each intake tower and two in the tailwater. For generation, four transducers (over intake bays 1, 3, 5, and 7) were mounted on each of the two intake towers in Lake Jocassee (Figure 1-1). For pumping, eight transducers (2 of the 3 discharge bays per unit) were mounted over the discharge bays in Lake Keowee (Figure 1-2). All transducers were pitched out from the intake and discharge walls by 8° to 10° to sample as close to the intake opening as possible without influence from the structure. Hydroacoustics sampling was triggered by hydro unit startup and ended with unit shutdown. An automated subsampling program controlled the operation of each of the four sonar systems to allow transmitting on two of the four transducers at one time (sampling 50% of the operational time on each transducer). This resulted in sampling 50% of the intake tower bays during 50% of generation, and 67% of the discharge bays during 50% of pump operation. Raw data were written to file for storage and transferred periodically to an offsite location for processing. Sampling parameters for all four sonar systems were the same: power level = 50 W, pulse duration = 0.256 msec.

The sonar systems were calibrated by Simrad prior to shipment and in situ calibrations were performed at the initial installation in June 2012, and again in August and October 2012, and June 2013. Calibrations for any transducer with differences greater than 0.5 dB from the expected echo strength of the 38.1mm tungsten carbide calibration sphere were offset during data processing. Data were processed using EchoView version 5.3 with the fish tracking module. Single echoes were detected with parameters in Table 1-1 and then tracked using the α-β tracking algorithm in Echoview. Single echo parameters were set to include as many echoes from fish traces as practical without including off-axis echoes from structures. Data processing involved enumerating fish tracked through the transducer beam and filtering to remove fish not classified as entrained based on the following criteria.

Tracked fish are considered entrained if all of the following 3 criteria are met:

1. **Corresponding hydro unit** is operating at the time the fish is observed, i.e., if the fish is observed at
   a. Generation intakes on Tower A: Unit 1 or Unit 2 generating
   b. Generation intakes on Tower B: Unit 3 or Unit 4 generating
   c. Pump intake of Unit 1 Cabinet 3 transducers 1 or 2: Unit 1 pumping
   d. Pump intake of Unit 2 Cabinet 3 transducers 3 or 4: Unit 2 pumping
   e. Pump intake of Unit 3 Cabinet 4 transducers 1 or 2: Unit 3 pumping
   f. Pump intake of Unit 4 Cabinet 4 transducers 3 or 4: Unit 4 pumping

2. **Horizontal direction** of movement relative to the wall of the intake. To be considered entrained the trajectory of the tracked fish has to have a horizontal direction > 120° and < 240° (Figure 1-3).

3. **Elevation** relative to the top of the intake. The mean elevation of the fish over the time it is tracked has to be 3 ft above the top of the intake opening or lower in the water column. **Vertical direction** of movement is a conditional filter. The range is 3 ft above the top of the intake to the intake top and all fish moving horizontally or moving deeper are considered entrained, while those moving shallower are not counted as entrained.

Numbers of fish entrained are expanded to account for the unensonified portion of sampled bays, bays not sampled, and time not sampled. To estimate the total number of fish entrained the number of tracked fish that met the entrainment criteria was expanded proportionately to compensate for:

1. **The effective beam width** (which is a function of fish size and range) **relative to the width of the intake sampled.** For example, if an entrained fish was observed at a range where the effective beam width for a fish of its size was half the width of the intake, it would be counted as 2 fish in the final estimate.

2. **The proportion of intakes sampled at any given time** (when data was being recorded as scheduled). At the generation intake towers 4 of 8 intakes were sampled 50% of the time. Thus the number of entrained fish tracked at the generation intakes was multiplied by 4 to estimate the total number of fish entrained. At the pump intakes 2 out of 3 intakes were sampled 50% of the time per unit. Thus the number of entrained fish tracked at the pump intakes was multiplied by a factor of 3.

3. **The proportion of time sampled.** Due to equipment problems, scheduled data collection was disrupted on several occasions. The final estimate was expanded in proportion to the time missed.

Estimates of fish length are calculated from Love's dorsal aspect equation (Love 1971) for a 333-kHz frequency;

$$Fish\ length\ (inches)\ =\ 10\hat{}((TS+26.1)/19.1)*1000)/25.4$$

where TS is the mean split beam corrected acoustic size for all echoes within a fish track.

We separated entrainment into day and night periods based on the sunrise/sunset times at JPSS for each calendar day. The total entrainment is the sum of the day and night entrainment, the entrainment rate and the sample percentage for each month is a weighted average of the day and night entrainment rates and the sample percentage is weighted by the number of hours of operation for each period.

The post startup entrainment distribution of fish passage is calculated as the time between hydro unit startup for any unit within a cabinet and the time an individual fish is observed and counted as entrained. This value is calculated by summing the expanded number of fish in 15-minute intervals after any generation or pump has started. This calculation resets the startup time after a second or subsequent hydro unit begins operating within a cabinet. This separates the effect of startup by intake tower on the generation side, and Units 1 and 2 from Units 3 and 4 on the pump side.

Entrainment rate is calculated for single and multiple hydro unit operation for both generation and pumping. The generation entrainment rate is calculated for each intake tower separately by dividing the number of fish entrained per month by the number of hours of operation. Rates are calculated separately for each hydro unit and for two unit operation at each tower. No estimate is made for multiple hydro unit operation between the towers. Pump entrainment rates are calculated as the mean of the daily entrainment rate and sorted by the number of hydro units operational each day.

Total fish entrainment is then corrected for turbine mortality using information from turbines similar to those at JPSS (Appendix A) to provide fish mortality estimates by month. We used the 9,050 cfs maximum discharge with a correlation factor of 0.15 for calculating the generation survival and 7,050 cfs maximum discharge with a 0.15 correlation factor for pumping survival. These values provided the lowest survival (i.e., highest mortality) presented in the Entrainment Survival Report. To calculate the monthly generation and pump mortality, the percentage survival by fish size group was multiplied by the percentage of fish within each size group for the month and this weighted mean survival was subtracted from 1 to obtain the monthly percent mortality. This was then multiplied by the expanded monthly generation and pump entrainment estimate to provide the monthly mortality estimate.

RESULTS

Fish entrainment and mortality estimates during 4,595 hours of generation operation spanning the period July 2012 through June 2013 are 552,894 and 13,253 fish, respectively (Table 1-2). In 5,904 hours of pumping an estimated 1,519,102 were entrained and 24, 328 fish were killed in the same period. Monthly generation entrainment rates ranged from 55 to 189 fish per hour, and pump rates ranged from 61 to 468 (Table 1-2).

Night entrainment rates were generally higher than day rates for both generation and pump operation (Table 1-3, Figure 1-4). Because of the higher rates during night, the total generation entrainment was similar for day and night (272,443 vs. 280,451) although 70% of the number of operation hours was during day. Ninety-three percent of the pump entrainment occurred at night when 83% of the pumping occurred.

Generation entrainment by hydro unit was similar for the four units (Table 1-4), although extreme events negatively influenced the relationship (Figure 1-5). Entrainment rates with both hydro units operating within a tower did not result in higher entrainment rates during the day, but rates were slightly higher when both units operated during the night.

Night pump entrainment rates were always highest for Unit 4, excepting day pumping in May and June 2013 and night pumping in June 2013 (Table 1-5). Rates for Unit 4 were 2 to 4 times the other units between September and March, but only 1 to 2 times in late spring and summer months. Pumping with multiple units resulted in higher entrainment rates than with a single unit (Table 1-6), but pumping with 2, 3, or 4 units were not different.

Entrainment rates at unit start up were similar to rates over the first 2 to 3 hours of operation during generation and then declined over time. Entrainment rates during pumping were higher at start up and declined over time, excepting November and December (Figure 1-6).

Entrained fish were small, 45 to 50% were in the 2-4 inch size bin (Figure 1-7). Seventy-one percent of fish entrained by generation were less than 6 inches, and 86% of the pump fish were less than 6 inches. These size distributions were slightly larger than those determined by in situ purse seine collections from both reservoirs in September and November 2012 and March 2013 (Appendix C). Converting acoustic size to fish length using Love's dorsal aspect equation is the likely cause of this difference in sizes. Threadfin shad and blueback herring were the dominant forage species in all purse seine collections.

DISCUSSION

The hydroacoustic data we processed was overall of high quality with noise levels sufficiently low to readily permit fish tracking. However, low-level noise on Unit 1, transducer 1 in the discharge was generally higher due to entrainment of air bubbles in station sump water releases near this transducer. This higher noise level was not apparent on the second transducer on Unit 1. Observations from the behavior of the fish near the discharge structure during JPSS operation lead us to believe most fish in the tailwater in the hydroacoustic beam are moving towards the discharge bay opening during pumping with a single or multiple hydro units operating. Water velocities at these depths average 4 feet per second (Appendix B) equaling or exceeding the burst swimming speed of forage fish typically found in lakes Jocassee and Keowee (Appendix A). As a result, the fish near bottom move straight into the opening, or move up in the water column, while fish near the top half of the opening move deeper. Fish more than 3 feet above the opening generally appear to be swimming parallel to the wall.

Fish of all sizes at the intake towers however, behave differently in that with a single hydro unit operating, the fish appear to be swimming away from, towards, and along the intake structure when viewing direction of movement with the split beam data. We also observed what appeared to be larger fish moving up from the bottom in front of the intakes and then back to the bottom and considered these resident non-entrained catfish unless their last observed direction of movement was towards the intake opening. Additionally, we also observed larger fish at or above the intake opening swim parallel to the structure, but generally not towards the intake opening. These behaviors are more indicative of milling fish that may be feeding in the area and were not considered entrained unless their last observed direction of movement was towards the intake opening. Large schools of smaller fish were in the intake area throughout the entire study. Most of these schools would swim across the intake opening but not demonstrate the characteristic movement of diving towards the opening exhibited by entrained fish. Occasionally, these schools would move towards the intake and exhibit this 'diving' behavior, resulting in very high daily entrainment. Water velocities measured by Acoustic Doppler Current Profiler average 0.48 and 1.08 feet per second with one and two units of generation, respectively (Jocassee Velocity Report, Appendix B), and appear to support the observations that water velocities are below the sustained and burst swimming speeds for most of the fish in the intake area (Normandeau 2013, Appendix A).

CONCLUSION

This 12-month study of fish entrainment at JPSS generally occurred in the midst of a long-term drought when the Jocassee surface elevation was between 24 and 28 ft below full pond. This lake elevation put the entire Jocassee epilimnetic forage fish population in close proximity to the intake openings during generation and would classify this study as a worst-case situation. To avoid potentially underestimating fish entrainment at this project, we:

1. Did not exclude fish (i.e., large fish) that have swimming speeds greater than the water velocity at the point where the acoustics is sampling,

2. Did not exclude fish near the intake top that are moving in a trajectory that would escape the intake,

3. Used the highest mortality estimate available for the JPSS turbines to calculate entrainment mortality, and

4. Used the larger, acoustically measured, length frequency distribution of entrained fish that would estimate higher fish mortality compared to the shorter, historically

supported, length frequency distribution of purse seine collected fish that would have the lowest mortality rates.

In consideration of these very conservative fish entrainment assumptions, we believe the 12-month mortality estimate provided for JPSS (13,253 killed during generation and 24,328 killed during pumping) is indicative of the actual magnitude, but possibly higher than actually occurred.

TABLE 1-1. SINGLE TARGET ECHO DETECTION PARAMETERS

Parameter	**Value**
TS threshold	-60 dB
Pulse length determination level	6 dB
Minimum normalized pulse length	0.5
Maximum normalized pulse length	1.5
Maximum beam compensation:	12 dB
Maximum standard deviation of minor angle	2.0
Maximum standard deviation of major angle	2.0

TABLE 1-2. MONTHLY MORTALITY, ENTRAINMENT, AND ENTRAINMENT RATE, NUMBER OF HOURS OF OPERATION, AND ACOUSTIC SAMPLING PERCENTAGE FOR GENERATION AND PUMP OPERATION, JULY 2012-JUNE 2013.

	Total mortality		Total entrainment		Rate (fish/hr)		Operation (hours)		% sampled	
	Generation	Pump	Generation	Pump	Generation	Pump	Generation	Pump	Generation	Pump
July	1,113	6,164	49,332	346,820	96	468	514	741	57%	59%
August	1,372	4,361	47,640	272,317	109	425	437	641	95%	94%
September	1,200	2,657	44,797	165,355	106	329	421	503	96%	93%
October	1,108	2,789	39,582	193,481	89	400	446	483	90%	94%
November	1,365	1,969	61,780	120,928	187	331	331	365	85%	85%
December	678	1,183	28,615	75,891	105	237	274	320	95%	91%
January	1,270	1,121	61,529	74,033	189	187	325	397	88%	100%
February	1,014	228	45,733	14,489	162	61	282	236	98%	60%
March	697	803	32,652	53,053	102	121	287	391	89%	89%
April	1,487	698	57,751	44,553	133	82	433	542	99%	99%
May	1,125	686	56,898	47,139	157	80	363	591	99%	92%
June	823	1,669	26,586	111,044	55	160	483	695	97%	83%
Total	13,253	24,328	552,894	1,519,102			4,595	5,904		

TABLE 1-3. MONTHLY DAY AND NIGHT ENTRAINMENT, MORTALITY RATE, MORTALITY, AND ENTRAINMENT RATE FOR GENERATION AND PUMP OPERATION, JULY 2012-JUNE 2013.

	Entrainment				Mortality rate		Mortality				Entrainment rate			
	Generation		Pump		Generation	Pump	Generation		Pump		Generation		Pump	
Month	Day	Night	Day	Night			Day	Night	Day	Night	Day	Night	Day	Night
July	41,513	7,818	10,955	335,865	2.26%	1.78%	937	176	195	5,969	50	113	53	321
August	32,011	15,629	4,445	267,871	2.88%	1.60%	922	450	71	4,290	77	287	37	475
September	28,466	16,331	2,953	162,402	2.68%	1.61%	763	438	47	2,609	83	170	58	333
October	27,520	12,062	1,692	191,789	2.80%	1.44%	771	338	24	2,764	91	64	75	387
November	13,118	48,661	15,831	105,097	2.21%	1.63%	290	1,075	258	1,711	82	214	169	315
December	5,150	23,465	9,854	66,037	2.37%	1.56%	122	556	154	1,030	55	120	164	225
January	17,417	44,111	10,972	63,061	2.06%	1.51%	359	910	166	955	88	255	134	200
February	13,404	32,329	7,670	6,818	2.22%	1.58%	297	717	121	107	96	219	48	28
March	6,343	26,309	15,949	37,105	2.13%	1.51%	135	562	241	562	40	160	97	134
April	31,065	26,686	3,685	40,868	2.57%	1.57%	800	687	58	640	95	243	108	79
May	34,413	22,486	3,700	43,439	1.98%	1.45%	680	445	54	632	112	396	45	78
June	22,022	4,564	6,148	104,895	3.10%	1.50%	682	141	92	1,577	48	124	40	154
Total	272,443	280,451	93,855	1,425,247			6,758	6,495	1,481	22,846				
	552,894		1,519,102				13,253		24,328					

TABLE 1-4. GENERATION ENTRAINMENT RATE BY MONTH AND MEAN FOR THE ANNUAL STUDY BY INTAKE TOWER, DAY/NIGHT PERIOD, AND UNIT OPERATION.

			Tower A - Cab 2						Tower B - Cab 1					
	Generation hours		Day			Night			Day			Night		
	Day	Night	Unit 1	Unit 2	Both	Unit 1	Unit 2	Both	Unit 3	Unit 4	Both	Unit 3	Unit 4	Both
Jul-12	477	37	58	8	31	203			149	90	21	0	64	18
Aug-12	386	51	121	19	31	268	284	248	178	54	23	399	128	226
Sep-12	326	94	119	141	30	134	137	175	106	62	15	235	103	281
Oct-12	289	157	128	27	419	64	65	104	90	74	31	57	50	71
Nov-12	142	190	89	58	19	118	97	623	139	112	9	95	41	288
Dec-12	86	188	62	13	9	109	78	412	103	82	36	98	60	167
Jan-13	163	162	141	15	18	341	142	229	96	91	34	136	212	104
Feb-13	138	145	205	57	31	159	140	445	70	43	40	273	125	179
Mar-13	140	147	49	10	5	140	231	133	101	65	16	156	145	225
Apr-13	324	109	107	53	13	245	251	123	56	305	140	137	641	246
May-13	306	57	38	56	41	325	318	158	377	337	120	933	354	619
Jun-13	447	36	37	49	51	123	153	56	21	30	72	97	87	281
Mean	3,222	1,373	96	42	58	186	172	246	124	112	46	218	167	226

TABLE 1-5. MONTHLY PUMP ENTRAINMENT RATES BY INTAKE TOWER, DAY/NIGHT PERIOD, AND UNIT OPERATION.

	Day				Night			
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 1	Unit 2	Unit 3	Unit 4
Jul-12	35	0	48	80	270	123	278	484
Aug-12	55	0	52	70	190	272	435	734
Sep-12	34	3	49	91	127	238	236	537
Oct-12	11		0	125	137	169	258	680
Nov-12	73	156	148	213	186	79	176	554
Dec-12	59	39	150	255	129	46	122	451
Jan-13	117	119	97	191	127	89	138	375
Feb-13	37	38	10	89	24	0	12	49
Mar-13	63	8	71	134	65	68	86	248
Apr-13	30	11	132	140	43	60	84	113
May-13	12	54	25	95	35	118	71	76
Jun-13	31	59	42	39	107	160	193	151

NOTE: Highlighted cells show the highest rates by month and daylight period. Data were unavailable for missing cells.

TABLE 1-6. MONTHLY AND ANNUAL MEAN PUMP ENTRAINMENT RATES FOR ONE UNIT AND MULTIPLE UNIT PUMP OPERATION FOR DAY AND NIGHT PERIODS.

	Pump hours		Day				Night			
	Day	Night	1 unit	2 unit	3 unit	4 unit	1 unit	2 unit	3 unit	4 unit
Jul-12	111	630	15	69	111		265		533	508
Aug-12	106	536	45	67	72		417	617	438	503
Sep-12	49	454	52	39	72		87	237	398	364
Oct-12	14	469	3	78			104	333	341	410
Nov-12	80	285	48	225	223		97	262	342	325
Dec-12	60	261	56	267	91	167	102	215	298	377
Jan-13	82	315	155	106		176	68	126	229	211
Feb-13	112	124	15	52	120	65	18	38	71	
Mar-13	141	250	86	26	251	55	100	85	216	128
Apr-13	34	508	61	18	106		145	96	130	87
May-13	70	521	12	54	25	95	35	118	71	76
Jun-13	125	570	24	31	18	65	104	195	133	199
Mean	983	4,921	48	86	109	104	128	211	267	290

NOTE: Multiple Unit Operation is when two or more of the four units operate concurrently and the rates are averaged for the units operating. Data were unavailable for missing cells.

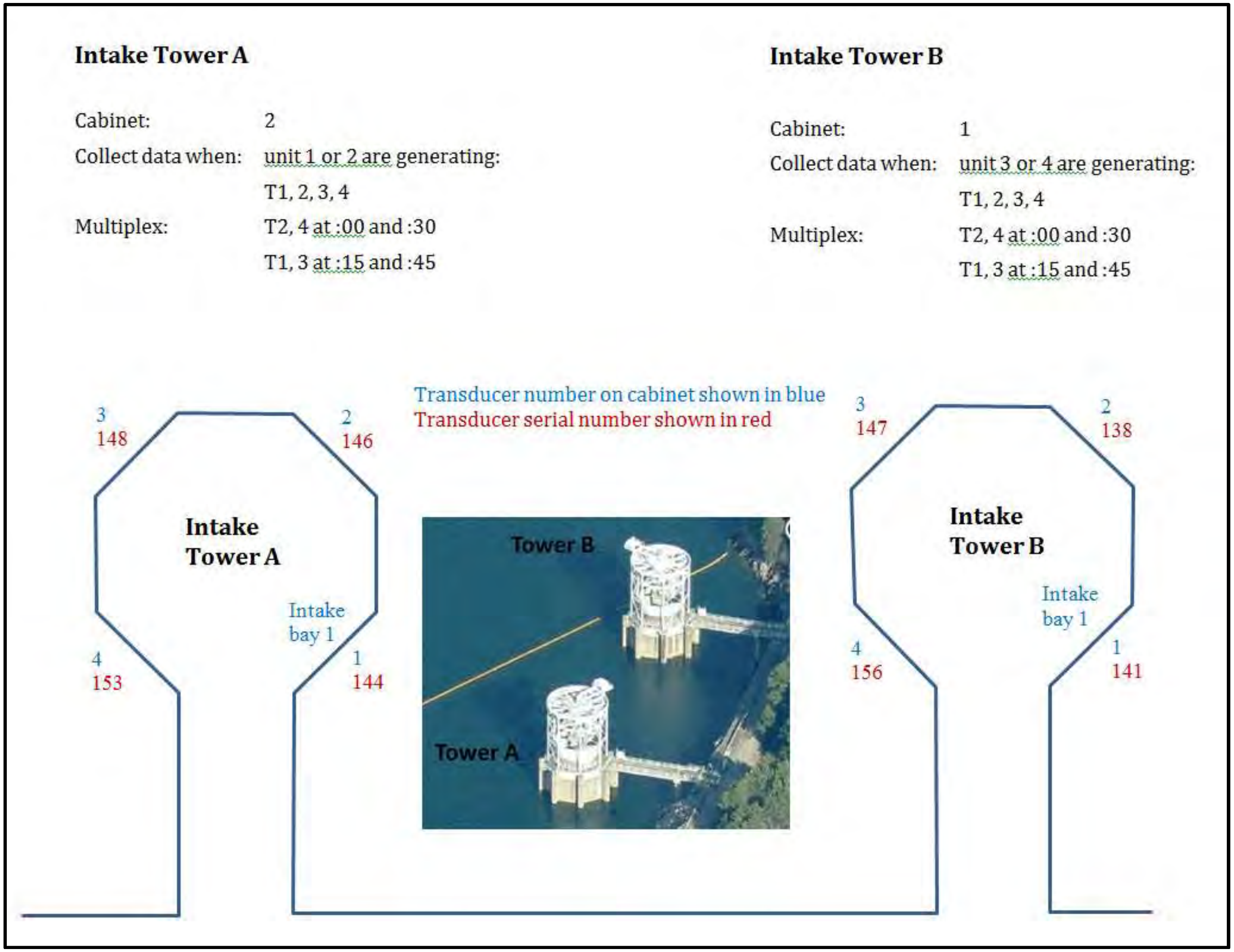

Figure 1-1. Schematic of the JPSS intake towers on Lake Jocassee, SC including transducer configuration and sampling sequence.

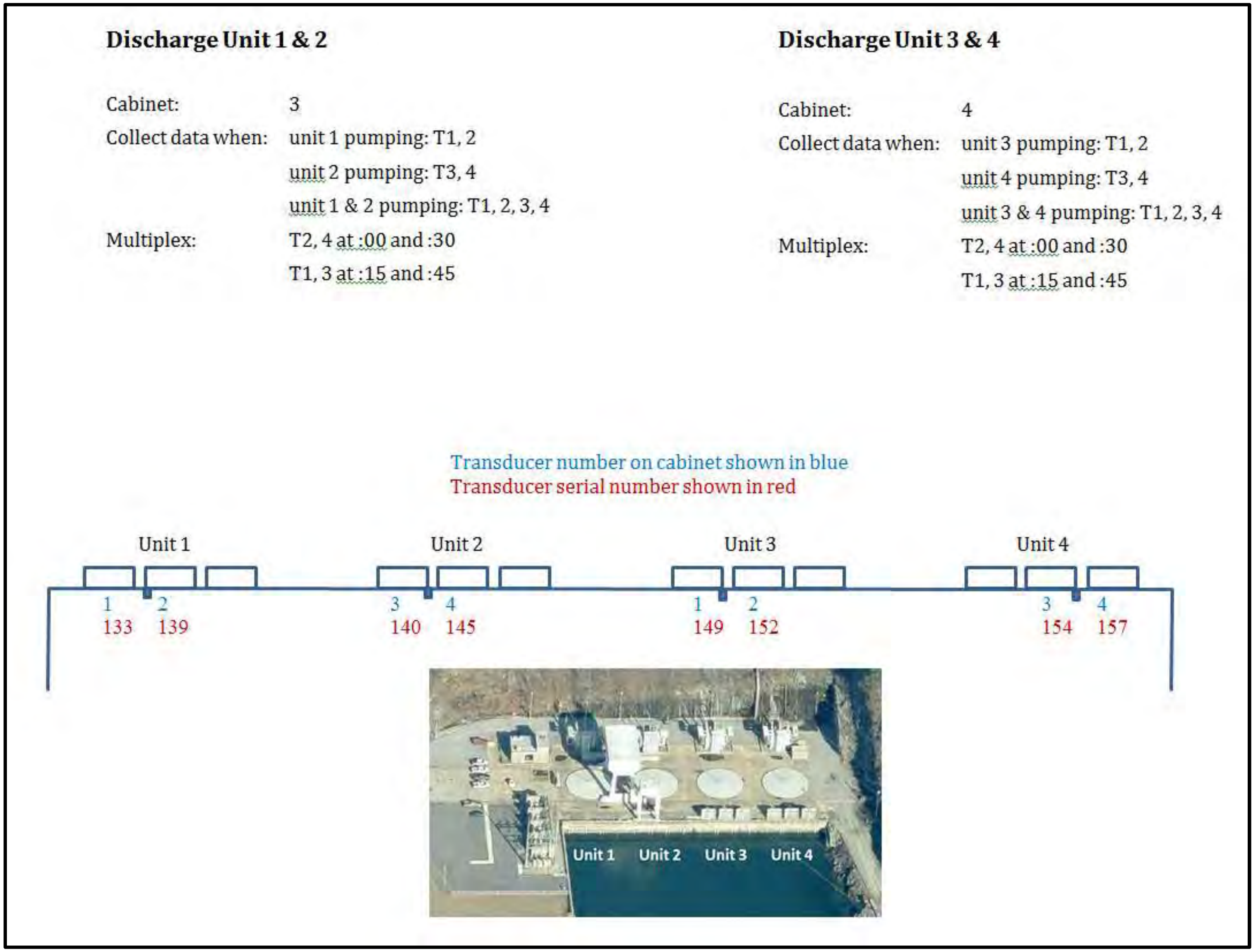

Figure 1-2 Schematic of the JPSS discharge structure on Lake Keowee, SC, including transducer configuration and sampling sequence.

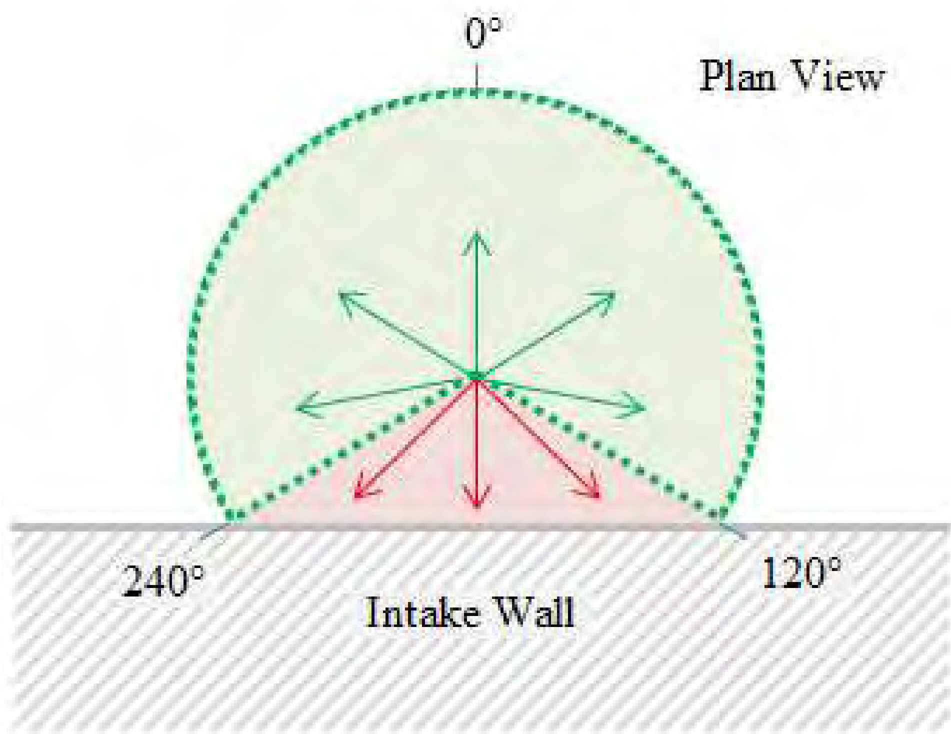

Figure 1-3. Sketch illustrating the definition of horizontal direction and which trajectories are considered to mark entrained fish. Red arrows represent examples of trajectories that are considered "entrained," green arrows are examples of "not entrained."

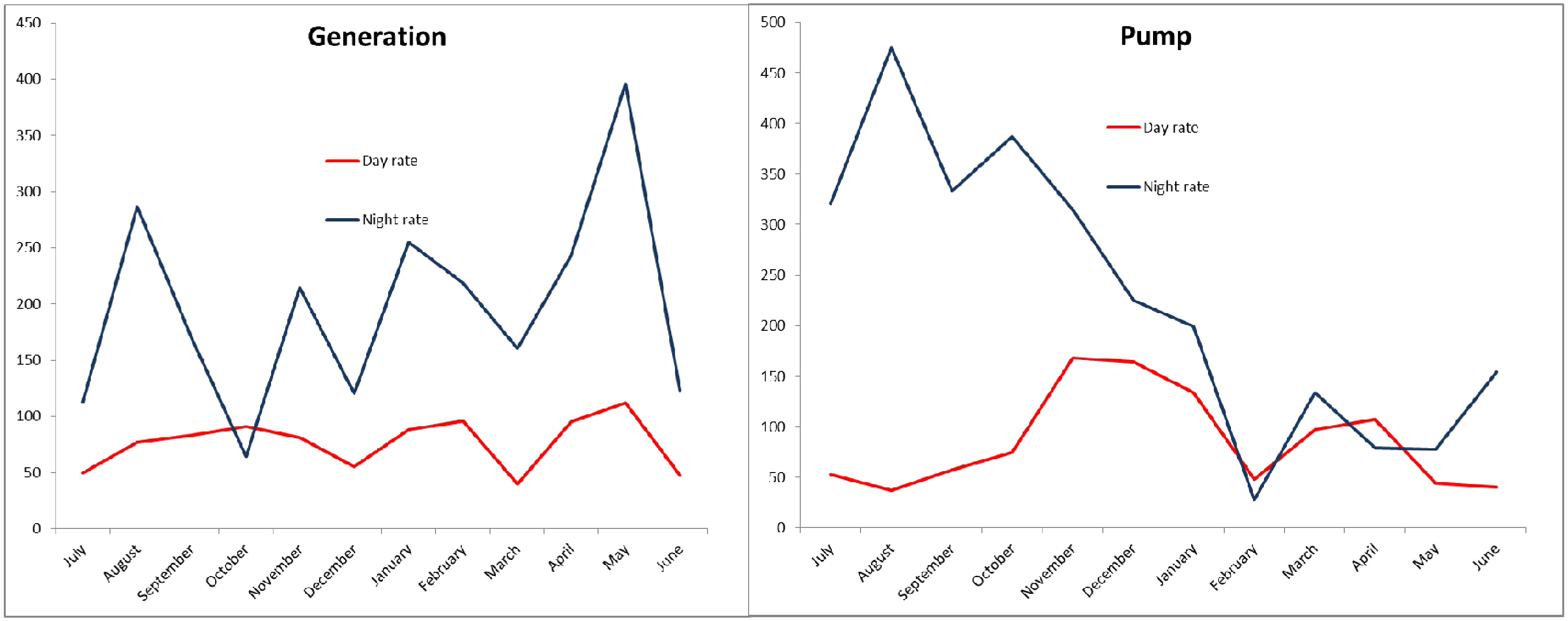

Figure 1-4. Day and night entrainment rates for generation and pumping at JPSS.

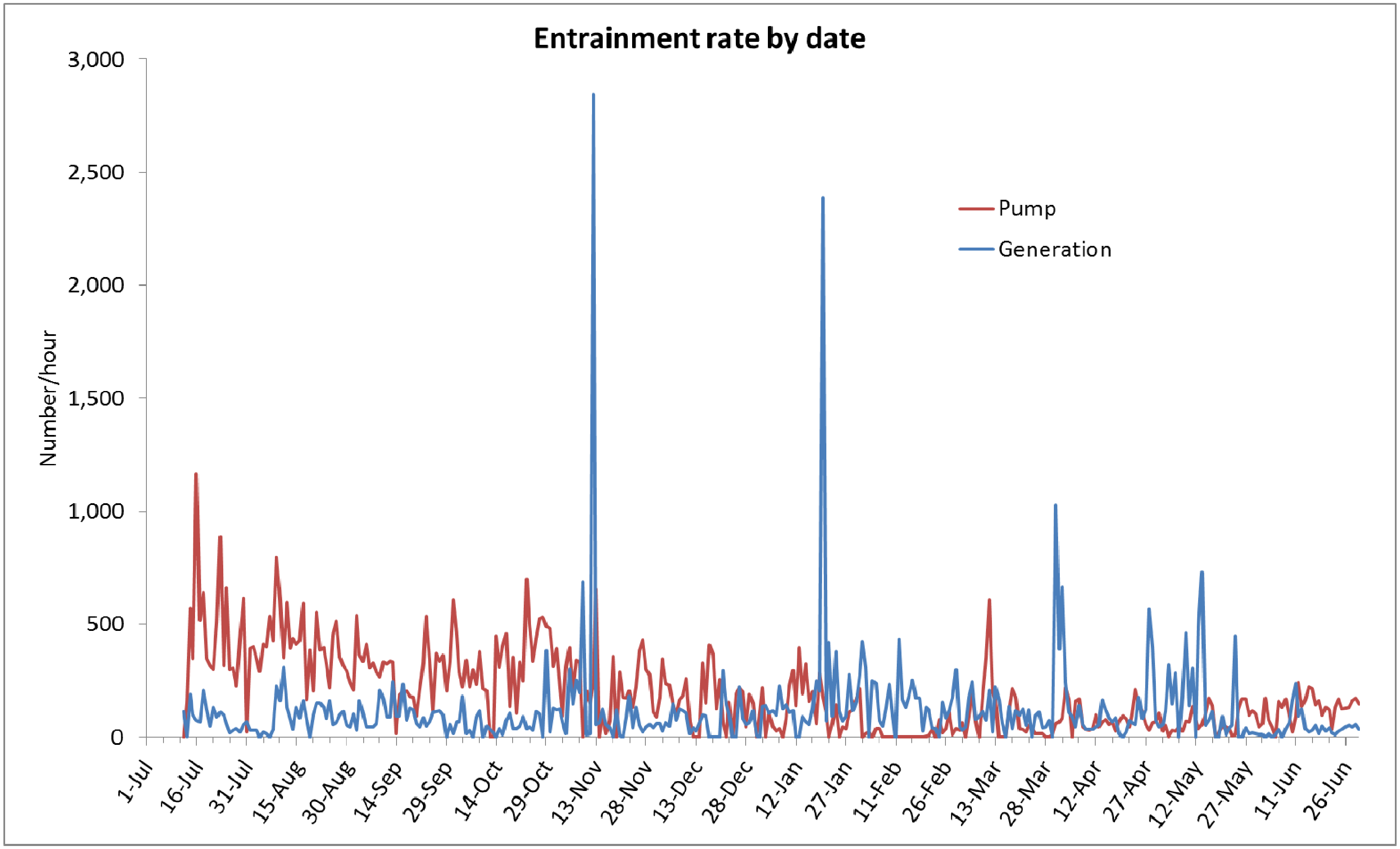

Figure 1-5. Daily entrainment rate for generation and pumping at JPSS July 2012 through June 2013.

	Generation												Pump											
Time	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
0:00	5.3%	5.5%	3.1%	3.2%	1.7%	3.0%	5.9%	17.0%	12.6%	4.6%	1.4%	2.6%	4.1%	4.0%	5.4%	3.8%	0.6%	0.5%	8.4%	4.4%	5.1%	7.6%	7.0%	8.4%
0:15	4.7%	3.1%	3.8%	2.6%	3.6%	3.7%	7.2%	9.1%	12.1%	5.2%	2.4%	3.6%	5.7%	5.0%	5.1%	5.9%	1.7%	0.6%	5.3%	7.8%	4.9%	5.9%	5.7%	6.6%
0:30	4.1%	2.5%	3.5%	4.9%	6.2%	8.1%	7.4%	8.2%	10.1%	6.4%	2.8%	6.6%	6.0%	5.4%	5.3%	6.3%	1.8%	0.8%	4.0%	6.3%	5.4%	4.6%	5.8%	6.2%
0:45	10.0%	3.0%	4.9%	3.6%	4.8%	3.6%	6.1%	5.8%	12.5%	7.2%	4.6%	2.5%	6.1%	5.6%	4.7%	5.6%	2.4%	2.3%	5.0%	6.8%	5.7%	5.1%	4.7%	6.5%
1:00	5.7%	3.6%	3.8%	4.5%	8.4%	8.6%	7.0%	8.5%	6.9%	7.2%	3.4%	4.2%	5.2%	6.0%	4.6%	6.0%	5.7%	5.3%	4.0%	4.1%	7.9%	5.3%	4.7%	5.8%
1:15	6.0%	3.7%	3.9%	5.4%	8.6%	5.8%	7.5%	5.6%	9.5%	8.9%	4.9%	3.5%	4.9%	5.8%	5.4%	4.6%	6.3%	4.9%	3.9%	5.0%	5.7%	5.9%	5.2%	5.2%
1:30	3.5%	3.3%	3.8%	4.8%	10.7%	6.8%	6.2%	6.3%	5.5%	9.4%	5.0%	3.9%	5.1%	5.4%	5.5%	4.8%	6.9%	6.4%	4.6%	3.2%	5.9%	5.8%	4.2%	4.7%
1:45	4.4%	2.7%	3.7%	5.0%	8.7%	4.8%	6.0%	6.2%	4.7%	7.2%	3.9%	2.1%	6.1%	5.1%	6.7%	4.9%	8.0%	5.8%	5.3%	4.1%	6.4%	5.3%	4.0%	4.0%
2:00	2.0%	2.7%	4.9%	4.4%	6.1%	5.7%	3.3%	5.4%	2.7%	4.3%	2.9%	4.0%	5.8%	5.0%	5.5%	5.4%	7.2%	7.0%	4.5%	2.9%	6.0%	5.6%	4.1%	3.8%
2:15	5.1%	3.3%	6.3%	5.4%	5.8%	5.2%	4.5%	4.1%	4.3%	3.7%	5.1%	5.0%	5.2%	4.1%	6.5%	4.7%	9.0%	7.7%	4.4%	3.4%	7.1%	5.6%	4.1%	3.1%
2:30	2.0%	2.8%	2.5%	5.7%	5.7%	6.4%	3.7%	4.6%	3.2%	3.4%	2.3%	6.0%	4.9%	4.7%	4.9%	4.6%	5.4%	6.9%	5.5%	3.9%	5.8%	4.6%	2.9%	3.3%
2:45	2.8%	4.0%	2.1%	4.1%	6.6%	4.9%	2.9%	6.7%	3.0%	1.5%	4.4%	4.4%	4.1%	4.1%	4.9%	4.3%	5.9%	6.6%	4.8%	2.5%	5.1%	4.4%	3.7%	3.1%
3:00	2.0%	3.5%	1.4%	4.9%	5.3%	5.4%	3.1%	2.7%	3.4%	1.8%	1.2%	3.4%	3.3%	4.1%	3.7%	4.2%	5.0%	4.5%	4.3%	2.8%	3.3%	4.2%	3.2%	3.4%
3:15	3.3%	2.7%	3.6%	2.8%	3.9%	3.7%	4.8%	1.7%	1.4%	1.6%	3.3%	4.4%	3.3%	3.8%	4.1%	3.9%	4.6%	5.8%	4.5%	4.5%	4.5%	3.5%	3.7%	3.3%
3:30	2.3%	2.2%	2.1%	3.0%	1.5%	4.7%	1.5%	1.5%	1.4%	1.3%	2.1%	2.6%	3.1%	3.7%	3.7%	4.2%	3.9%	5.7%	4.0%	2.8%	2.8%	3.2%	3.0%	3.4%
3:45	3.5%	2.9%	2.5%	1.9%	0.9%	4.7%	0.9%	1.3%	1.1%	0.8%	5.2%	1.4%	2.6%	3.2%	3.6%	3.6%	4.8%	6.1%	2.8%	2.9%	3.2%	3.3%	3.2%	2.9%
4:00	2.5%	2.8%	2.4%	2.9%	0.9%	4.0%	1.0%	1.2%	0.6%	1.4%	5.3%	1.0%	2.6%	2.9%	3.0%	3.4%	2.6%	3.8%	2.8%	3.7%	2.4%	2.6%	4.0%	3.0%
4:15	1.2%	3.3%	2.4%	2.3%	0.6%	2.9%	0.9%	0.8%	0.1%	1.2%	3.9%	2.9%	2.7%	2.5%	2.7%	2.9%	3.0%	4.0%	2.5%	5.3%	2.2%	2.3%	2.9%	2.9%
4:30	2.3%	4.8%	2.0%	2.3%	0.3%	2.4%	0.9%	0.7%	1.1%	1.3%	3.7%	3.1%	2.2%	2.6%	2.0%	2.6%	1.6%	2.9%	3.9%	6.0%	2.1%	2.1%	2.2%	2.3%
4:45	1.4%	3.1%	2.5%	3.0%	1.6%	1.6%	0.4%	0.6%	0.2%	2.3%	2.6%	1.6%	2.3%	2.4%	2.0%	2.3%	2.6%	3.2%	2.4%	3.1%	1.9%	2.4%	2.6%	2.4%
5:00	0.7%	2.3%	3.1%	1.5%	0.7%	0.4%	0.9%	0.5%	0.5%	1.9%	1.8%	1.4%	1.7%	1.9%	2.1%	2.2%	1.7%	2.2%	2.5%	3.1%	1.5%	1.7%	2.5%	2.1%
5:15	2.5%	0.9%	1.3%	1.9%	0.2%	0.9%	0.5%	0.5%	0.3%	1.6%	1.9%	1.7%	1.8%	1.4%	1.8%	2.0%	2.3%	2.6%	2.0%	2.2%	1.1%	1.5%	2.3%	1.7%
5:30	2.3%	1.3%	2.5%	3.1%	0.4%	0.4%	2.3%	0.3%	0.0%	1.5%	1.4%	1.9%	1.5%	1.6%	1.5%	1.5%	1.3%	1.5%	2.0%	2.6%	1.1%	1.1%	2.1%	1.7%
5:45	2.1%	1.9%	2.4%	1.0%	2.2%	0.1%	0.6%	0.2%	0.5%	3.9%	2.0%	1.3%	1.4%	1.3%	1.1%	1.2%	1.5%	1.5%	1.5%	2.5%	0.5%	1.5%	2.1%	1.6%
6:00	1.8%	2.3%	1.8%	0.9%	0.1%	0.0%	0.8%	0.1%	0.3%	0.6%	1.4%	1.9%	1.1%	1.1%	1.0%	1.2%	0.9%	0.8%	1.3%	1.1%	0.7%	1.2%	1.7%	1.2%

Figure 1-6. Entrainment for generation and pumping after unit startup with the red cells indicating the highest rates.

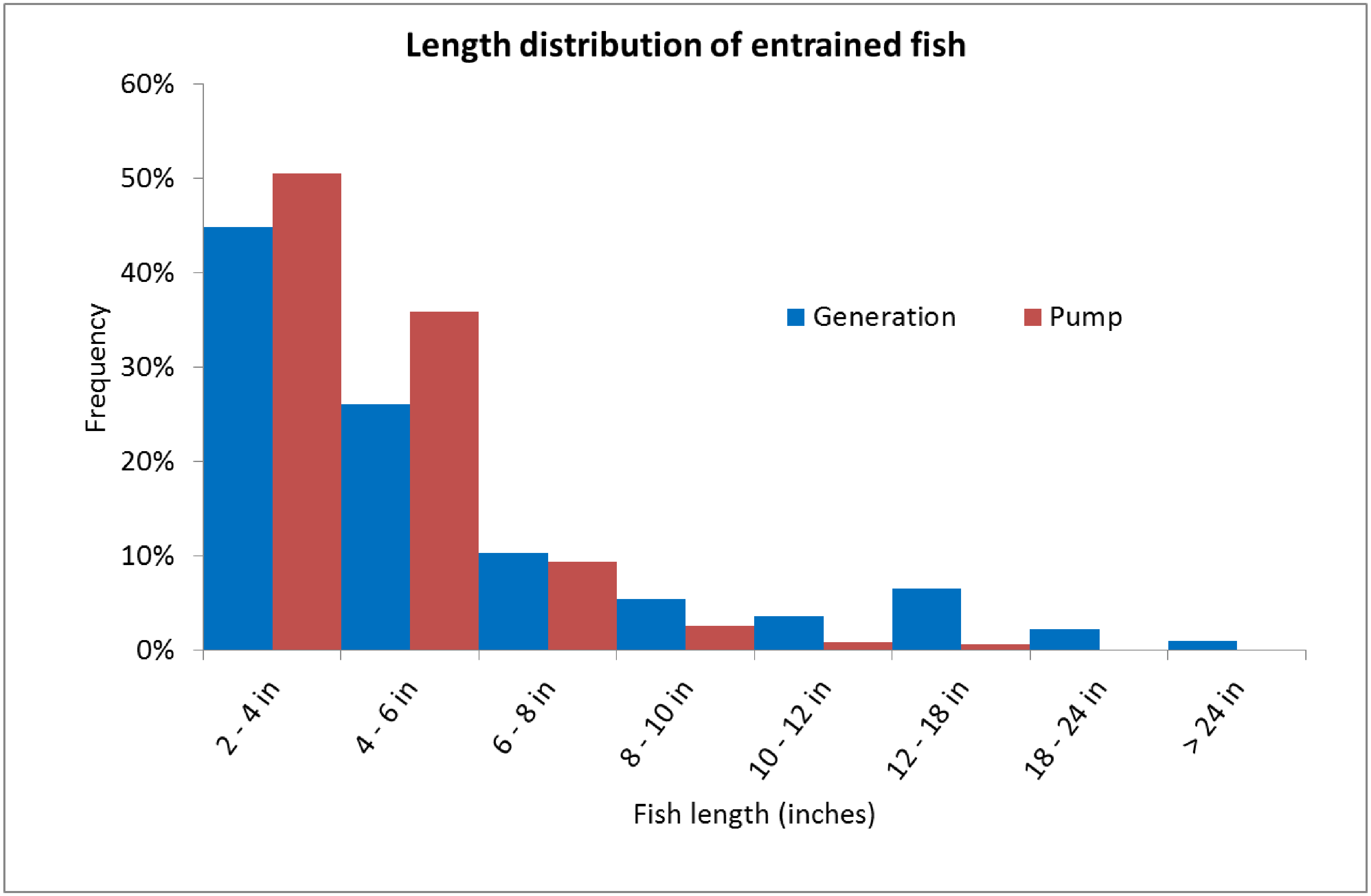

Figure 1-7. Fish length distribution for generation and pumping at JPSS July 2012 through June 2013.

REFERENCES

Love, R.H. 1971. Measurements of fish target strength: a review. Fisheries Bulletin, 69(4): 703-715.

APPENDIX TABLES

Appendix Table 1. Fish entrainment by date and unit at JPSS.

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jul	0	0	No Data	No Data	No Data	No Data
2-Jul	0	0	No Data	No Data	No Data	No Data
3-Jul	0	0	No Data	No Data	No Data	No Data
4-Jul	0	0	No Data	No Data	No Data	No Data
5-Jul	0	0	No Data	No Data	No Data	No Data
6-Jul	0	0	No Data	No Data	No Data	No Data
7-Jul	0	0	No Data	No Data	No Data	No Data
8-Jul	0	0	No Data	No Data	No Data	No Data
9-Jul	0	0	No Data	No Data	No Data	No Data
10-Jul	0	0	No Data	No Data	No Data	No Data
11-Jul	0	1,909	No Data	No Data	No Data	No Data
12-Jul	92	0	No Data	No Data	No Data	No Data
13-Jul	102	2,643	No Data	No Data	No Data	18
14-Jul	389	700	0	No Data	No Data	No Data
15-Jul	1,159	161	249	No Data	819	1,064
16-Jul	236	882	144	No Data	31	172
17-Jul	2,165	462	0	No Data	72	433
18-Jul	361	1,117	No Data	No Data	38	87
19-Jul	424	199	0	No Data	0	No Data
20-Jul	606	212	0	No Data	0	33
21-Jul	1,134	248	0	No Data	0	134
22-Jul	92	324	19	No Data	114	102
23-Jul	580	808	No Data	No Data	No Data	No Data
24-Jul	684	369	105	No Data	No Data	177
25-Jul	0	298	0	No Data	No Data	No Data
26-Jul	0	364	No Data	No Data	0	0
27-Jul	123	688	No Data	No Data	No Data	0
28-Jul	238	118	310	No Data	278	624
29-Jul	152	1,030	84	0	234	52
30-Jul	506	436	No Data	0	No Data	No Data
31-Jul	1,157	647	0	No Data	218	303
Total	**10,200**	**13,617**	**910**	**0**	**1,805**	**3,200**
Combined Total	**23,817**		**5,916**			
Monthly Total	**41,513**		**10,955**			
Total mortality	**937**		**195**			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jul	0	0	No Data	No Data	No Data	No Data
2-Jul	0	0	No Data	No Data	No Data	No Data
3-Jul	0	0	No Data	No Data	No Data	No Data
4-Jul	0	0	No Data	No Data	No Data	No Data
5-Jul	0	0	No Data	No Data	No Data	No Data
6-Jul	0	0	No Data	No Data	No Data	No Data
7-Jul	0	0	No Data	No Data	No Data	No Data
8-Jul	0	0	No Data	No Data	No Data	No Data
9-Jul	0	0	No Data	No Data	No Data	No Data
10-Jul	0	0	No Data	No Data	No Data	No Data
11-Jul	0	0	No Data	No Data	No Data	No Data
12-Jul	0	0	No Data	No Data	No Data	2,221
13-Jul	0	0	1,137	No Data	3,711	5,817
14-Jul	0	0	2,870	No Data	334	4,239
15-Jul	0	0	4,943	No Data	7,537	12,930
16-Jul	0	0	1,889	2,887	4,308	6,873
17-Jul	789	61	3,129	2,039	3,298	5,386
18-Jul	389	279	2,263	No Data	2,200	5,009
19-Jul	441	141	1,298	1,143	2,097	3,122
20-Jul	0	0	1,032	1,662	1,447	3,496
21-Jul	0	0	1,407	No Data	1,208	4,518
22-Jul	262	0	3,222	No Data	2,154	6,108
23-Jul	173	0	132	No Data	2,074	2,904
24-Jul	48	22	2,949	No Data	4,077	8,255
25-Jul	0	0	2,361	1,188	2,713	4,915
26-Jul	0	106	1,808	No Data	2,994	5,113
27-Jul	0	0	2,264	0	1,097	2,635
28-Jul	47	80	1,964	No Data	3,397	4,524
29-Jul	0	0	2,229	2,639	3,917	6,441
30-Jul	0	0	517	0	No Data	No Data
31-Jul	1,185	209	374	No Data	3,598	6,242
Total	**3,335**	**898**	**37,790**	**11,558**	**52,159**	**100,748**
Combined Total	**4,233**		**202,255**			
Monthly Total	**7,818**		**335,865**			
Total mortality	**176**		**5,969**			

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Aug	184	84	0	No Data	168	0
2-Aug	277	204	82	No Data	11	82
3-Aug	158	65	0	0	14	0
4-Aug	0	0	No Data	No Data	No Data	130
5-Aug	0	129	No Data	No Data	No Data	153
6-Aug	0	183	No Data	No Data	0	No Data
7-Aug	0	0	No Data	No Data	No Data	No Data
8-Aug	325	85	220	No Data	0	No Data
9-Aug	0	2,098	0	0	No Data	No Data
8-Aug	857	1,547	No Data	No Data	No Data	No Data
11-Aug	0	3,024	0	No Data	384	0
12-Aug	652	311	31	No Data	247	432
13-Aug	398	778	No Data	0	No Data	11
14-Aug	5	0	0	No Data	0	0
15-Aug	528	0	No Data	No Data	No Data	0
16-Aug	235	555	0	No Data	95	138
17-Aug	1,460	306	No Data	No Data	No Data	No Data
18-Aug	437	363	450	No Data	No Data	No Data
19-Aug	0	0	34	No Data	61	177
20-Aug	1	186	No Data	No Data	0	0
21-Aug	1,780	177	No Data	No Data	No Data	No Data
22-Aug	616	1,105	No Data	No Data	No Data	31
23-Aug	1,768	276	No Data	No Data	No Data	26
24-Aug	372	450	No Data	No Data	49	184
25-Aug	685	450	No Data	No Data	35	0
26-Aug	413	272	0	No Data	80	539
27-Aug	520	347	No Data	No Data	No Data	No Data
28-Aug	969	461	15	No Data	No Data	0
29-Aug	456	1,488	60	No Data	6	No Data
30-Aug	553	339	No Data	0	No Data	0
31-Aug	529	164	No Data	No Data	0	No Data
Total	**14,179**	**15,446**	**891**	**0**	**1,149**	**1,903**
Combined Total	**29,626**		**3,943**			
Monthly Total	**32,011**		**4,445**			
Total mortality	**922**		**71**			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Aug	199	0	1,640	No Data	1,876	5,817
2-Aug	0	74	2,250	0	2,401	5,499
3-Aug	0	229	1,576	2,106	3,255	5,452
4-Aug	0	0	No Data	No Data	No Data	2,274
5-Aug	0	0	No Data	No Data	1,143	2,987
6-Aug	0	0	No Data	No Data	2,987	No Data
7-Aug	0	0	No Data	No Data	2,864	2,756
8-Aug	0	0	1,243	No Data	2,940	3,762
9-Aug	231	1,943	1,400	2,667	9,521	9,460
8-Aug	642	77	822	1,520	4,825	7,116
11-Aug	612	925	691	No Data	2,018	4,573
12-Aug	337	624	398	No Data	3,829	6,873
13-Aug	0	148	No Data	No Data	6,661	7,303
14-Aug	542	0	678	No Data	2,316	5,557
15-Aug	0	0	626	No Data	1,741	3,946
16-Aug	291	292	767	No Data	2,805	4,797
17-Aug	1,072	857	1,407	No Data	2,162	3,533
18-Aug	0	0	No Data	No Data	1,089	475
19-Aug	0	0	1,584	No Data	1,956	6,582
20-Aug	723	0	No Data	No Data	595	1,682
21-Aug	760	504	No Data	No Data	1,643	2,838
22-Aug	434	0	144	No Data	1,409	4,838
23-Aug	647	0	305	No Data	1,470	5,562
24-Aug	0	0	1,246	873	2,617	5,020
25-Aug	893	581	No Data	No Data	1,352	2,127
26-Aug	246	0	374	No Data	2,354	5,657
27-Aug	255	52	1,536	No Data	2,173	5,560
28-Aug	0	215	1,193	No Data	1,422	5,293
29-Aug	10	0	1,505	310	2,099	5,105
30-Aug	0	66	920	1,855	3,017	6,172
31-Aug	186	76	593	1,554	2,484	3,303
Total	**8,079**	**6,664**	**22,898**	**10,884**	**79,022**	**141,917**
Combined Total	**14,743**		**254,722**			
Monthly Total	**15,629**		**267,871**			
Total mortality	**450**		**4,290**			

Appendix Table 1, continued. Fish entrainment by date and unit at JPSS.

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Sep	642	598	No Data	No Data	265	0
2-Sep	192	0	56	0	227	422
3-Sep	1,075	373	0	No Data	0	0
4-Sep	1,477	284	No Data	No Data	No Data	No Data
5-Sep	363	153	No Data	0	48	No Data
6-Sep	189	153	No Data	No Data	No Data	No Data
7-Sep	468	161	No Data	No Data	No Data	No Data
8-Sep	333	194	0	No Data	56	21
9-Sep	2,111	103	0	11	33	318
10-Sep	1,327	111	No Data	No Data	No Data	68
11-Sep	399	1,113	No Data	No Data	No Data	No Data
12-Sep	674	255	No Data	No Data	No Data	55
13-Sep	1,830	1,627	0	No Data	No Data	No Data
14-Sep	894	100	No Data	No Data	No Data	No Data
15-Sep	116	119	208	0	No Data	No Data
16-Sep	478	194	180	No Data	0	333
17-Sep	70	0	No Data	No Data	No Data	No Data
18-Sep	175	768	No Data	No Data	No Data	No Data
19-Sep	695	0	No Data	No Data	No Data	No Data
20-Sep	291	0	No Data	No Data	No Data	87
21-Sep	0	432	No Data	No Data	No Data	No Data
22-Sep	1,006	255	0	No Data	No Data	260
23-Sep	0	280	12	No Data	0	190
24-Sep	105	75	No Data	No Data	No Data	No Data
25-Sep	563	403	No Data	No Data	No Data	No Data
26-Sep	342	544	No Data	No Data	No Data	No Data
27-Sep	605	851	No Data	No Data	No Data	No Data
28-Sep	1,284	289	No Data	No Data	No Data	No Data
29-Sep	0	0	No Data	No Data	No Data	0
30-Sep	0	68	No Data	No Data	No Data	No Data
Total	**17,703**	**9,502**	**456**	**11**	**628**	**1,752**
Combined Total	**27,205**		**2,847**			
Monthly Total	**28,466**		**2,953**			
Total mortality	**763**		**47**			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Sep	0	0	No Data	No Data	703	2,021
2-Sep	0	0	881	1,427	3,636	7,651
3-Sep	161	0	180	No Data	1,745	2,960
4-Sep	210	61	No Data	No Data	1,668	1,790
5-Sep	214	116	991	1,628	3,200	7,171
6-Sep	246	346	741	1,222	1,436	4,466
7-Sep	60	0	247	No Data	1,163	3,503
8-Sep	669	169	1,046	No Data	1,030	3,408
9-Sep	332	263	722	632	1,403	3,659
10-Sep	553	575	445	452	1,372	4,265
11-Sep	181	41	240	498	1,170	3,690
12-Sep	358	302	354	493	1,757	4,040
13-Sep	39	1,571	641	665	1,761	2,904
14-Sep	283	297	293	No Data	No Data	No Data
15-Sep	578	1,189	204	784	No Data	4,102
16-Sep	237	1,648	353	No Data	1,407	2,587
17-Sep	280	317	No Data	No Data	535	1,859
18-Sep	173	426	No Data	No Data	394	1,158
19-Sep	378	0	No Data	No Data	749	1,321
20-Sep	170	0	No Data	No Data	No Data	No Data
21-Sep	0	348	No Data	No Data	651	1,227
22-Sep	379	243	654	No Data	1,714	3,450
23-Sep	81	132	635	No Data	2,570	6,918
24-Sep	335	134	No Data	No Data	1,142	2,891
25-Sep	238	260	No Data	No Data	711	No Data
26-Sep	232	159	340	No Data	1,356	4,702
27-Sep	286	319	601	No Data	1,640	4,194
28-Sep	0	115	485	1,262	2,055	3,914
29-Sep	0	0	No Data	No Data	804	2,007
30-Sep	0	315	No Data	No Data	428	1,907
Total	**6,672**	**9,345**	**10,054**	**9,063**	**38,198**	**93,765**
Combined Total	**16,017**		**151,080**			
Monthly Total	**16,331**		**162,402**			
Total mortality	**438**		**2,609**			

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Oct	0	205	No Data	No Data	No Data	No Data
2-Oct	1,068	499	No Data	No Data	No Data	No Data
3-Oct	568	719	No Data	No Data	No Data	No Data
4-Oct	3,588	607	No Data	No Data	No Data	No Data
5-Oct	0	52	No Data	No Data	No Data	No Data
6-Oct	0	58	5	No Data	No Data	No Data
7-Oct	0	0	41	No Data	0	1,009
8-Oct	816	691	No Data	No Data	No Data	No Data
9-Oct	586	928	No Data	No Data	No Data	No Data
10-Oct	0	0	No Data	No Data	No Data	No Data
11-Oct	378	0	No Data	No Data	No Data	No Data
12-Oct	0	325	No Data	No Data	No Data	No Data
13-Oct	33	0	No Data	No Data	No Data	No Data
14-Oct	0	0	No Data	No Data	0	0
15-Oct	31	383	No Data	No Data	No Data	No Data
16-Oct	0	0	No Data	No Data	No Data	No Data
17-Oct	0	75	No Data	No Data	No Data	No Data
18-Oct	289	810	No Data	No Data	No Data	No Data
19-Oct	64	292	No Data	No Data	No Data	No Data
20-Oct	249	0	No Data	No Data	No Data	No Data
21-Oct	96	102	No Data	No Data	No Data	No Data
22-Oct	87	116	No Data	No Data	No Data	No Data
23-Oct	0	485	No Data	No Data	No Data	No Data
24-Oct	0	252	No Data	No Data	No Data	No Data
25-Oct	0	300	No Data	No Data	No Data	No Data
26-Oct	1,087	1,181	No Data	No Data	No Data	No Data
27-Oct	1,066	832	0	No Data	No Data	0
28-Oct	0	0	No Data	No Data	No Data	0
29-Oct	4,022	2,157	No Data	No Data	No Data	No Data
30-Oct	0	0	No Data	No Data	No Data	No Data
31-Oct	1,188	95	No Data	No Data	No Data	No Data
Total	**15,217**	**11,164**	**47**	**0**	**0**	**1,009**
Combined Total	**26,380**		**1,055**			
Monthly Total	**27,520**		**1,692**			
Total mortality	**771**		**24**			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Oct	15	27	No Data	No Data	1,581	3,434
2-Oct	59	169	468	33	2,123	6,490
3-Oct	359	107	581	742	2,117	4,345
4-Oct	325	491	609	No Data	662	3,045
5-Oct	170	22	511	No Data	1,266	4,029
6-Oct	124	318	542	No Data	1,302	3,927
7-Oct	0	0	819	No Data	1,750	4,602
8-Oct	747	300	288	No Data	682	2,723
9-Oct	241	216	409	508	1,634	4,522
10-Oct	0	0	No Data	No Data	544	2,208
11-Oct	211	0	No Data	No Data	711	1,107
12-Oct	0	0	No Data	No Data	No Data	No Data
13-Oct	0	0	No Data	No Data	No Data	No Data
14-Oct	0	0	348	No Data	2,121	6,747
15-Oct	66	245	No Data	No Data	1,286	2,249
16-Oct	56	0	No Data	No Data	1,831	327
17-Oct	275	139	342	No Data	1,123	6,387
18-Oct	396	446	335	No Data	No Data	1,971
19-Oct	106	156	540	No Data	930	3,098
20-Oct	0	65	No Data	No Data	No Data	631
21-Oct	65	173	No Data	No Data	937	2,304
22-Oct	417	566	No Data	No Data	1,084	361
23-Oct	121	96	522	548	2,927	10,325
24-Oct	205	458	1,016	769	2,385	7,317
25-Oct	227	31	975	No Data	1,405	4,571
26-Oct	492	24	903	966	2,644	5,071
27-Oct	0	0	1,740	No Data	2,560	6,840
28-Oct	0	0	2,065	946	3,506	8,565
29-Oct	804	175	No Data	No Data	2,361	4,042
30-Oct	61	117	442	No Data	1,269	6,576
31-Oct	133	42	105	No Data	0	3,005
Total	**5,676**	**4,383**	**13,561**	**4,511**	**42,740**	**120,817**
Combined Total	**10,059**		**181,630**			
Monthly Total	**12,062**		**191,789**			
Total mortality	**338**		**2,764**			

Appendix Table 1, continued. Fish entrainment by date and unit at JPSS.

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Nov	0	101	No Data	No Data	No Data	No Data
2-Nov	521	76	No Data	No Data	No Data	No Data
3-Nov	134	276	No Data	No Data	No Data	No Data
4-Nov	0	0	No Data	No Data	0	122
5-Nov	316	2,150	No Data	No Data	No Data	No Data
6-Nov	159	2,184	No Data	No Data	No Data	No Data
7-Nov	147	0	No Data	No Data	No Data	25
8-Nov	263	187	No Data	No Data	No Data	100
9-Nov	68	1,307	No Data	No Data	No Data	No Data
10-Nov	26	0	No Data	No Data	1,504	1,008
11-Nov	28	0	No Data	No Data	No Data	No Data
12-Nov	0	0	0	No Data	0	No Data
13-Nov	0	0	No Data	No Data	No Data	No Data
14-Nov	714	16	No Data	No Data	No Data	No Data
15-Nov	256	67	No Data	No Data	No Data	No Data
16-Nov	35	0	No Data	No Data	17	No Data
17-Nov	16	0	No Data	No Data	No Data	No Data
18-Nov	0	0	No Data	No Data	89	0
19-Nov	0	0	No Data	No Data	No Data	No Data
20-Nov	0	47	No Data	No Data	No Data	No Data
21-Nov	0	0	No Data	No Data	No Data	No Data
22-Nov	40	711	334	427	1,056	0
23-Nov	563	0	No Data	No Data	1,306	No Data
24-Nov	139	0	No Data	No Data	184	1,181
25-Nov	197	22	206	No Data	637	2,925
26-Nov	140	58	No Data	No Data	No Data	No Data
27-Nov	75	0	No Data	No Data	No Data	No Data
28-Nov	174	23	No Data	No Data	No Data	No Data
29-Nov	94	26	No Data	No Data	486	1,045
30-Nov	203	0	No Data	No Data	147	647
Total	4,308	7,249	540	427	5,425	7,053
Combined Total	11,557		13,446			
Monthly Total	13,118		15,831			
Total mortality	290		258			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Nov	1,203	295	316	No Data	742	3,550
2-Nov	1,635	91	No Data	No Data	696	1,310
3-Nov	146	250	No Data	No Data	8	497
4-Nov	16	0	No Data	No Data	1,106	4,881
5-Nov	3,947	640	No Data	No Data	2,197	2,204
6-Nov	142	275	150	0	477	1,698
7-Nov	849	1,565	710	393	2,276	6,219
8-Nov	159	1,194	158	No Data	589	4,910
9-Nov	79	2,805	No Data	No Data	0	No Data
10-Nov	36	0	No Data	No Data	358	No Data
11-Nov	0	0	No Data	No Data	785	1,246
12-Nov	15,727	111	507	No Data	1,162	3,442
13-Nov	273	101	2,869	No Data	995	6,029
14-Nov	325	51	0	No Data	No Data	No Data
15-Nov	1,014	252	678	No Data	No Data	No Data
16-Nov	731	0	No Data	No Data	No Data	No Data
17-Nov	89	350	0	No Data	190	0
18-Nov	0	0	2,428	No Data	683	5,560
19-Nov	621	56	No Data	No Data	No Data	No Data
20-Nov	29	0	No Data	No Data	1,484	No Data
21-Nov	0	0	No Data	No Data	800	No Data
22-Nov	0	0	42	0	1,528	1,729
23-Nov	1,276	0	92	No Data	321	932
24-Nov	217	0	No Data	No Data	137	No Data
25-Nov	1,796	237	0	No Data	0	271
26-Nov	160	38	874	No Data	957	4,358
27-Nov	144	108	808	No Data	283	6,516
28-Nov	402	151	No Data	No Data	2,090	1,435
29-Nov	824	0	No Data	No Data	1,639	1,144
30-Nov	209	0	No Data	No Data	237	No Data
Total	32,050	8,570	9,632	393	21,742	57,932
Combined Total	40,619		89,699			
Monthly Total	48,661		105,097			
Total mortality	1,075		1,711			

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Dec	181	0	No Data	No Data	No Data	290
2-Dec	49	0	No Data	No Data	0	0
3-Dec	46	0	No Data	No Data	No Data	No Data
4-Dec	81	276	No Data	No Data	No Data	No Data
5-Dec	0	0	No Data	No Data	No Data	No Data
6-Dec	16	0	No Data	No Data	No Data	No Data
7-Dec	0	0	No Data	No Data	No Data	No Data
8-Dec	101	0	No Data	No Data	No Data	No Data
9-Dec	0	0	No Data	No Data	No Data	No Data
10-Dec	0	186	No Data	No Data	No Data	No Data
11-Dec	0	0	No Data	No Data	No Data	No Data
12-Dec	186	0	No Data	No Data	No Data	No Data
13-Dec	0	104	No Data	No Data	No Data	No Data
14-Dec	18	242	No Data	No Data	No Data	No Data
15-Dec	352	0	No Data	No Data	449	2,799
16-Dec	27	76	No Data	No Data	No Data	No Data
17-Dec	0	0	No Data	No Data	No Data	No Data
18-Dec	0	0	No Data	No Data	No Data	No Data
19-Dec	0	0	No Data	No Data	No Data	No Data
20-Dec	0	0	No Data	No Data	No Data	No Data
21-Dec	346	360	No Data	No Data	No Data	No Data
22-Dec	0	0	No Data	No Data	No Data	No Data
23-Dec	85	232	No Data	No Data	926	129
24-Dec	0	0	No Data	No Data	No Data	No Data
25-Dec	0	0	No Data	No Data	47	No Data
26-Dec	0	819	No Data	No Data	No Data	No Data
27-Dec	234	406	No Data	No Data	No Data	No Data
28-Dec	40	0	No Data	No Data	No Data	No Data
29-Dec	0	0	305	157	1,288	0
30-Dec	284	0	201	81	743	2,436
31-Dec	0	0	No Data	No Data	No Data	0
Total	2,044	2,702	506	237	3,451	5,654
Combined Total	4,746		9,849			
Monthly Total	5,150		9,854			
Total mortality	122		154			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Dec	0	0	No Data	No Data	0	No Data
2-Dec	201	329	No Data	No Data	1,358	1,569
3-Dec	109	0	No Data	No Data	1,793	2,225
4-Dec	204	357	No Data	No Data	855	1,661
5-Dec	53	336	394	No Data	920	2,374
6-Dec	483	1,107	No Data	No Data	378	1,149
7-Dec	157	374	No Data	No Data	277	707
8-Dec	726	358	No Data	No Data	1,196	No Data
9-Dec	409	500	No Data	No Data	898	1,933
10-Dec	0	125	365	No Data	716	2,947
11-Dec	76	55	No Data	No Data	338	No Data
12-Dec	109	194	No Data	No Data	No Data	No Data
13-Dec	0	0	No Data	No Data	No Data	No Data
14-Dec	328	336	No Data	No Data	No Data	No Data
15-Dec	353	0	No Data	No Data	0	No Data
16-Dec	382	936	0	No Data	782	822
17-Dec	0	0	1,024	No Data	635	6,222
18-Dec	0	0	579	199	1,263	6,684
19-Dec	0	0	No Data	No Data	598	No Data
20-Dec	0	0	No Data	No Data	1,384	No Data
21-Dec	4,558	1,106	No Data	No Data	367	No Data
22-Dec	1,056	57	No Data	No Data	No Data	No Data
23-Dec	822	428	No Data	No Data	313	No Data
24-Dec	0	0	No Data	No Data	No Data	No Data
25-Dec	0	0	No Data	No Data	553	2,620
26-Dec	2,679	375	No Data	No Data	469	3,291
27-Dec	456	328	No Data	No Data	589	1,604
28-Dec	694	249	No Data	No Data	221	No Data
29-Dec	0	303	2,239	No Data	932	1,103
30-Dec	405	384	0	No Data	68	No Data
31-Dec	83	36	No Data	No Data	0	No Data
Total	14,344	8,274	4,600	199	16,901	36,912
Combined Total	22,618		58,612			
Monthly Total	23,465		66,037			
Total mortality	556		1,030			

Appendix Table 1, continued. Fish entrainment by date and unit at JPSS.

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jan	0	0	No Data	No Data	27	65
2-Jan	198	0	No Data	No Data	No Data	No Data
3-Jan	56	0	No Data	No Data	No Data	No Data
4-Jan	0	277	No Data	No Data	227	269
5-Jan	0	101	No Data	No Data	129	227
6-Jan	0	0	No Data	No Data	No Data	No Data
7-Jan	575	243	No Data	No Data	No Data	No Data
8-Jan	1,325	110	No Data	No Data	No Data	No Data
9-Jan	613	146	No Data	No Data	No Data	No Data
10-Jan	0	381	No Data	No Data	No Data	No Data
11-Jan	2,365	0	No Data	No Data	No Data	No Data
12-Jan	0	0	No Data	No Data	806	No Data
13-Jan	0	0	No Data	No Data	77	31
14-Jan	689	0	No Data	No Data	No Data	No Data
15-Jan	0	0	No Data	No Data	No Data	No Data
16-Jan	34	0	No Data	No Data	No Data	No Data
17-Jan	0	0	No Data	No Data	No Data	No Data
18-Jan	61	334	No Data	No Data	376	No Data
19-Jan	740	101	No Data	No Data	520	2,083
20-Jan	0	0	497	413	1,401	1,971
21-Jan	0	146	No Data	No Data	273	166
22-Jan	481	546	No Data	No Data	No Data	No Data
23-Jan	87	237	No Data	No Data	No Data	No Data
24-Jan	550	1,040	No Data	No Data	No Data	No Data
25-Jan	715	418	No Data	No Data	No Data	No Data
26-Jan	428	0	No Data	No Data	84	No Data
27-Jan	16	298	No Data	No Data	41	No Data
28-Jan	0	0	No Data	No Data	No Data	No Data
29-Jan	40	0	No Data	No Data	274	932
30-Jan	1,096	0	No Data	No Data	No Data	No Data
31-Jan	0	0	No Data	No Data	No Data	51
Total	10,069	4,377	497	413	4,234	5,795
Combined Total	14,446		10,939			
Monthly Total	17,417		10,972			
Total mortality	166		166			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jan	0	0	264	No Data	807	1,594
2-Jan	193	760	377	193	1,252	2,380
3-Jan	400	0	No Data	No Data	No Data	No Data
4-Jan	1,065	266	No Data	No Data	No Data	No Data
5-Jan	841	122	No Data	No Data	32	No Data
6-Jan	0	336	No Data	No Data	170	No Data
7-Jan	1,258	545	No Data	No Data	197	No Data
8-Jan	74	640	No Data	No Data	No Data	No Data
9-Jan	442	136	No Data	No Data	277	505
10-Jan	813	632	509	No Data	670	2,269
11-Jan	331	0	1,716	No Data	764	2,229
12-Jan	0	0	No Data	No Data	515	No Data
13-Jan	0	0	707	286	4,150	5,472
14-Jan	814	0	28	No Data	1,337	2,119
15-Jan	2,144	0	1,441	No Data	882	3,473
16-Jan	1,002	0	955	310	881	2,088
17-Jan	131	0	566	817	1,426	2,245
18-Jan	1,930	2,941	No Data	No Data	149	No Data
19-Jan	420	230	No Data	No Data	58	11
20-Jan	9,474	0	No Data	No Data	819	No Data
21-Jan	0	17	No Data	No Data	387	1,136
22-Jan	2,263	732	No Data	No Data	No Data	No Data
23-Jan	615	493	No Data	No Data	22	No Data
24-Jan	1,819	601	No Data	No Data	558	1,153
25-Jan	1,559	724	No Data	No Data	No Data	No Data
26-Jan	0	0	No Data	No Data	No Data	No Data
27-Jan	181	57	No Data	No Data	No Data	No Data
28-Jan	403	0	No Data	No Data	117	No Data
29-Jan	174	0	435	93	436	1,597
30-Jan	980	826	248	738	968	2,481
31-Jan	1,204	712	481	191	1,496	3,401
Total	30,530	10,770	7,725	2,628	18,368	34,152
Combined Total	41,299		62,874			
Monthly Total	44,111		63,061			
Total mortality	910		955			

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Feb	1,593	543	No Data	No Data	No Data	No Data
2-Feb	1,788	90	No Data	No Data	No Data	37
3-Feb	0	0	No Data	No Data	No Data	No Data
4-Feb	439	149	No Data	No Data	No Data	No Data
5-Feb	655	276	No Data	No Data	50	339
6-Feb	0	90	No Data	No Data	No Data	177
7-Feb	317	83	No Data	No Data	No Data	No Data
8-Feb	338	217	No Data	No Data	No Data	No Data
9-Feb	1,600	214	No Data	No Data	No Data	No Data
10-Feb	386	295	No Data	No Data	No Data	No Data
11-Feb	0	0	No Data	No Data	No Data	No Data
12-Feb	20	0	No Data	No Data	No Data	No Data
13-Feb	35	0	No Data	No Data	No Data	No Data
14-Feb	58	42	No Data	No Data	No Data	No Data
15-Feb	117	14	No Data	No Data	No Data	No Data
16-Feb	90	366	No Data	No Data	No Data	No Data
17-Feb	409	437	No Data	No Data	No Data	No Data
18-Feb	32	14	No Data	No Data	No Data	No Data
19-Feb	120	0	No Data	No Data	No Data	No Data
20-Feb	183	0	No Data	No Data	No Data	49
21-Feb	510	66	No Data	No Data	25	No Data
22-Feb	0	12	No Data	No Data	No Data	No Data
23-Feb	351	67	No Data	No Data	No Data	No Data
24-Feb	0	0	338	164	221	1,653
25-Feb	77	316	No Data	No Data	No Data	No Data
26-Feb	223	31	No Data	No Data	No Data	No Data
27-Feb	321	263	134	No Data	146	2,014
28-Feb	0	0	No Data	No Data	No Data	22
Total	9,665	3,585	472	164	442	4,291
Combined Total	13,250		5,369			
Monthly Total	13,404		7,670			
Total mortality	297		121			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Feb	3,027	1,240	No Data	No Data	0	No Data
2-Feb	768	741	No Data	No Data	No Data	No Data
3-Feb	0	0	No Data	No Data	59	No Data
4-Feb	1,066	185	No Data	No Data	No Data	No Data
5-Feb	721	352	No Data	No Data	50	No Data
6-Feb	0	293	No Data	No Data	No Data	0
7-Feb	385	174	No Data	No Data	No Data	No Data
8-Feb	209	115	No Data	No Data	No Data	No Data
9-Feb	0	0	No Data	No Data	No Data	No Data
10-Feb	284	246	No Data	No Data	No Data	No Data
11-Feb	0	0	No Data	No Data	No Data	No Data
12-Feb	595	3,275	No Data	No Data	No Data	No Data
13-Feb	307	909	No Data	No Data	No Data	No Data
14-Feb	1,103	394	No Data	No Data	No Data	No Data
15-Feb	1,155	385	No Data	No Data	No Data	No Data
16-Feb	649	1,480	No Data	No Data	No Data	No Data
17-Feb	478	879	No Data	No Data	No Data	No Data
18-Feb	1,669	461	No Data	No Data	No Data	No Data
19-Feb	33	0	No Data	No Data	No Data	No Data
20-Feb	752	24	No Data	No Data	No Data	No Data
21-Feb	478	393	No Data	No Data	0	No Data
22-Feb	486	300	No Data	No Data	100	267
23-Feb	448	49	No Data	No Data	No Data	No Data
24-Feb	0	0	6	0	27	1,200
25-Feb	2,403	837	No Data	No Data	82	No Data
26-Feb	346	330	No Data	No Data	157	69
27-Feb	39	30	305	No Data	182	812
28-Feb	665	519	No Data	No Data	22	108
Total	18,064	13,610	311	0	680	2,455
Combined Total	31,675		3,446			
Monthly Total	32,329		6,818			
Total mortality	717		54			

Appendix Table 1, continued. Fish entrainment by date and unit at JPSS.

Day Fish Entrainment Day (# fish)

	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Mar	139	47	No Data	No Data	No Data	23
2-Mar	38	0	No Data	No Data	No Data	No Data
3-Mar	0	0	61	24	179	739
4-Mar	127	0	No Data	No Data	No Data	No Data
5-Mar	0	0	No Data	No Data	No Data	No Data
6-Mar	63	591	No Data	No Data	No Data	No Data
7-Mar	92	32	No Data	No Data	No Data	192
8-Mar	226	72	No Data	No Data	No Data	No Data
9-Mar	42	142	No Data	No Data	1,212	No Data
10-Mar	89	48	1,013	No Data	508	4,451
11-Mar	0	28	191	No Data	No Data	No Data
12-Mar	0	0	No Data	No Data	210	No Data
13-Mar	18	286	No Data	No Data	No Data	No Data
14-Mar	15	0	No Data	No Data	No Data	No Data
15-Mar	13	60	No Data	No Data	No Data	No Data
16-Mar	0	0	No Data	No Data	No Data	No Data
17-Mar	0	0	0	No Data	No Data	No Data
18-Mar	131	92	No Data	No Data	No Data	No Data
19-Mar	78	16	185	No Data	1,071	2,265
20-Mar	203	446	No Data	No Data	No Data	159
21-Mar	526	0	No Data	No Data	No Data	No Data
22-Mar	81	76	No Data	No Data	No Data	No Data
23-Mar	243	0	124	No Data	No Data	383
24-Mar	0	0	0	No Data	No Data	0
25-Mar	270	840	No Data	No Data	No Data	No Data
26-Mar	32	67	No Data	No Data	No Data	No Data
27-Mar	37	0	No Data	No Data	16	123
28-Mar	0	19	No Data	No Data	No Data	No Data
29-Mar	0	0	No Data	No Data	No Data	No Data
30-Mar	0	0	No Data	No Data	88	137
31-Mar	291	0	No Data	No Data	117	289
Total	**2,751**	**2,861**	**1,575**	**24**	**3,401**	**8,762**
Combined Total	**5,612**		**13,762**			
Monthly Total	**6,343**		**15,949**			
Total mortality	**135**		**241**			

Night Fish Entrainment Night (# fish)

	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Mar	1,052	77	No Data	No Data	233	321
2-Mar	209	0	No Data	No Data	106	No Data
3-Mar	427	0	No Data	No Data	No Data	No Data
4-Mar	480	0	No Data	No Data	No Data	No Data
5-Mar	302	0	No Data	No Data	36	156
6-Mar	1,410	2,025	144	No Data	214	2,474
7-Mar	359	144	No Data	No Data	479	No Data
8-Mar	456	666	No Data	No Data	No Data	No Data
9-Mar	211	173	No Data	No Data	16	No Data
10-Mar	210	0	No Data	No Data	No Data	471
11-Mar	940	1,028	819	No Data	1,303	6,843
12-Mar	61	0	763	784	1,233	2,315
13-Mar	1,184	667	269	261	500	1,703
14-Mar	767	1,011	No Data	No Data	No Data	No Data
15-Mar	407	161	No Data	No Data	No Data	No Data
16-Mar	0	0	No Data	No Data	0	No Data
17-Mar	245	197	375	217	814	1,644
18-Mar	320	572	No Data	No Data	1,537	343
19-Mar	1,005	201	502	No Data	480	1,240
20-Mar	184	396	No Data	No Data	237	31
21-Mar	738	713	No Data	No Data	72	284
22-Mar	950	196	No Data	No Data	6	No Data
23-Mar	0	0	68	No Data	267	335
24-Mar	0	0	253	No Data	195	672
25-Mar	312	398	38	32	18	86
26-Mar	46	693	76	43	No Data	No Data
27-Mar	124	281	No Data	No Data	No Data	No Data
28-Mar	0	343	No Data	No Data	No Data	No Data
29-Mar	0	408	No Data	No Data	No Data	No Data
30-Mar	0	0	No Data	No Data	0	39
31-Mar	821	0	No Data	No Data	559	1,561
Total	**13,219**	**10,348**	**3,305**	**1,337**	**8,305**	**20,518**
Combined Total	**23,567**		**33,466**			
Monthly Total	**26,309**		**37,105**			
Total mortality	**562**		**562**			

Day Fish Entrainment (# fish)

	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Apr	0	0	No Data	No Data	No Data	No Data
2-Apr	3,517	598	No Data	No Data	No Data	No Data
3-Apr	775	96	No Data	No Data	No Data	No Data
4-Apr	676	598	No Data	No Data	No Data	No Data
5-Apr	103	41	No Data	No Data	No Data	No Data
6-Apr	45	0	No Data	No Data	602	No Data
7-Apr	36	306	207	No Data	1,381	1,212
8-Apr	129	0	No Data	No Data	No Data	No Data
9-Apr	207	183	No Data	No Data	No Data	No Data
10-Apr	263	257	No Data	No Data	No Data	No Data
11-Apr	351	212	No Data	No Data	No Data	No Data
12-Apr	118	218	No Data	No Data	No Data	No Data
13-Apr	76	58	0	No Data	6	0
14-Apr	15	0	0	15	7	59
15-Apr	583	559	No Data	No Data	No Data	No Data
16-Apr	190	577	No Data	No Data	No Data	No Data
17-Apr	437	444	No Data	No Data	No Data	No Data
18-Apr	224	1,413	No Data	No Data	No Data	No Data
19-Apr	102	103	No Data	No Data	No Data	No Data
20-Apr	0	0	11	No Data	77	No Data
21-Apr	31	0	No Data	No Data	36	No Data
22-Apr	175	570	No Data	No Data	No Data	No Data
23-Apr	33	0	No Data	No Data	No Data	No Data
24-Apr	163	0	No Data	No Data	No Data	No Data
25-Apr	170	896	No Data	No Data	No Data	No Data
26-Apr	0	552	No Data	No Data	No Data	No Data
27-Apr	0	0	0	No Data	7	28
28-Apr	690	5,887	0	No Data	0	0
29-Apr	2,672	5,150	No Data	No Data	No Data	No Data
30-Apr	322	0	No Data	No Data	No Data	No Data
Total	**12,102**	**18,717**	**217**	**15**	**2,115**	**1,299**
Combined Total	**30,819**		**3,647**			
Monthly Total	**31,065**		**3,685**			
Total mortality	**793**		**58**			

Night Fish Entrainment (# fish)

	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Apr	1,148	48	No Data	No Data	101	1,121
2-Apr	2,916	3,455	214	No Data	127	876
3-Apr	982	0	No Data	No Data	779	No Data
4-Apr	1,419	943	No Data	No Data	894	No Data
5-Apr	454	423	No Data	No Data	No Data	No Data
6-Apr	403	0	20	No Data	551	217
7-Apr	0	0	600	438	1,013	1,551
8-Apr	394	47	183	172	347	420
9-Apr	404	110	55	227	262	213
10-Apr	230	165	44	263	292	204
11-Apr	180	204	61	240	314	362
12-Apr	291	149	291	175	638	942
13-Apr	318	43	272	No Data	225	627
14-Apr	670	216	181	369	637	832
15-Apr	145	862	544	166	410	647
16-Apr	352	631	134	142	290	785
17-Apr	237	742	170	327	383	725
18-Apr	144	278	65	85	249	212
19-Apr	137	0	165	No Data	448	282
20-Apr	0	0	473	No Data	714	No Data
21-Apr	0	0	No Data	No Data	676	95
22-Apr	153	139	No Data	No Data	244	No Data
23-Apr	255	23	61	23	320	336
24-Apr	226	79	411	730	1,906	2,223
25-Apr	710	589	345	310	957	804
26-Apr	683	204	197	262	504	912
27-Apr	207	0	310	No Data	490	542
28-Apr	350	907	205	No Data	137	250
29-Apr	343	1,490	151	No Data	207	714
30-Apr	396	644	175	No Data	209	826
Total	**14,148**	**12,391**	**5,326**	**3,929**	**14,328**	**16,718**
Combined Total	**26,539**		**40,301**			
Monthly Total	**26,686**		**40,868**			
Total mortality	**687**		**640**			

Appendix Table 1, continued. Fish entrainment by date and unit at JPSS.

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-May	182	0	No Data	No Data	No Data	No Data
2-May	78	516	No Data	No Data	No Data	No Data
3-May	0	0	No Data	No Data	No Data	0
4-May	0	0	15	No Data	No Data	No Data
5-May	0	0	0	No Data	No Data	20
6-May	385	5,572	No Data	No Data	No Data	No Data
7-May	0	0	No Data	No Data	0	No Data
8-May	906	0	No Data	No Data	No Data	No Data
9-May	480	3,174	No Data	No Data	No Data	0
10-May	578	2,104	No Data	No Data	0	154
11-May	657	4,994	7	68	190	685
12-May	0	0	31	0	24	172
13-May	0	0	No Data	No Data	No Data	0
14-May	129	5,776	No Data	No Data	No Data	No Data
15-May	239	228	No Data	No Data	0	No Data
16-May	472	730	0	No Data	No Data	0
17-May	382	1,009	No Data	No Data	12	28
18-May	0	0	No Data	No Data	No Data	No Data
19-May	0	0	No Data	No Data	No Data	No Data
20-May	0	509	No Data	No Data	No Data	No Data
21-May	0	97	No Data	No Data	No Data	0
22-May	0	457	No Data	No Data	No Data	0
23-May	0	222	No Data	No Data	No Data	No Data
24-May	0	3,500	No Data	No Data	No Data	No Data
25-May	0	0	No Data	No Data	246	400
26-May	0	0	No Data	No Data	64	213
27-May	0	57	No Data	No Data	208	427
28-May	54	167	No Data	No Data	0	60
29-May	205	76	No Data	No Data	6	0
30-May	94	87	No Data	No Data	0	60
31-May	65	118	No Data	No Data	4	31
Total	**4,906**	**29,396**	**53**	**68**	**754**	**2,250**
Combined Total	**34,302**		**3,125**			
Monthly Total	**34,413**		**3,700**			
Total mortality	**680**		**54**			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-May	384	240	118	342	826	1,373
2-May	362	154	213	116	300	51
3-May	70	270	127	309	281	741
4-May	272	706	43	No Data	61	0
5-May	228	397	50	No Data	279	351
6-May	137	203	36	No Data	102	354
7-May	0	0	140	82	250	525
8-May	1,381	0	6	10	305	159
9-May	646	3,587	173	253	667	482
10-May	392	0	130	103	575	800
11-May	152	795	296	215	629	1,298
12-May	0	0	367	100	595	1,148
13-May	392	0	66	131	315	503
14-May	1,810	6,057	No Data	No Data	432	272
15-May	271	334	274	222	695	1,248
16-May	238	450	462	383	1,132	2,121
17-May	265	718	617	No Data	425	1,511
18-May	0	0	No Data	No Data	No Data	No Data
19-May	0	0	No Data	No Data	No Data	436
20-May	0	555	No Data	No Data	No Data	363
21-May	0	25	No Data	No Data	No Data	341
22-May	0	74	No Data	No Data	No Data	276
23-May	0	375	No Data	No Data	No Data	35
24-May	0	0	No Data	No Data	47	No Data
25-May	0	0	No Data	No Data	896	717
26-May	0	0	No Data	No Data	1,540	1,264
27-May	0	154	No Data	No Data	1,688	698
28-May	0	107	No Data	No Data	1,021	527
29-May	89	45	No Data	No Data	1,495	391
30-May	0	71	No Data	No Data	1,400	479
31-May	0	0	No Data	No Data	441	239
Total	**7,089**	**15,317**	**3,118**	**2,265**	**16,396**	**18,702**
Combined Total	**22,406**		**40,481**			
Monthly Total	**22,486**		**43,439**			
Total mortality	**445**		**632**			

	Day Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jun	76	91	No Data	No Data	0	0
2-Jun	0	0	392	461	507	747
3-Jun	52	109	No Data	No Data	No Data	No Data
4-Jun	0	0	No Data	No Data	18	57
5-Jun	0	114	No Data	No Data	No Data	No Data
6-Jun	459	97	No Data	No Data	No Data	No Data
7-Jun	0	0	No Data	No Data	0	30
8-Jun	229	110	No Data	0	0	57
9-Jun	1,038	152	95	0	No Data	No Data
10-Jun	590	2,420	No Data	No Data	No Data	No Data
11-Jun	3,452	517	0	334	No Data	No Data
12-Jun	401	1,296	0	0	159	104
13-Jun	987	1,676	0	No Data	0	17
14-Jun	311	24	No Data	No Data	0	0
15-Jun	142	191	239	0	0	164
16-Jun	184	133	30	8	7	79
17-Jun	271	422	72	No Data	0	5
18-Jun	159	103	0	0	0	42
19-Jun	0	217	No Data	No Data	221	62
20-Jun	278	93	No Data	No Data	0	No Data
21-Jun	292	113	No Data	No Data	16	23
22-Jun	86	10	No Data	No Data	No Data	58
23-Jun	61	48	No Data	No Data	76	45
24-Jun	120	182	0	0	160	87
25-Jun	189	249	0	No Data	0	0
26-Jun	274	494	0	0	10	24
27-Jun	209	678	0	0	129	77
28-Jun	351	480	0	0	0	33
29-Jun	312	412	11	13	100	138
30-Jun	130	232	30	0	59	50
Total	**10,656**	**10,665**	**868**	**816**	**1,460**	**1,900**
Combined Total	**21,320**		**5,044**			
Monthly Total	**22,022**		**6,148**			
Total mortality	**682**		**92**			

	Night Fish Entrainment (# fish)					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jun	0	52	83	No Data	406	522
2-Jun	0	0	1,181	739	1,327	1,366
3-Jun	100	11	308	No Data	547	488
4-Jun	0	0	No Data	No Data	555	427
5-Jun	0	0	No Data	No Data	No Data	No Data
6-Jun	152	27	851	No Data	1,031	560
7-Jun	0	0	670	No Data	905	549
8-Jun	245	48	444	594	1,132	808
9-Jun	107	55	996	1,320	No Data	No Data
10-Jun	263	457	258	No Data	No Data	No Data
11-Jun	135	75	996	1,120	No Data	No Data
12-Jun	157	0	1,052	808	2,317	2,093
13-Jun	0	81	743	No Data	1,094	1,150
14-Jun	157	103	740	No Data	1,524	882
15-Jun	0	0	768	499	2,383	1,385
16-Jun	0	239	1,017	991	1,308	1,271
17-Jun	427	0	683	557	1,160	932
18-Jun	0	0	545	651	1,832	1,820
19-Jun	113	149	No Data	No Data	1,241	1,153
20-Jun	0	0	No Data	No Data	1,379	912
21-Jun	302	0	No Data	No Data	1,342	1,044
22-Jun	126	89	No Data	No Data	9	694
23-Jun	53	0	No Data	No Data	1,934	904
24-Jun	223	0	514	896	1,705	1,739
25-Jun	0	0	414	317	1,145	795
26-Jun	119	0	515	542	1,207	1,013
27-Jun	0	193	409	749	1,208	890
28-Jun	0	0	640	903	1,489	1,175
29-Jun	0	207	800	785	1,457	1,634
30-Jun	0	0	588	621	1,499	1,059
Total	**2,678**	**1,786**	**15,215**	**12,093**	**33,135**	**27,267**
Combined Total	**4,465**		**87,710**			
Monthly Total	**4,564**		**104,895**			
Total mortality	**141**		**1,577**			

Appendix Table 2. Fish entrainment rate by date and unit at JPSS. High fish passage rates are highlighted for generation and pump operation.

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jul	0	0	No Data	No Data	No Data	No Data
2-Jul	0	0	No Data	No Data	No Data	No Data
3-Jul	0	0	No Data	No Data	No Data	No Data
4-Jul	0	0	No Data	No Data	No Data	No Data
5-Jul	0	0	No Data	No Data	No Data	No Data
6-Jul	0	0	No Data	No Data	No Data	No Data
7-Jul	0	0	No Data	No Data	No Data	No Data
8-Jul	0	0	No Data	No Data	No Data	No Data
9-Jul	0	0	No Data	No Data	No Data	No Data
10-Jul	0	0	No Data	No Data	No Data	No Data
11-Jul	0	227	No Data	No Data	No Data	No Data
12-Jul	15	No Data	No Data	No Data	No Data	No Data
13-Jul	15	292	No Data	No Data	No Data	15
14-Jul	42	79	0	No Data	No Data	No Data
15-Jul	170	20	90	No Data	235	417
16-Jul	30	100	76	No Data	25	114
17-Jul	281	45	0	No Data	37	188
18-Jul	38	125	No Data	No Data	29	75
19-Jul	47	24	0	No Data	0	No Data
20-Jul	99	27	0	No Data	0	25
21-Jul	165	35	0	No Data	0	63
22-Jul	13	51	14	No Data	41	62
23-Jul	59	81	No Data	No Data	No Data	No Data
24-Jul	72	35	58	No Data	No Data	84
25-Jul	0	39	0	No Data	No Data	No Data
26-Jul	0	35	No Data	No Data	0	0
27-Jul	13	72	No Data	No Data	No Data	0
28-Jul	35	15	83	No Data	85	231
29-Jul	62	195	61	0	142	44
30-Jul	59	48	No Data	No Data	No Data	No Data
31-Jul	158	66	0	No Data	88	140
Total	46	54	35	0	48	80
Combined Total	50		53			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jul	No Data	0	No Data	No Data	No Data	No Data
2-Jul	0	0	No Data	No Data	No Data	No Data
3-Jul	No Data	0	No Data	No Data	No Data	No Data
4-Jul	No Data	No Data	No Data	No Data	No Data	No Data
5-Jul	No Data	No Data	No Data	No Data	No Data	No Data
6-Jul	No Data	0	No Data	No Data	No Data	No Data
7-Jul	0	0	No Data	No Data	No Data	No Data
8-Jul	0	No Data	No Data	No Data	No Data	No Data
9-Jul	0	0	No Data	No Data	No Data	No Data
10-Jul	No Data	No Data	No Data	No Data	No Data	No Data
11-Jul	No Data	No Data	No Data	No Data	No Data	No Data
12-Jul	No Data	No Data	No Data	No Data	No Data	325
13-Jul	No Data	0	335	No Data	735	918
14-Jul	No Data	No Data	1037	No Data	69	626
15-Jul	No Data	No Data	687	No Data	1014	1626
16-Jul	No Data	No Data	272	446	601	935
17-Jul	544	45	454	No Data	478	712
18-Jul	190	130	392	No Data	351	724
19-Jul	252	86	218	224	315	455
20-Jul	No Data	No Data	156	No Data	208	503
21-Jul	No Data	No Data	313	No Data	247	683
22-Jul	143	No Data	567	No Data	356	947
23-Jul	242	0	495	No Data	322	392
24-Jul	58	17	418	No Data	538	1056
25-Jul	No Data	0	337	No Data	406	702
26-Jul	0	55	275	No Data	409	653
27-Jul	No Data	No Data	327	0	163	375
28-Jul	354	49	451	No Data	546	657
29-Jul	No Data	No Data	422	572	714	918
30-Jul	No Data	No Data	408	0	No Data	No Data
31-Jul	1226	126	91	No Data	567	905
Total	203	43	270	123	278	484
Combined Total	113		321			

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Aug	27	11	0	No Data	106	0
2-Aug	35	22	59	No Data	8	71
3-Aug	29	9	0	0	13	0
4-Aug	No Data	0	No Data	No Data	No Data	54
5-Aug	No Data	22	No Data	No Data	No Data	49
6-Aug	0	34	No Data	No Data	0	No Data
7-Aug	No Data	No Data	No Data	No Data	No Data	No Data
8-Aug	51	15	139	No Data	0	No Data
9-Aug	0	245	0	0	No Data	No Data
8-Aug	111	183	No Data	No Data	No Data	No Data
11-Aug	0	473	0	No Data	214	0
12-Aug	98	52	23	No Data	168	186
13-Aug	58	91	No Data	0	No Data	9
14-Aug	1	0	0	No Data	0	0
15-Aug	131	No Data	No Data	No Data	No Data	0
16-Aug	33	85	0	No Data	64	128
17-Aug	175	35	No Data	No Data	No Data	No Data
18-Aug	232	44	190	No Data	No Data	No Data
19-Aug	No Data	No Data	19	No Data	32	77
20-Aug	1	37	No Data	No Data	0	0
21-Aug	204	20	No Data	No Data	No Data	No Data
22-Aug	80	192	No Data	No Data	No Data	22
23-Aug	191	33	No Data	No Data	No Data	19
24-Aug	58	122	No Data	No Data	31	85
25-Aug	99	96	No Data	No Data	27	0
26-Aug	52	39	0	No Data	56	320
27-Aug	62	46	No Data	No Data	No Data	No Data
28-Aug	130	58	12	No Data	No Data	0
29-Aug	47	212	37	No Data	5	No Data
30-Aug	67	38	No Data	0	No Data	0
31-Aug	53	20	No Data	No Data	0	No Data
Total	75	78	55	0	52	70
Combined Total	77		37			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Aug	144	No Data	241	No Data	251	747
2-Aug	No Data	63	333	0	322	727
3-Aug	No Data	103	234	317	483	810
4-Aug	No Data	No Data	No Data	No Data	No Data	393
5-Aug	No Data	No Data	No Data	No Data	2016	443
6-Aug	No Data	No Data	No Data	No Data	441	No Data
7-Aug	No Data	No Data	No Data	No Data	585	495
8-Aug	No Data	No Data	226	No Data	432	748
9-Aug	127	1177	251	506	1578	1645
8-Aug	428	54	196	411	899	1089
11-Aug	350	685	143	No Data	295	669
12-Aug	194	1703	161	No Data	651	1082
13-Aug	No Data	120	No Data	No Data	1119	1014
14-Aug	313	0	138	No Data	377	809
15-Aug	No Data	No Data	157	No Data	356	636
16-Aug	246	266	153	No Data	477	736
17-Aug	323	330	338	No Data	587	851
18-Aug	No Data	No Data	No Data	No Data	185	713
19-Aug	No Data	No Data	231	No Data	282	918
20-Aug	402	No Data	No Data	No Data	169	242
21-Aug	456	242	No Data	No Data	378	757
22-Aug	473	No Data	104	No Data	236	618
23-Aug	359	0	149	No Data	223	658
24-Aug	No Data	No Data	208	254	374	717
25-Aug	331	320	No Data	No Data	193	334
26-Aug	149	No Data	153	No Data	374	795
27-Aug	209	57	268	No Data	356	904
28-Aug	No Data	137	185	No Data	223	728
29-Aug	16	No Data	208	395	232	623
30-Aug	No Data	73	115	237	379	704
31-Aug	136	94	87	259	351	536
Total	287	286	190	272	435	734
Combined Total	287		475			

Appendix Table 2, continued. Fish entrainment rate by date and unit at JPSS. High fish passage rates are highlighted for generation and pump operation.

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Sep	97	108	No Data	No Data	109	0
2-Sep	29	No Data	38	0	111	226
3-Sep	207	130	0	No Data	0	0
4-Sep	159	38	No Data	No Data	No Data	No Data
5-Sep	58	18	No Data	0	34	No Data
6-Sep	21	17	No Data	No Data	No Data	No Data
7-Sep	62	25	No Data	No Data	No Data	No Data
8-Sep	39	19	0	No Data	39	19
9-Sep	356	23	0	8	17	180
10-Sep	175	43	No Data	No Data	No Data	28
11-Sep	42	159	No Data	No Data	No Data	No Data
12-Sep	92	42	No Data	No Data	No Data	66
13-Sep	211	204	0	No Data	No Data	No Data
14-Sep	151	16	No Data	No Data	No Data	No Data
15-Sep	14	15	88	0	No Data	No Data
16-Sep	110	155	47	No Data	0	133
17-Sep	38	0	No Data	No Data	No Data	No Data
18-Sep	23	311	No Data	No Data	No Data	No Data
19-Sep	100	No Data	No Data	No Data	No Data	No Data
20-Sep	53	No Data	No Data	No Data	No Data	94
21-Sep	0	61	No Data	No Data	No Data	No Data
22-Sep	120	34	0	No Data	No Data	120
23-Sep	No Data	32	8	No Data	0	101
24-Sep	698	15	No Data	No Data	No Data	No Data
25-Sep	139	125	No Data	No Data	No Data	No Data
26-Sep	97	144	No Data	No Data	No Data	No Data
27-Sep	85	139	No Data	No Data	No Data	No Data
28-Sep	176	50	No Data	No Data	No Data	No Data
29-Sep	No Data	No Data	No Data	No Data	No Data	0
30-Sep	No Data	No Data	No Data	No Data	No Data	No Data
Total	100	63	34	3	49	91
Combined Total	83		58			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Sep	No Data	No Data	No Data	No Data	180	287
2-Sep	No Data	No Data	213	363	523	1490
3-Sep	90	No Data	1804	No Data	356	495
4-Sep	197	46	No Data	No Data	259	467
5-Sep	116	71	158	244	371	937
6-Sep	151	225	120	220	187	700
7-Sep	62	No Data	99	No Data	178	597
8-Sep	316	98	248	No Data	168	610
9-Sep	205	186	170	221	223	676
10-Sep	240	226	148	238	308	532
11-Sep	145	38	79	223	260	492
12-Sep	160	162	80	159	336	628
13-Sep	16	952	124	188	339	781
14-Sep	115	141	59	No Data	No Data	No Data
15-Sep	242	463	47	190	No Data	485
16-Sep	100	572	118	No Data	216	356
17-Sep	148	132	No Data	No Data	122	250
18-Sep	153	569	No Data	No Data	124	219
19-Sep	202	No Data	No Data	No Data	121	242
20-Sep	74	No Data	No Data	No Data	No Data	No Data
21-Sep	No Data	127	No Data	No Data	146	284
22-Sep	118	83	156	No Data	367	521
23-Sep	61	396	169	No Data	477	1169
24-Sep	158	61	No Data	No Data	205	464
25-Sep	94	77	No Data	No Data	116	No Data
26-Sep	101	107	76	No Data	249	634
27-Sep	133	142	102	No Data	271	589
28-Sep	0	34	95	303	351	635
29-Sep	No Data	No Data	No Data	No Data	130	297
30-Sep	No Data	No Data	No Data	No Data	No Data	No Data
Total	140	201	127	238	236	537
Combined Total	170		333			

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Oct	0	17	No Data	No Data	No Data	No Data
2-Oct	107	47	No Data	No Data	No Data	No Data
3-Oct	48	72	No Data	No Data	No Data	No Data
4-Oct	307	55	No Data	No Data	No Data	No Data
5-Oct	0	6	No Data	No Data	No Data	No Data
6-Oct	0	8	3	No Data	No Data	No Data
7-Oct	No Data	No Data	18	No Data	0	216
8-Oct	71	77	No Data	No Data	No Data	No Data
9-Oct	86	268	No Data	No Data	No Data	No Data
10-Oct	No Data	0	No Data	No Data	No Data	No Data
11-Oct	85	0	No Data	No Data	No Data	No Data
12-Oct	No Data	43	No Data	No Data	No Data	No Data
13-Oct	20	No Data	No Data	No Data	No Data	No Data
14-Oct	No Data	No Data	No Data	No Data	0	0
15-Oct	7	46	No Data	No Data	No Data	No Data
16-Oct	No Data	No Data	No Data	No Data	No Data	No Data
17-Oct	0	55	No Data	No Data	No Data	No Data
18-Oct	667	90	No Data	No Data	No Data	No Data
19-Oct	13	51	No Data	No Data	No Data	No Data
20-Oct	59	No Data	No Data	No Data	No Data	No Data
21-Oct	338	118	No Data	No Data	No Data	No Data
22-Oct	20	161	No Data	No Data	No Data	No Data
23-Oct	0	44	No Data	No Data	No Data	No Data
24-Oct	0	35	No Data	No Data	No Data	No Data
25-Oct	0	43	No Data	No Data	No Data	No Data
26-Oct	99	143	No Data	No Data	No Data	No Data
27-Oct	129	95	0	No Data	No Data	0
28-Oct	0	No Data	No Data	No Data	No Data	0
29-Oct	781	353	No Data	No Data	No Data	No Data
30-Oct	0	No Data	No Data	No Data	No Data	No Data
31-Oct	396	38	No Data	No Data	No Data	No Data
Total	117	70	11	Non- op	0	125
Combined Total	91		75			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Oct	7	9	No Data	No Data	524	658
2-Oct	25	56	81	85	291	976
3-Oct	152	59	100	129	276	551
4-Oct	122	228	106	No Data	102	436
5-Oct	58	20	108	No Data	213	633
6-Oct	65	159	85	No Data	178	522
7-Oct	No Data	No Data	160	No Data	224	645
8-Oct	172	106	65	No Data	124	472
9-Oct	56	90	102	163	279	777
10-Oct	No Data	0	No Data	No Data	87	332
11-Oct	55	0	No Data	No Data	156	251
12-Oct	No Data	0	No Data	No Data	No Data	No Data
13-Oct	No Data	No Data	No Data	No Data	No Data	No Data
14-Oct	No Data	0	61	No Data	322	924
15-Oct	17	85	No Data	No Data	228	391
16-Oct	31	0	No Data	No Data	448	261
17-Oct	104	81	72	No Data	205	921
18-Oct	99	95	70	No Data	No Data	302
19-Oct	29	76	165	No Data	228	568
20-Oct	No Data	16	No Data	No Data	No Data	104
21-Oct	17	49	No Data	No Data	189	480
22-Oct	116	121	No Data	No Data	209	555
23-Oct	44	35	123	197	476	1414
24-Oct	55	135	189	197	352	1038
25-Oct	57	9	169	No Data	197	592
26-Oct	108	38	176	209	461	803
27-Oct	No Data	0	297	No Data	400	814
28-Oct	0	No Data	326	152	464	1093
29-Oct	189	54	No Data	No Data	384	583
30-Oct	14	34	106	No Data	210	933
31-Oct	31	25	65	No Data	0	758
Total	69	58	137	169	258	680
Combined Total	64		387			

Appendix Table 2, continued. Fish entrainment rate by date and unit at JPSS. High fish passage rates are highlighted for generation and pump operation.

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Nov	0	64	No Data	No Data	No Data	No Data
2-Nov	98	22	No Data	No Data	No Data	No Data
3-Nov	79	84	No Data	No Data	No Data	No Data
4-Nov	No Data	No Data	No Data	No Data	0	28
5-Nov	57	314	No Data	No Data	No Data	No Data
6-Nov	22	306	No Data	No Data	No Data	No Data
7-Nov	35	No Data	No Data	No Data	No Data	12
8-Nov	79	49	No Data	No Data	No Data	25
9-Nov	42	533	No Data	No Data	No Data	No Data
10-Nov	9	0	No Data	No Data	304	304
11-Nov	16	No Data	No Data	No Data	No Data	No Data
12-Nov	0	No Data	0	No Data	0	No Data
13-Nov	No Data	No Data	No Data	No Data	No Data	No Data
14-Nov	199	3	No Data	No Data	No Data	No Data
15-Nov	124	21	No Data	No Data	No Data	No Data
16-Nov	36	No Data	No Data	No Data	14	No Data
17-Nov	6	0	No Data	No Data	No Data	No Data
18-Nov	No Data	No Data	No Data	No Data	28	0
19-Nov	0	No Data	No Data	No Data	No Data	No Data
20-Nov	0	13	No Data	No Data	No Data	No Data
21-Nov	0	0	No Data	No Data	No Data	No Data
22-Nov	12	178	93	156	214	0
23-Nov	236	0	No Data	No Data	211	No Data
24-Nov	48	No Data	No Data	No Data	51	377
25-Nov	96	8	60	No Data	123	809
26-Nov	95	32	No Data	No Data	No Data	No Data
27-Nov	14	0	No Data	No Data	No Data	No Data
28-Nov	46	19	No Data	No Data	No Data	No Data
29-Nov	55	11	No Data	No Data	126	342
30-Nov	86	0	No Data	No Data	62	234
Total	58	107	73	156	148	213
Combined Total	82		169			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Nov	243	55	108	No Data	160	862
2-Nov	276	23	No Data	No Data	162	257
3-Nov	44	75	No Data	No Data	53	96
4-Nov	14	No Data	No Data	No Data	164	594
5-Nov	637	134	No Data	No Data	385	407
6-Nov	67	111	109	0	124	289
7-Nov	220	751	119	84	290	806
8-Nov	136	1404	47	No Data	123	972
9-Nov	86	2337	No Data	No Data	0	No Data
10-Nov	23	No Data	No Data	No Data	63	No Data
11-Nov	No Data	No Data	No Data	No Data	104	217
12-Nov	4309	66	85	No Data	163	487
13-Nov	61	43	509	No Data	196	1365
14-Nov	67	12	0	No Data	No Data	No Data
15-Nov	143	604	107	No Data	No Data	No Data
16-Nov	56	No Data	No Data	No Data	No Data	No Data
17-Nov	29	122	0	No Data	97	0
18-Nov	No Data	No Data	354	No Data	112	948
19-Nov	268	18	No Data	No Data	No Data	No Data
20-Nov	7	0	No Data	No Data	286	No Data
21-Nov	0	0	No Data	No Data	179	No Data
22-Nov	0	No Data	27	0	219	349
23-Nov	209	No Data	61	No Data	100	451
24-Nov	37	No Data	No Data	No Data	30	No Data
25-Nov	308	38	0	No Data	0	52
26-Nov	45	60	199	No Data	165	716
27-Nov	32	28	158	No Data	44	1040
28-Nov	65	30	No Data	No Data	354	243
29-Nov	113	0	No Data	No Data	328	308
30-Nov	101	0	No Data	No Data	57	No Data
Total	262	128	186	79	176	554
Combined Total	214		315			

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Dec	73	No Data	No Data	No Data	No Data	93
2-Dec	43	No Data	No Data	No Data	0	0
3-Dec	38	No Data	No Data	No Data	No Data	No Data
4-Dec	79	148	No Data	No Data	No Data	No Data
5-Dec	0	0	No Data	No Data	No Data	No Data
6-Dec	37	No Data	No Data	No Data	No Data	No Data
7-Dec	0	0	No Data	No Data	No Data	No Data
8-Dec	27	No Data	No Data	No Data	No Data	No Data
9-Dec	0	0	No Data	No Data	No Data	No Data
10-Dec	No Data	90	No Data	No Data	No Data	No Data
11-Dec	0	0	No Data	No Data	No Data	No Data
12-Dec	38	No Data	No Data	No Data	No Data	No Data
13-Dec	No Data	33	No Data	No Data	No Data	No Data
14-Dec	8	133	No Data	No Data	No Data	No Data
15-Dec	108	No Data	No Data	No Data	90	627
16-Dec	5	134	No Data	No Data	No Data	No Data
17-Dec	No Data	No Data	No Data	No Data	No Data	No Data
18-Dec	No Data	No Data	No Data	No Data	No Data	No Data
19-Dec	0	0	No Data	No Data	No Data	No Data
20-Dec	0	0	No Data	No Data	No Data	No Data
21-Dec	58	117	No Data	No Data	No Data	No Data
22-Dec	No Data	No Data	No Data	No Data	No Data	No Data
23-Dec	30	87	No Data	No Data	266	85
24-Dec	0	No Data	No Data	No Data	No Data	No Data
25-Dec	No Data	No Data	No Data	No Data	19	No Data
26-Dec	No Data	97	No Data	No Data	No Data	No Data
27-Dec	76	136	No Data	No Data	No Data	No Data
28-Dec	12	0	No Data	No Data	No Data	No Data
29-Dec	No Data	No Data	79	52	232	0
30-Dec	194	No Data	43	27	115	485
31-Dec	0	0	No Data	No Data	No Data	0
Total	39	81	59	39	150	255
Combined Total	55		164			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Dec	0	No Data	No Data	No Data	0	No Data
2-Dec	47	81	No Data	No Data	151	241
3-Dec	22	No Data	No Data	No Data	349	349
4-Dec	36	64	No Data	No Data	156	327
5-Dec	33	66	93	No Data	135	476
6-Dec	105	184	No Data	No Data	70	232
7-Dec	49	112	No Data	No Data	53	147
8-Dec	220	140	No Data	No Data	165	No Data
9-Dec	97	172	No Data	No Data	112	268
10-Dec	No Data	150	87	No Data	123	547
11-Dec	27	24	No Data	No Data	67	No Data
12-Dec	35	44	No Data	No Data	No Data	No Data
13-Dec	No Data	0	No Data	No Data	No Data	No Data
14-Dec	40	133	No Data	No Data	No Data	No Data
15-Dec	93	No Data	No Data	No Data	0	No Data
16-Dec	85	198	0	No Data	130	189
17-Dec	No Data	No Data	151	No Data	97	1046
18-Dec	0	No Data	85	46	182	1194
19-Dec	0	0	No Data	No Data	126	No Data
20-Dec	0	No Data	No Data	No Data	258	No Data
21-Dec	627	202	No Data	No Data	67	No Data
22-Dec	206	22	No Data	No Data	No Data	No Data
23-Dec	149	114	No Data	No Data	80	No Data
24-Dec	No Data	No Data	No Data	No Data	No Data	No Data
25-Dec	No Data	No Data	No Data	No Data	80	554
26-Dec	578	90	No Data	No Data	73	538
27-Dec	75	66	No Data	No Data	116	268
28-Dec	131	42	No Data	No Data	45	No Data
29-Dec	No Data	63	383	No Data	141	293
30-Dec	146	78	0	No Data	18	No Data
31-Dec	14	8	No Data	No Data	0	No Data
Total	142	95	129	46	122	451
Combined Total	120		225			

Appendix Table 2, continued. Fish entrainment rate by date and unit at JPSS. High fish passage rates are highlighted for generation and pump operation.

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jan	No Data	No Data	No Data	No Data	7	59
2-Jan	46	No Data	No Data	No Data	No Data	No Data
3-Jan	168	No Data	No Data	No Data	No Data	No Data
4-Jan	0	69	No Data	No Data	80	152
5-Jan	0	38	No Data	No Data	27	84
6-Jan	No Data	0	No Data	No Data	No Data	No Data
7-Jan	356	128	No Data	No Data	No Data	No Data
8-Jan	442	30	No Data	No Data	No Data	No Data
9-Jan	400	144	No Data	No Data	No Data	No Data
10-Jan	0	57	No Data	No Data	No Data	No Data
11-Jan	237	0	No Data	No Data	No Data	No Data
12-Jan	No Data	No Data	No Data	No Data	562	No Data
13-Jan	No Data	No Data	No Data	No Data	69	115
14-Jan	69	No Data	No Data	No Data	No Data	No Data
15-Jan	0	0	No Data	No Data	No Data	No Data
16-Jan	5	0	No Data	No Data	No Data	No Data
17-Jan	0	No Data	No Data	No Data	No Data	No Data
18-Jan	19	89	No Data	No Data	116	No Data
19-Jan	393	38	No Data	No Data	114	484
20-Jan	No Data	No Data	117	119	192	274
21-Jan	No Data	87	No Data	No Data	55	55
22-Jan	465	287	No Data	No Data	No Data	No Data
23-Jan	36	139	No Data	No Data	No Data	No Data
24-Jan	589	1387	No Data	No Data	No Data	No Data
25-Jan	70	41	No Data	No Data	No Data	No Data
26-Jan	121	0	No Data	No Data	46	No Data
27-Jan	7	138	No Data	No Data	38	No Data
28-Jan	0	No Data	No Data	No Data	No Data	No Data
29-Jan	104	No Data	No Data	No Data	40	141
30-Jan	105	0	No Data	No Data	No Data	No Data
31-Jan	0	No Data	No Data	No Data	No Data	15
Total	**110**	**61**	**117**	**119**	**97**	**191**
Combined Total	**88**		**134**			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jan	No Data	No Data	66	No Data	93	206
2-Jan	93	351	70	49	241	508
3-Jan	136	No Data	No Data	No Data	No Data	No Data
4-Jan	235	111	No Data	No Data	No Data	No Data
5-Jan	424	78	No Data	No Data	88	No Data
6-Jan	No Data	102	No Data	No Data	27	No Data
7-Jan	294	147	No Data	No Data	39	No Data
8-Jan	55	71	No Data	No Data	No Data	No Data
9-Jan	83	100	No Data	No Data	57	109
10-Jan	139	144	141	No Data	108	432
11-Jan	80	0	322	No Data	138	434
12-Jan	No Data	No Data	No Data	No Data	63	No Data
13-Jan	No Data	No Data	136	83	470	667
14-Jan	174	0	8	No Data	170	301
15-Jan	368	0	290	No Data	125	600
16-Jan	246	0	134	62	116	300
17-Jan	160	No Data	88	132	216	383
18-Jan	271	415	No Data	No Data	28	No Data
19-Jan	365	147	No Data	No Data	112	131
20-Jan	2388	No Data	No Data	No Data	130	No Data
21-Jan	No Data	30	No Data	No Data	68	242
22-Jan	501	335	No Data	No Data	No Data	No Data
23-Jan	107	96	No Data	No Data	59	No Data
24-Jan	438	125	No Data	No Data	95	194
25-Jan	287	157	No Data	No Data	No Data	No Data
26-Jan	No Data	No Data	No Data	No Data	No Data	No Data
27-Jan	187	142	No Data	No Data	No Data	No Data
28-Jan	299	No Data	No Data	No Data	109	No Data
29-Jan	119	No Data	137	192	58	250
30-Jan	248	207	40	130	143	369
31-Jan	324	251	80	39	261	562
Total	**334**	**153**	**127**	**89**	**138**	**375**
Combined Total	**255**		**200**			

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Feb	1165	267	No Data	No Data	No Data	No Data
2-Feb	1450	30	No Data	No Data	No Data	14
3-Feb	No Data	No Data	No Data	No Data	No Data	No Data
4-Feb	293	87	No Data	No Data	No Data	No Data
5-Feb	517	197	No Data	No Data	10	94
6-Feb	0	70	No Data	No Data	No Data	38
7-Feb	76	12	No Data	No Data	No Data	No Data
8-Feb	193	73	No Data	No Data	No Data	No Data
9-Feb	533	52	No Data	No Data	No Data	No Data
10-Feb	102	90	No Data	No Data	No Data	No Data
11-Feb	No Data	No Data	No Data	No Data	No Data	No Data
12-Feb	53	No Data	No Data	No Data	No Data	No Data
13-Feb	115	No Data	No Data	No Data	No Data	No Data
14-Feb	26	17	No Data	No Data	No Data	No Data
15-Feb	53	5	No Data	No Data	No Data	No Data
16-Feb	87	998	No Data	No Data	No Data	No Data
17-Feb	134	185	No Data	No Data	No Data	No Data
18-Feb	12	6	No Data	No Data	No Data	No Data
19-Feb	25	No Data	No Data	No Data	No Data	No Data
20-Feb	74	0	No Data	No Data	No Data	13
21-Feb	109	15	No Data	No Data	6	No Data
22-Feb	0	2	No Data	No Data	No Data	No Data
23-Feb	36	10	No Data	No Data	No Data	No Data
24-Feb	No Data	No Data	47	38	25	150
25-Feb	7	137	No Data	No Data	No Data	No Data
26-Feb	38	30	No Data	No Data	No Data	No Data
27-Feb	138	182	23	No Data	23	312
28-Feb	0	No Data	No Data	No Data	No Data	4
Total	**130**	**57**	**37**	**38**	**10**	**89**
Combined Total	**96**		**48**			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Feb	430	265	No Data	No Data	0	No Data
2-Feb	235	215	No Data	No Data	No Data	No Data
3-Feb	No Data	No Data	No Data	No Data	23	No Data
4-Feb	410	116	No Data	No Data	No Data	No Data
5-Feb	243	124	No Data	No Data	15	No Data
6-Feb	0	235	No Data	No Data	No Data	0
7-Feb	84	39	No Data	No Data	No Data	No Data
8-Feb	179	164	No Data	No Data	No Data	No Data
9-Feb	0	No Data	No Data	No Data	No Data	No Data
10-Feb	98	92	No Data	No Data	No Data	No Data
11-Feb	No Data	No Data	No Data	No Data	No Data	No Data
12-Feb	128	826	No Data	No Data	No Data	No Data
13-Feb	77	277	No Data	No Data	No Data	No Data
14-Feb	198	241	No Data	No Data	No Data	No Data
15-Feb	525	236	No Data	No Data	No Data	No Data
16-Feb	137	370	No Data	No Data	No Data	No Data
17-Feb	266	159	No Data	No Data	No Data	No Data
18-Feb	381	150	No Data	No Data	No Data	No Data
19-Feb	33	No Data	No Data	No Data	No Data	No Data
20-Feb	537	22	No Data	No Data	No Data	No Data
21-Feb	326	332	No Data	No Data	0	No Data
22-Feb	104	62	No Data	No Data	17	53
23-Feb	76	22	No Data	No Data	No Data	No Data
24-Feb	No Data	No Data	7	0	4	171
25-Feb	407	188	No Data	No Data	17	No Data
26-Feb	163	190	No Data	No Data	32	55
27-Feb	42	35	102	No Data	31	154
28-Feb	178	186	No Data	No Data	56	17
Total	**223**	**213**	**24**	**0**	**12**	**49**
Combined Total	**219**		**28**			

Appendix Table 2, continued. Fish entrainment rate by date and unit at JPSS. High fish passage rates are highlighted for generation and pump operation.

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Mar	94	60	No Data	No Data	No Data	5
2-Mar	22	No Data	No Data	No Data	No Data	No Data
3-Mar	0	0	17	8	40	154
4-Mar	108	0	No Data	No Data	No Data	No Data
5-Mar	No Data	No Data	No Data	No Data	No Data	No Data
6-Mar	18	135	No Data	No Data	No Data	No Data
7-Mar	44	29	No Data	No Data	No Data	36
8-Mar	90	35	No Data	No Data	No Data	No Data
9-Mar	27	103	No Data	No Data	188	No Data
10-Mar	55	46	218	No Data	98	608
11-Mar	0	168	201	No Data	No Data	No Data
12-Mar	0	No Data	No Data	No Data	53	No Data
13-Mar	10	129	No Data	No Data	No Data	No Data
14-Mar	7	No Data	No Data	No Data	No Data	No Data
15-Mar	4	17	No Data	No Data	No Data	No Data
16-Mar	No Data	No Data	No Data	No Data	No Data	No Data
17-Mar	No Data	No Data	0	No Data	No Data	No Data
18-Mar	11	9	No Data	No Data	No Data	No Data
19-Mar	19	5	37	No Data	164	377
20-Mar	68	158	No Data	No Data	No Data	31
21-Mar	114	0	No Data	No Data	No Data	No Data
22-Mar	17	16	No Data	No Data	No Data	No Data
23-Mar	121	No Data	21	No Data	No Data	62
24-Mar	No Data	No Data	0	No Data	No Data	0
25-Mar	35	146	No Data	No Data	No Data	No Data
26-Mar	13	30	No Data	No Data	No Data	No Data
27-Mar	9	0	No Data	No Data	3	23
28-Mar	0	8	No Data	No Data	No Data	No Data
29-Mar	0	0	No Data	No Data	No Data	No Data
30-Mar	0	No Data	No Data	No Data	18	30
31-Mar	4360	No Data	No Data	No Data	21	34
Total	34	48	63	8	71	134
Combined Total	40		97			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Mar	820	90	No Data	No Data	48	62
2-Mar	56	No Data	No Data	No Data	31	No Data
3-Mar	81	0	No Data	No Data	No Data	No Data
4-Mar	102	0	No Data	No Data	No Data	No Data
5-Mar	176	No Data	No Data	No Data	32	167
6-Mar	319	484	35	No Data	43	474
7-Mar	97	169	No Data	No Data	104	No Data
8-Mar	66	187	No Data	No Data	No Data	No Data
9-Mar	144	253	No Data	No Data	65	No Data
10-Mar	104	No Data	No Data	No Data	No Data	372
11-Mar	210	277	221	No Data	257	1287
12-Mar	31	No Data	123	207	185	343
13-Mar	302	400	56	91	127	370
14-Mar	157	259	No Data	No Data	No Data	No Data
15-Mar	191	116	No Data	No Data	No Data	No Data
16-Mar	No Data	No Data	No Data	No Data	0	No Data
17-Mar	123	158	54	58	115	235
18-Mar	74	126	No Data	No Data	394	72
19-Mar	314	198	142	No Data	89	213
20-Mar	48	147	No Data	No Data	47	33
21-Mar	124	155	No Data	No Data	15	55
22-Mar	95	43	No Data	No Data	24	No Data
23-Mar	No Data	No Data	61	No Data	34	242
24-Mar	No Data	No Data	34	No Data	24	80
25-Mar	97	146	31	33	4	17
26-Mar	27	501	15	12	No Data	No Data
27-Mar	72	219	No Data	No Data	No Data	No Data
28-Mar	0	231	No Data	No Data	No Data	No Data
29-Mar	0	437	No Data	No Data	No Data	No Data
30-Mar	0	No Data	No Data	No Data	0	7
31-Mar	807	No Data	No Data	No Data	69	172
Total	142	192	65	68	86	248
Combined Total	160		134			

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Apr	No Data	No Data	No Data	No Data	No Data	No Data
2-Apr	676	262	No Data	No Data	No Data	No Data
3-Apr	226	75	No Data	No Data	No Data	No Data
4-Apr	53	47	No Data	No Data	No Data	No Data
5-Apr	24	15	No Data	No Data	No Data	No Data
6-Apr	12	0	No Data	No Data	156	No Data
7-Apr	23	340	58	No Data	301	237
8-Apr	21	No Data	No Data	No Data	No Data	No Data
9-Apr	16	22	No Data	No Data	No Data	No Data
10-Apr	20	25	No Data	No Data	No Data	No Data
11-Apr	32	20	No Data	No Data	No Data	No Data
12-Apr	13	72	No Data	No Data	No Data	No Data
13-Apr	23	20	0	No Data	4	0
14-Apr	28	0	0	11	7	37
15-Apr	78	91	No Data	No Data	No Data	No Data
16-Apr	21	78	No Data	No Data	No Data	No Data
17-Apr	37	40	No Data	No Data	No Data	No Data
18-Apr	22	150	No Data	No Data	No Data	No Data
19-Apr	9	11	No Data	No Data	No Data	No Data
20-Apr	No Data	No Data	9	No Data	50	No Data
21-Apr	21	No Data	No Data	No Data	27	No Data
22-Apr	23	199	No Data	No Data	No Data	No Data
23-Apr	24	No Data	No Data	No Data	No Data	No Data
24-Apr	33	No Data	No Data	No Data	No Data	No Data
25-Apr	26	316	No Data	No Data	No Data	No Data
26-Apr	0	48	No Data	No Data	No Data	No Data
27-Apr	No Data	No Data	0	No Data	5	17
28-Apr	92	2042	0	No Data	0	0
29-Apr	353	381	No Data	No Data	No Data	No Data
30-Apr	24	No Data	No Data	No Data	No Data	No Data
Total	64	138	30	11	132	140
Combined Total	95		108			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Apr	638	37	No Data	No Data	15	184
2-Apr	583	1063	50	No Data	28	173
3-Apr	337	No Data	No Data	No Data	217	No Data
4-Apr	359	277	No Data	No Data	171	No Data
5-Apr	146	461	No Data	No Data	No Data	No Data
6-Apr	168	No Data	1183	No Data	591	56
7-Apr	No Data	No Data	99	104	132	229
8-Apr	164	34	30	31	52	71
9-Apr	144	52	10	52	48	33
10-Apr	88	86	8	49	40	26
11-Apr	71	85	10	46	46	51
12-Apr	104	83	54	43	98	183
13-Apr	162	36	43	No Data	31	82
14-Apr	302	90	29	63	84	118
15-Apr	70	380	94	48	62	99
16-Apr	194	368	21	29	45	120
17-Apr	98	318	29	63	61	114
18-Apr	69	140	12	18	41	34
19-Apr	62	No Data	56	No Data	79	68
20-Apr	No Data	No Data	117	No Data	103	No Data
21-Apr	No Data	No Data	No Data	No Data	125	31
22-Apr	83	101	No Data	No Data	46	No Data
23-Apr	113	18	121	231	216	64
24-Apr	134	57	67	121	260	401
25-Apr	330	343	67	113	175	234
26-Apr	212	112	41	87	103	192
27-Apr	121	No Data	49	No Data	72	70
28-Apr	183	573	37	No Data	20	37
29-Apr	254	876	35	No Data	32	118
30-Apr	171	278	35	No Data	32	137
Total	216	284	43	60	84	113
Combined Total	243		79			

Appendix Table 2, continued. Fish entrainment rate by date and unit at JPSS. High fish passage rates are highlighted for generation and pump operation.

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-May	13	0	No Data	No Data	No Data	No Data
2-May	23	39	No Data	No Data	No Data	No Data
3-May	0	0	No Data	No Data	No Data	0
4-May	No Data	0	9	No Data	No Data	No Data
5-May	No Data	0	0	No Data	No Data	10
6-May	42	486	No Data	No Data	No Data	No Data
7-May	No Data	No Data	No Data	No Data	0	No Data
8-May	83	No Data	No Data	No Data	No Data	No Data
9-May	61	550	No Data	No Data	No Data	0
10-May	56	240	No Data	No Data	0	56
11-May	69	575	3	36	78	264
12-May	No Data	No Data	16	0	12	72
13-May	No Data	No Data	No Data	No Data	No Data	0
14-May	27	580	No Data	No Data	No Data	No Data
15-May	34	25	No Data	No Data	0	No Data
16-May	43	70	0	No Data	No Data	0
17-May	40	110	No Data	No Data	9	19
18-May	No Data	No Data	No Data	No Data	No Data	No Data
19-May	0	No Data	No Data	No Data	No Data	No Data
20-May	No Data	49	No Data	No Data	No Data	No Data
21-May	No Data	9	No Data	No Data	No Data	0
22-May	No Data	40	No Data	No Data	No Data	0
23-May	No Data	23	No Data	No Data	No Data	No Data
24-May	0	460	No Data	No Data	No Data	No Data
25-May	No Data	No Data	No Data	No Data	71	150
26-May	No Data	No Data	No Data	No Data	28	76
27-May	No Data	16	No Data	No Data	59	108
28-May	6	22	No Data	No Data	0	34
29-May	23	7	No Data	No Data	4	0
30-May	13	12	No Data	No Data	0	22
31-May	10	14	No Data	No Data	3	20
Total	38	167	5	20	32	68
Combined Total	112		45			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-May	186	120	20	65	112	192
2-May	215	130	32	22	45	7
3-May	63	178	19	54	39	104
4-May	233	718	7	No Data	8	0
5-May	123	271	12	No Data	35	48
6-May	283	162	7	No Data	14	54
7-May	No Data	No Data	27	28	36	78
8-May	812	No Data	2	6	45	23
9-May	497	1682	32	93	98	72
10-May	138	No Data	26	30	88	122
11-May	80	507	83	101	109	281
12-May	No Data	No Data	71	36	75	154
13-May	490	No Data	11	21	46	66
14-May	823	3106	No Data	No Data	70	45
15-May	110	308	45	46	107	198
16-May	115	284	84	83	184	327
17-May	169	784	135	No Data	78	254
18-May	No Data	No Data	No Data	No Data	No Data	No Data
19-May	No Data	No Data	No Data	No Data	No Data	57
20-May	No Data	378	No Data	No Data	No Data	49
21-May	No Data	24	No Data	No Data	No Data	48
22-May	No Data	50	No Data	No Data	No Data	37
23-May	No Data	278	No Data	No Data	No Data	6
24-May	No Data	No Data	No Data	No Data	11	No Data
25-May	No Data	No Data	No Data	No Data	141	127
26-May	No Data	No Data	No Data	No Data	208	221
27-May	No Data	95	No Data	No Data	249	208
28-May	0	48	No Data	No Data	160	72
29-May	59	44	No Data	No Data	216	54
30-May	No Data	63	No Data	No Data	167	63
31-May	No Data	No Data	No Data	No Data	70	38
Total	257	528	33	47	91	95
Combined Total	396		78			

	Day Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jun	9	11	No Data	No Data	0	0
2-Jun	No Data	No Data	93	113	195	168
3-Jun	6	13	No Data	No Data	No Data	No Data
4-Jun	0	0	No Data	No Data	10	30
5-Jun	0	24	No Data	No Data	No Data	No Data
6-Jun	41	10	No Data	No Data	No Data	No Data
7-Jun	No Data	No Data	No Data	No Data	0	17
8-Jun	27	20	No Data	0	0	37
9-Jun	109	17	68	0	No Data	No Data
10-Jun	64	252	No Data	No Data	No Data	No Data
11-Jun	482	56	0	180	No Data	No Data
12-Jun	42	142	0	0	120	71
13-Jun	93	157	0	No Data	0	16
14-Jun	31	7	No Data	No Data	0	0
15-Jun	20	27	133	0	0	69
16-Jun	21	15	21	7	5	52
17-Jun	25	47	49	No Data	0	5
18-Jun	21	13	0	0	0	21
19-Jun	0	35	No Data	No Data	90	38
20-Jun	41	13	No Data	No Data	0	No Data
21-Jun	32	19	No Data	No Data	13	17
22-Jun	12	2	No Data	No Data	No Data	32
23-Jun	7	8	No Data	No Data	39	22
24-Jun	12	18	0	0	110	49
25-Jun	28	43	0	No Data	0	0
26-Jun	26	62	0	0	8	12
27-Jun	25	67	0	0	65	28
28-Jun	36	51	0	0	0	20
29-Jun	38	53	8	11	51	53
30-Jun	25	40	19	0	29	23
Total	46	49	31	59	42	39
Combined Total	48		40			

	Night Entrainment Rate					
	Generation		Pump			
Date	Units 1 & 2	Units 3 & 4	Unit 1	Unit 2	Unit 3	Unit 4
1-Jun	No Data	51	110	No Data	65	73
2-Jun	No Data	No Data	183	349	193	182
3-Jun	75	13	59	No Data	85	81
4-Jun	0	No Data	No Data	No Data	88	68
5-Jun	No Data	No Data	No Data	No Data	No Data	No Data
6-Jun	106	57	193	No Data	185	101
7-Jun	No Data	No Data	185	No Data	215	97
8-Jun	140	37	132	258	219	180
9-Jun	105	32	266	381	No Data	No Data
10-Jun	153	231	104	No Data	No Data	No Data
11-Jun	542	76	212	313	No Data	No Data
12-Jun	192	No Data	187	211	317	335
13-Jun	No Data	87	126	No Data	167	145
14-Jun	131	100	133	No Data	242	140
15-Jun	No Data	No Data	176	162	443	247
16-Jun	No Data	153	238	336	286	267
17-Jun	281	No Data	133	130	201	167
18-Jun	No Data	No Data	92	119	275	219
19-Jun	59	86	No Data	No Data	196	183
20-Jun	No Data	No Data	No Data	No Data	264	207
21-Jun	224	No Data	No Data	No Data	275	150
22-Jun	76	59	No Data	No Data	27	110
23-Jun	67	No Data	No Data	No Data	239	138
24-Jun	181	No Data	84	151	269	250
25-Jun	No Data	No Data	77	221	185	126
26-Jun	222	No Data	100	109	219	169
27-Jun	No Data	156	82	161	210	172
28-Jun	No Data	No Data	117	180	235	198
29-Jun	No Data	327	148	157	263	305
30-Jun	No Data	No Data	121	133	278	206
Total	140	105	107	160	193	151
Combined Total	124		154			

CHAPTER 2

THE PELAGIC FORAGE FISH COMMUNITY OF LAKE JOCASSEE, SOUTH CAROLINA

RELATIONSHIPS TO OPERATIONS AT JOCASSEE AND BAD CREEK PUMPED STORAGE STATIONS

FALL 1997 – SPRING 2013

September 2013

M. S. Rodriguez, for
Duke Energy Carolinas, LLC, Huntersville, NC

CHAPTER TWO

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INTRODUCTION

This report documents characteristics of the pelagic forage fish community of Lake Jocassee based on hydroacoustics and purse seine data collected by Duke Energy, fall 1997 through spring 2013. In addition, variation in spring and fall forage fish abundance and distribution is investigated in relation to environmental parameters and operations at Jocassee Pumped Storage Station and Bad Creek Pumped Storage Station.

The pelagic forage fish community of Lake Jocassee consists of threadfin shad (*Dorosoma petenense*) and blueback herring (*Alosa aestivalis*). Both species became established in Lake Jocassee shortly after impoundment of the reservoir in 1971 (Prince and Barwick 1981). Distribution of threadfin shad ranges from Central America to Indiana, with northern distribution limited by a lower temperature tolerance of 7°-14°C. Threadfin shad tend to school near the surface in pelagic areas of reservoirs (Tomelleri and Eberle 1990; Hassan-Williams and Bonner 2008). The reported life span of threadfin shad is two to three years (Etnier and Starnes 1993), although the South Carolina Department of Natural Resources (SCDNR) noted that few threadfin shad in South Carolina reservoirs survive longer than one year. Spawning of threadfin shad typically occurs in May and June in South Carolina reservoirs (SCDNR 2009). Threadfin shad are capable of both filter- and particulate-feeding. In a study on Lake Jocassee, 24 to 32% of the diet of threadfin shad consisted of phytoplankton, with the remainder consisting of small zooplankton (Davis and Foltz 1991).

Distribution of anadromous blueback herring ranges from Florida to Nova Scotia. Landlocked populations of blueback herring have become common in reservoirs of the southeastern United States (Wheeler et al. 2004). Blueback herring tolerate temperatures as low as 2°C (Pardue 1983); during stratified periods, blueback herring in southeastern reservoirs tend to prefer cool (13°-24°C), deep water with dissolved oxygen concentrations exceeding 3 mg/L (Dennerline and Degan 1999; Goodrich 2002). Life spans of blueback herring in landlocked reservoirs range from two to four years (Wheeler et al. 2004). Blueback herring are predominantly sight-feeding size-selective predators (Pardue 1983; Davis and Foltz 1991). Davis and Foltz (1991) reported that blueback herring in Lake Jocassee consumed primarily larger copepods and cladocerans.

STUDY AREA

Lake Jocassee, located in the Blue Ridge region of North and South Carolina, was formed in 1971 by impoundment of the upper reaches of the Keowee River (Figure 1). Lake Jocassee is characterized by a surface area of 3,559 ha, a mean depth of 48 m, a maximum depth of 107 m, and a watershed area of 383 km^2 (Table 1).

Two electric generating facilities utilize water from Lake Jocassee: the 610-MW Jocassee Pumped Storage Station (JJPSSPSS), located at the Jocassee dam; and the 1,065-MW Bad Creek Pumped Storage Station (BCPSS), located on the western arm of the reservoir (Figure 1). JPSS utilizes water from Lake Jocassee to generate electricity during hours of peak demand, discharging to Lake Keowee; during off-peak hours, water is pumped from Lake Keowee back to Lake Jocassee for storage. BCPSS operates similarly, discharging water from the 127-ha Bad Creek Reservoir to Lake Jocassee to generate electricity, and pumping water from Lake Jocassee back to Bad Creek Reservoir for storage. Monthly mean JPSS generation flows and BCPSS pumping flows are plotted for the forage fish study period in Figure 2.

In the current study, annual winter minimum surface (0-4 m mean) lakewide temperatures on Lake Jocassee ranged from 9.0-11.1°C, while annual summer maximum surface (0-4 m mean) lakewide temperatures ranged from 25.5-28.1°C. Lake Jocassee is classified as oligomictic, thermally stratified in summer and characterized by complete vertical mixing during the winter in colder years; during warmer winters, the lake typically mixed to a depth of 40-50 meters (Clawson 1988; Duke Power Company 1995). Based on data collected for the current study in the top ten meters of the water column monthly in 2012, Lake Jocassee exhibited a mean annual lakewide total phosphorus concentration of <0.0055 mg P/L; a mean annual total nitrogen concentration of <0.1510 mg N/L; and a mean annual chlorophyll concentration of 2.36 mg/m^3. Based on these values, Lake Jocassee is best described as oligotrophic (Carlson and Simpson 1996).

The fish community of Lake Jocassee consists of a warmwater assemblage dominated by centrarchids and clupeids. In addition, the South Carolina Department of Natural Resources stocks brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) annually. Major game fish include brown trout and largemouth bass (*Micropterus salmoides*) (Barwick et al. 1994, 2005; Rankin 2007). Species likely to prey on the pelagic forage base of threadfin shad and blueback herring in Lake Jocassee include brown trout, rainbow trout, largemouth bass, and redeye bass (*Micropterus coosae*) (Barwick and Moore 1983; Vaughan 1983; SCDNR 2009; Taylor and Bulak 2011).

METHODS

Sources and treatment of data

Pelagic forage fish abundance – This study analyzes pelagic forage fish abundance data collected by Duke Energy fall 1997 through spring 2013. Hydroacoustics sampling with multiplexing, side-scan, and down-looking transducers was carried out in spring (March) and fall (typically November). Areal forage fish density estimates (fish/ha) were reported for four sampling zones on Lake Jocassee (Figure 1). Areal estimates for zones were converted to total fish and added to obtain estimates of total lakewide numbers of forage fish.

Pelagic forage fish species composition – Purse seine sampling was carried out in conjunction with fall hydroacoustics sampling to characterize species composition of the pelagic forage fish community. Purse seine samples were collected at one to two locations on Lake Jocassee; locations varied among years. Forage fish species composition was characterized as the percents of the purse seine haul consisting of threadfin shad and blueback herring. Percents were applied to estimates of total forage fish numbers produced by hydroacoustics sampling to estimate lakewide numbers of threadfin shad and blueback herring in fall.

Age structure of pelagic forage fish populations – Lengths of blueback herring and threadfin shad collected in fall purse seine samples were recorded in millimeters. For each species, length-frequency charts were developed; based on modes in length-frequency distributions, maximum lengths were chosen to classify individuals as young-of-the-year (YOY). Based on data collected 1990-2012, blueback herring less than 113 mm and threadfin shad less than 108 mm in length were classified as YOY. The percent of each population consisting of YOY fish was calculated based on these classifications. In addition, median lengths of YOY fish were calculated for each year, as an indicator of growth rate. Medians rather than means were employed for this purpose as annual YOY forage fish length measurements were not typically normally distributed.

Nutrients – Nutrient data collected monthly in 2012 were utilized to characterize the nutrient status of Lake Jocassee. Samples were collected at depths of 0.3, 5, and 10 meters at eight locations: 558 and 558.7 in forage fish sampling Zone 1; 559, 560, and 562 in Zone 2; 557 in Zone 3; and 554.8 and 556 in Zone 4 (Figure 1). Data were averaged over depths and locations within zones to obtain zonal nutrient concentrations. Zonal estimates were averaged over zones and months to obtain mean annual lakewide estimates of nutrient concentrations in the top ten meters of the water column. The following reporting limits were applied to nutrient parameters: 0.010 mg N/L for nitrate + nitrite nitrogen; 0.100 mg N/L for total Kjeldahl nitrogen; and 0.005 mg P/L for total phosphorus. The majority of nitrate + nitrite nitrogen observations fell below the reporting limit (57%); 44% of total Kjeldahl nitrogen observations and 68% of total phosphorus observations were below the respective reporting limits. Total nitrogen was calculated as the sum of nitrate + nitrite nitrogen and total Kjeldahl nitrogen after reporting limits were applied, creating a de facto reporting limit of 0.110 mg N/L for total nitrogen.

Chlorophyll – During the forage fish study period, surface (0.3 m) chlorophyll concentrations were measured quarterly in 1997, 2007-2010, and 2012, at Locations 558 and 558.7 (Zone 1); 560 (Zone 2); 557 (Zone 3); and 556 (Zone 4) (Figure 1). Limited data were available from 1999 as well. A comprehensive chlorophyll sampling program was carried out in 2012, when chlorophyll samples were collected monthly at depths of 0.3, 5, and 10 meters. This report utilized 2012 chlorophyll data from the following locations in forage fish sampling zones:

Zone 1: 558, 558.7
Zone 2: 559, 560, 562
Zone 3: 557
Zone 4: 554.8, 556

Zooplankton – Over the years of the forage fish study period, zooplankton data were available only in 2012. Zooplankton were sampled quarterly (February, May, August, November), at Locations 558.7 (Zone 1); 560 (Zone 2); 557 (Zone 3); and 556 (Zone 4). Samples were collected with a net towed from a depth of 20 meters to the lake surface.

Temperature and oxygen – Duke Energy measured temperature and oxygen profiles monthly 1997-2013 at eight locations on Lake Jocassee: Locations 554.8, 556, 557, 558, 558.7, 559, 560, and 562 (Figure 1). For the current study, temperature data measured in the top four meters of the water column were averaged to obtain a mean surface temperature. Surface (0.3 to 4-m mean) temperatures in forage fish sampling zones were calculated based on data from the following locations:

Zone 1: 558, 558.7
Zone 2: 559, 560, 562
Zone 3: 557
Zone 4: 554.8, 556

Lakewide surface (0.3 to 4-m mean) temperatures were calculated as the average of zonal surface temperatures. Because the data set of minimum winter temperature for the study period was incomplete (no data for 2002), two variables for winter temperature were analyzed: minimum winter temperature (N=15); and mean temperature observed January-February (N=16). Mean January-February temperature data were available for the entire forage fish study period. All surface temperatures referred to in this document refer to mean temperature in the top four meters of the water column.

Lake level – Lake level was recorded by Duke Energy daily at midnight throughout the study period. Lake level data are expressed as meters below full pool (positive number) throughout this report; therefore, statistically, maximum lake level represents greatest drawdown, or lowest physical lake level. Reference to lowest lake level throughout this report refers to physically low lake level, while reference to maximum lake levels in variable abbreviations corresponds to the statistical maximum, i.e., maximum drawdown (lowest physical lake level).

Gill net data – All littoral gill net data were provided by Rankin (2013). Data are expressed as numbers and biomass (kg) per 40 gill net sets.

Electrofishing data – Duke Energy conducted spring shoreline electrofishing on Lake Jocassee in 1999, 2002, 2005, 2008, and 2011. Ten 300-m shoreline transects were sampled in two zones. The Upper zone corresponded to forage fish sampling Zone 4 plus the upper reaches of forage fish sampling Zone 2. The Lower zone corresponded to forage fish sampling Zones 1 and 3, plus the lower area of Zone 2. Electrofishing data are expressed in this report as species numbers and biomass (kg) per km of shoreline.

Jocassee Pumped Storage Station operational data – Hourly generation and pumpback data were supplied by Duke Energy for the study period. For JPSS data through 2007, generation rates expressed as megawatt-hours were multiplied by 49 to obtain hourly average flows from Lake Jocassee to Lake Keowee in cubic feet per second (cfs). Pumpback rates expressed as megawatt-hours were multiplied by 37.73 to obtain hourly pumping flows from Lake Keowee to Lake Jocassee in cfs. These conversion factors were also applied to data for Units 1 and 2 at JPSS for the years 2008 through 2010. Conversion from MWH to cfs for Units 3 and 4 for the years 2008 through 2010 was accomplished using conversion factors of 44 cfs/MWH for generation and 35 cfs/MWH for pumping. Conversion of generation data from MWH to cfs for January 2011 through May 2013 data was accomplished using a conversion factor of 44 cfs/MWH for the entire station. Conversion of pumping data from MWH to cfs for January 2011 through May 2013 was accomplished using a conversion factor of 35 cfs/MWH for the entire station. Conversion factors were supplied by Duke Energy. Data were converted from cfs to m^3/sec using a conversion factor of 35.314444 ft^3/m^3.

Bad Creek Pumped Storage Station operational data – Bad Creek Pumped Storage Station hourly pumpback data for the study period (January 1997 through May 2013) were supplied by Duke Energy. Megawatt hours (MWH) were converted to pumping flow in cubic feet per second (cfs) using a conversion factor of 14 cfs/MWH, supplied by Duke Energy. Pumping flow data were converted from cfs to m^3/sec using a conversion factor of 35.314444 ft^3/m^3.

Statistical methods

Results of all statistical analyses were designated as significant using a reference probability of $P \leq 0.0500$. All statistical analyses were carried out using the SAS system of statistical analysis, Release 9.2 on the XP-PRO platform, produced by SAS Institute, Inc., Cary, North Carolina (copyright 2002-2008).

Univariate analysis including calculation of the Shapiro-Wilk statistic (W) was carried out on all data sets to determine the probability that data were normally distributed. Data were assumed to come from a normal distribution where $prob<W \geq 0.0500$. Data were log_{10}-transformed where useful to allow assumption of a normal distribution for parametric analyses and to reduce skew in non-normally-distributed data. Individual observations were identified as outliers where the data point was less than the 25% quartile (low outlier) or greater than the 75% quartile (high outlier) by between 1.5 and 3 times the interquartile range. Observations were identified as extreme outliers where the data point was less than the 25% quartile (extreme low outlier) or greater than the 75% quartile (extreme high outlier) by more than 3 times the interquartile range (SAS Institute, Inc. 1990). All spring and fall forage fish numbers and density data required log-transformation to allow assumption of a normal distribution.

Characterization of long-term temporal trends in parameters was carried out with time series analysis, consisting of linear regressions of annual data on year. Seasonal and spatial variation was examined with nonparametric analysis of variance.

Spring forage fish lakewide numbers and densities in forage fish sampling zones were analyzed in relation to winter environmental conditions and operational regimes. Winter temperature was quantified as minimum annual temperature. As noted previously, data were missing for 2002. Therefore spring forage fish were also analyzed in relation to mean January-February temperature to allow use of the complete data set, and to investigate the effects of sustained low temperature. Winter JPSS generation flow, BCPSS pumping flow, and lake level were characterized with three variables each: mean, maximum daily, and maximum 30-day average observed December-February. These variables were intended to quantify the influence of general winter conditions (mean); short-term high flow or low lake level (maximum daily); and sustained high flows or low lake levels (maximum 30-day average) occurring during the winter. Thirty-day averages were moving averages calculated daily for the current and previous 30 days; the maximum 30-day average observed December 30 through the end of February was chosen to characterize sustained periods of high flow or low lake level.

Other than for temperature, 'winter' as used in this report refers to December-February. The year with which winter data are associated is the year in which January-February measurements were made.

Fall forage fish lakewide numbers and densities in forage fish sampling zones were analyzed in relation to conditions encountered between spring forage fish spawning and fall forage fish sampling (May-October). JPSS generation flow, BCPSS pumping flow, and lake level observed May-October were characterized with three variables each: mean, maximum daily, and maximum 30-day average. These variables were intended to quantify the influence of general conditions (mean); short-term high flow or low lake level (maximum daily); and sustained high flows or low lake levels (maximum 30-day average), for the period May-October. Thirty-day averages were moving averages calculated daily for the current and previous 30 days; the maximum 30-day average observed May 30 through October 31 was chosen to characterize sustained periods of high flow or low lake level.

Relationships of forage fish parameters to environmental and operational parameters were initially examined with Spearman rank order correlation analysis. These relationships were examined in greater detail with linear and multiple regression analysis, $\log_{10}$-transforming forage fish data to allow assumption of a normal distribution. Data for independent variables were log-transformed where useful to allow assumption of a normal distribution or to reduce skewness; regression analysis does not require that independent variables be normally distributed, although it is desirable (Tabachnick and Fidell 1983; Norman and Streiner 2008).

Combined influences of environmental and operational parameters on pelagic forage fish abundance in Lake Jocassee were investigated with multiple regression analyses as follows:

Spring forage fish total numbers lakewide:
- Winter JPSS generation flow and temperature
- Winter BCPSS pumping flow and temperature
- Winter JPSS generation flow and lake level
- Winter BCPSS pumping flow and lake level
- Winter JPSS generation flow and Bad Creek pumping flow
- Winter JPSS generation flow, Bad Creek pumping flow, and lake level
- Winter JPSS generation flow, Bad Creek pumping flow, and temperature

Spring forage fish density (no/ha) in Zone 1:
- Winter JPSS generation flow and temperature
- Winter JPSS generation flow and lake level

Spring forage fish density (no/ha) in Zone 2:
- Winter BCPSS pumping flow and temperature
- Winter BCPSS pumping flow and lake level

Fall forage fish total numbers lakewide:
- May-October JPSS generation flow and lake level
- May-October BCPSS pumping flow and lake level
- May-October JPSS generation flow and Bad Creek pumping flow
- May-October JPSS generation flow, Bad Creek pumping flow, and lake level
- May-October JPSS generation flow and total numbers and biomass of trout and black basses from gill net data
- May-October BCPSS pumping flow and total numbers and biomass of trout and black basses from gill net data
- May-October lake level and total numbers and biomass of trout and black basses from gill net data

Fall forage fish density (no/ha) in Zone 1:
- May-October JPSS generation flow and lake level

Fall forage fish density (no/ha) in Zone 2:
- May-October BCPSS pumping flow and lake level

Multiple regressions of spring and fall total forage fish numbers run with two independent variables were re-run with addition of an interaction term to examine whether the dependent variable may have been influenced by interacting independent variables (with the exception of multiple regressions involving predator data). Independent variables are considered to interact when the influence of one independent variable changes at different levels of another independent variable (Norman and Streiner 2008; Garson 2010). The interaction term was calculated as the product of the two independent variables (Norman and Streiner 2008). To avoid multicollinearity due to correlations between the interaction variable and the independent variables, independent variables were centered by calculating the mean over the dataset for each independent variable, and subtracting the mean from the observed value for each year.

Interaction terms were calculated as the product of the centered variables (Helsel and Hirsch 2002). Centering of the independent variables produces no changes in model R^2 or Pr>F values, but eliminates multicollinearity, changing the significance probabilities associated with the parameter estimates for the independent variables (prob>|t|) and thus providing information regarding the relative significance of the independent variables towards explaining variance in the dependent variable.

Outlying observations in regression analysis were identified where the absolute value of the studentized residual statistic exceeded 2.5 (Freund et al. 2006). Highly influential data points, observations that disproportionately influence the outcome of regression analysis, were identified where values of the Cook's D statistic exceeded a critical value for the F statistic, using a reference probability of 0.05. Helsel and Hirsch (2002) define the critical F value as follows:

$$\text{Critical Cook's D} = F_{(p+1,n-p)}$$

where

p = number of coefficients in regression equation (2 for linear regression)
n = number of observations

Where outlying or highly influential data points were identified in linear regression analyses, regressions were repeated, excluding outlying or highly influential data, for informational purposes. Both initial and follow-up results were reported. Multiple regressions where outlying observations were identified were not routinely repeated, due to the relatively small number of observations available for analysis (see below), and to the potential loss of information associated with excluding an observation with no known reason to do so.

It should be kept in mind that statistical identification of an observation as an outlier does not of itself indicate error in the observation, and exclusion of outliers could lead to a loss of information about relationships between dependent and independent variables. Due to the potential loss of important information, Kleinbaum et al. (1998) recommended that outlying observations not be excluded from regression analyses unless there is strong evidence of measurement, recording, or other error associated with the observations. In the current study, while outliers were identified in some analyses and results were reported both with and without the outlying observations, in no case was there a known reason to exclude the outlying observation.

Not infrequently in these analyses, the significance or lack thereof of a given regression analysis was dependent on the inclusion or exclusion of one observation, likely as a result of the relatively small number of observations available for analysis (see discussion of sample size below). Regressions where significance is dependent on inclusion of a single observation cannot be considered robust; similarly, regressions where significance depends on exclusion of a single observation must be interpreted with caution, as the excluded observation may contain important information about the relationship being investigated.

The SPEC option in the SAS procedure PROC REG (SAS institute, Inc. 1990) was utilized to test for homoscedasticity of variance in regression analysis. Deviations from homoscedasticity were designated as statistically significant where prob>chi-square≤0.0500) (Christiansen 1997). Kleinbaum et al. (1998) indicated that minor deviations from homoscedasticity do not generally affect regression results. No deviations from homoscedasticity were noted in the analyses reported here.

Multicollinearity, or correlations among independent variables in multiple regression analysis, may produce unrealistic results regarding the contribution of individual independent variables to explaining variance in the dependent variable. In multiple regression analyses, the potential for multicollinearity was examined with the variance inflation factor (VIF). VIF values greater than 10 indicate a problem with multicollinearity (Kleinbaum et al. 1998; Helsel and Hirsch 2002). All VIF values in this study were substantially less than 10.

The number of observations available in this study was relatively small for multiple regression analysis, with N for most analyses equal to 16 or less. A suggested minimum sample size for regression analysis is five times the number of independent variables (Norman and Streiner 2008; Garson 2010). As sample size decreases, the influence of each individual observation becomes greater, potentially producing unrealistic results (Kleinbaum et al. 1998). In the current study, at times the significance or lack of significance of a regression result depended on the presence or absence of a single observation, indicating that a relationship may not have been robust. This does not invalidate the results of these analyses; however, it does suggest that additional observations would allow results to be interpreted with greater confidence.

PELAGIC FORAGE FISH COMMUNITY CHARACTERISTICS, 1997-2013

Based on hydroacoustics sampling carried out on Lake Jocassee from fall 1997 through spring 2013, total numbers of pelagic forage fish in Lake Jocassee averaged 2,004,460 fish in spring and 4,570,844 fish in fall. Lakewide forage fish densities averaged 587 fish/ha in spring and 1,356 fish/ha in fall (Table 2; Figure 3).

Seasonal variation – Total numbers of forage fish in Lake Jocassee ranged from 315,678 to 7,055,096 in spring, and from 1,651,468 to 13,082,248 in fall. Total forage fish numbers were significantly higher in fall than in spring (prob>chi-square = 0.0003 in nonparametric analysis of variance). Forage fish densities were significantly higher in fall than spring in all four forage fish sampling zones as well (Table 2; Figure 4).

Spatial variation – Substantial and statistically significant spatial variation in forage fish abundance was evident on Lake Jocassee in both spring and fall, with highest forage fish densities observed in Zone 4, encompassing the upper Toxaway and Horsepasture Rivers area (Figure 4).

During the spring, forage fish density in Zone 4 averaged 2,084 fish/ha, more than six times the average spring forage fish density observed in Zones 1, 2, and 3 (304 fish/ha, 170 fish/ha, and 335 fish/ha, respectively) (Table 2; Figure 4).

During the fall, forage fish density in Zone 4 averaged 2,744 fish/ha, more than twice the average fall forage fish densities in Zones 1, 2, and 3 (1,360 fish/ha, 608 fish/ha, and 1,077 fish/ha, respectively (Table 2; Figure 4).

Statistically, nonparametric analysis of variance indicated that forage fish density in Zone 4 was significantly higher than in any other zone, in both spring and fall. In fall, forage fish density in Zone 2 was significantly lower than in any other zone. No other significant spatial differences in forage fish density were detected.

Higher forage fish density in Zone 4 during the spring may have been related to greater food availability during the winter, based on chlorophyll concentrations measured in February. Relationships of forage fish density to chlorophyll are examined later in this report.

Long-term temporal variation – Time series analysis of forage fish lakewide numbers measured fall 1997 through spring 2013 detected no consistent long-term upward or downward linear trends in either spring or fall data (Figure 3). Similarly, time series analysis of forage fish density data for individual zones detected no long-term trends in either spring or fall data (Figures 5 through 8).

Substantial variation among years was evident in both spring and fall data, lakewide and in individual forage fish sampling zones. Highest total forage fish numbers of the study period were observed in fall 2012 (13,082,248 fish); numbers were nearly twice as high as the previously-observed fall maximum of 6,965,453 fish, observed in 1999 (Table 2; Figure 3). Similarly, the highest spring total forage fish number of the study period was observed in spring 2013 (7,055,096 fish), again nearly twice as high as the previous spring maximum of 3,975,478 fish, observed in spring 1999. Univariate analysis of fall and spring forage fish lakewide numbers for fall 1997 through spring 2013 identified the fall 2012 and spring 2013 observations as extreme high outliers in fall and spring data, respectively. The 2012 fall forage fish density observation was identified as a high outlier in data for Zones 1 and 4, and as an extremely high outlier in data for Zone 2. The 2013 spring forage fish density observation was identified as a high outlier in data for Zone 3, and an extremely high outlier in data for Zone 4 (Figures 5 through 8).

Community composition – Blueback herring constituted 75% of the pelagic forage fish community of Lake Jocassee on average, while threadfin shad constituted 25%, based on purse seine data collected 1997-2012 (Table 3). Percent composition varied substantially among years, although blueback herring comprised the majority of fall pelagic forage fish numbers in all but two of the sixteen years for which data were available (Table 3; Figure 9). It is interesting to note that blueback herring comprised greater than 90% of the fall pelagic forage fish community for the four most recently-sampled years (2009-2012), and accounted for 99.9% of the unusually high forage fish numbers observed in fall 2012 (Table 3; Figure 10). No significant long-term linear trends were detected in time series analysis of percent composition of the pelagic forage community.

Annual fall population estimates of blueback herring and threadfin shad numbers were calculated as the product of percent composition of fall purse seine samples and lakewide forage fish numbers from fall hydroacoustics sampling (Table 3). While population numbers varied substantially among years, no significant long-term upward or downward linear trends in numbers of blueback herring or threadfin shad were detected in time series analysis (Figure 10).

Age structure of fall forage fish populations – Based on length-frequency plots of the lengths of forage fish in fall purse seine samples, blueback herring less than 113 mm in length and threadfin shad less than 108 mm in length were classified as young-of-the-year (YOY). YOY blueback herring comprised from 14.8 to 99.5% of the total population in fall, averaging 72.2%. In contrast, virtually the entire fall threadfin shad population consisted of YOY fish in all years (Table 4; Figure 11).

YOY growth rates – Median lengths of YOY fish in fall purse seine samples were calculated as an indicator of growth rates. From 1997-2012, annual median lengths of YOY blueback herring in fall averaged 79 mm, ranging from 67 to 92 mm. Annual median lengths of YOY threadfin shad in fall averaged 67 mm, ranging from 57 to 81 mm (Table 4; Figure 12). Differences among years in lengths of YOY forage fish were statistically significant for both blueback herring and threadfin shad, based on nonparametric analysis of variance (prob>chi-square<0.0001 for each species).

RELATIONSHIPS OF FORAGE FISH ABUNDANCE TO ENVIRONMENTAL AND OPERATIONAL PARAMETERS

Forage fish abundance on Lake Jocassee was analyzed in relation to parameters related to habitat (temperature, oxygen, lake level); food availability (chlorophyll, zooplankton); predation; and operations at Jocassee Pumped Storage Station (generation flow) and Bad Creek Pumped Storage Station (pumping flow). Potential effects of environmental and operational parameters on forage fish abundance in spring and fall were investigated through graphical analysis, analysis of variance, correlation analysis, and regression analysis.

Temperature and oxygen

The two species that comprise the forage fish community of Lake Jocassee exhibit differing habitat preferences. Threadfin shad have been observed to congregate in surface waters at temperatures exceeding 30°C (Schael et al. 1995), and would be expected to have ample, favorable habitat in Lake Jocassee during the warmer months. The lower temperature tolerance of this species has been reported as 7-14°C (Lee et al. 1980). Cold-induced mortality of threadfin shad has been observed at temperatures of 9-12°C; massive winter die-offs are not uncommon at the limits of this species' range. Mobility of threadfin shad may be impaired at temperatures below about 14°C, potentially increasing susceptibility to entrainment and predation (Griffith 1978; Burgess 1980; McLean et al. 1982, 1985; Etnier and Starnes 1993). Blueback herring have exhibited a preference for habitat with temperatures between 13° and 24°C and oxygen concentrations exceeding 3 mg/L during the warmer months (Dennerline and Degan 1999; Goodrich 2002). In contrast to threadfin shad, blueback herring tolerate winter temperatures as low as 2°C (Lee et al. 1980; Page and Burr 1991). Species-specific responses to low winter temperatures on Lake Jocassee could not be examined due to a lack of species-specific spring population numbers; therefore total numbers of forage fish in spring are examined in relation to winter temperature. All surface temperatures referred to below represent the mean temperature in the top four meters of the water column. Lakewide temperatures were calculated as the mean of surface temperatures in forage fish sampling zones.

Temperature characterization – Monthly mean surface temperatures observed in forage fish sampling zones on Lake Jocassee over the forage fish study period ranged from 8.8 to 28.7°C (Table 5). Lakewide, minimum winter surface temperature averaged 10.0°C over the forage fish study period, while maximum summer surface temperature averaged 27.1°C (Table 6). Minimum winter surface temperature was most often observed in February, while maximum summer temperature was typically observed in August (Figure 13). Minimum annual surface temperatures did not differ significantly among forage fish sampling zones on Lake Jocassee, based on nonparametric analysis of variance. Maximum annual surface temperatures averaged 26.7°C in Zone 1; 27.2°C in Zone 2; 27.1°C in Zone 3; and 27.3°C in Zone 4, based on data collected 1997-2012 (excluding 2006, when August data were available only for Zone 1). Maximum annual surface temperatures were significantly lower in Zone 1 than in Zones 2 and 4, based on nonparametric analysis of variance. No long-term upward or downward linear trends in annual winter minimum or summer maximum surface temperature were detected in time series analysis of lakewide mean surface temperature data collected fall 1997 through spring 2013.

Effect of winter minimum temperature on spring forage fish abundance – Minimum winter surface lakewide mean temperatures ranged from 9° to 11.1°C over the forage fish study period (Table 6). Total forage fish numbers lakewide in spring are plotted against annual minimum winter temperature and mean January-February temperature in Figure 14. Spearman correlation analysis of data collected 1998-2013 detected a significant, positive correlation between total numbers of forage fish lakewide in spring and mean January-February surface temperature (r_s=0.53; P=0.0350; N=16), revealing a tendency for the total number of forage fish present in spring to be lower following colder winters. Spearman correlation between total forage fish and minimum winter temperature did not meet the reference probability for statistical significance (r_s=0.48; P=0.0687; N=15).

For individual forage fish sampling zones, Spearman correlation analyses of spring forage fish zonal densities with zonal surface minimum winter temperature and mean January-February temperature detected a significant tendency for forage fish densities in Zone 4 to be lower following winters with colder mean January-February temperatures (r_s=0.59; P=0.0159; N=16)

(Figure 15). No significant relationships were detected between spring forage fish densities in zones and minimum annual or mean January-February temperatures in Zones 1, 2, or 3.

To further investigate the relationship of forage fish abundance to winter temperature, linear regression analyses were carried out relating spring forage fish total numbers and densities in zones to minimum winter temperature and mean January-February temperature. None of these analyses produced results which met the reference probability for statistical significance. The relationship of spring forage fish lakewide numbers to mean January-February temperature, identified as significant in Spearman correlation analysis, yielded the following model, which approached, but did not meet, the defined reference probability for statistical significance:

(1)
logSprFish = 3.93947 + 0.21340 JanFebLWTemp
R^2 = 0.2362
Pr>F = 0.0563
N = 16
Prob>|t| for intercept = 0.0027
Prob>|t| for temperature = 0.0563
Data set: 1998-2013
Outlying or highly influential observations: (none)
where logSprFish= log Total number of forage fish lakewide in spring
JanFebLWTemp = lakewide mean surface (0-4 m) temperature observed January-February

It is possible that low winter temperature may have exerted a threshold effect on forage fish. Nonparametric analysis of variance comparing spring forage fish numbers in years where mean January-February temperature fell below 10.5°C (N=7) to years where mean January-February temperature was equal to or greater than 10.5°C (N=9) indicated that spring forage fish numbers were significantly higher following winters where mean January-February temperature did not fall below 10.5°C (prob>chi-square = 0.0070) (Figure 14). Total spring forage fish numbers averaged 2,781,152 after warmer winters as compared to 1,005,856 after colder winters (mean January-February temperature < 10.5°C).

These analyses suggest that spring forage fish abundance on Lake Jocassee may have been influenced by low winter temperatures during colder winters, potentially through cold-induced mortality and/or increased susceptibility to predation due to reduced mobility. The potential for combined effects of low temperature and winter operations at Bad Creek and Jocassee Pumped Storage Stations is examined later in this report.

Relationship of summer maximum temperature to fall forage fish – Maximum lakewide mean surface temperatures observed in summer ranged from 25.5° to 28.1°C (Table 6). Total forage fish numbers lakewide in fall were not significantly correlated with maximum surface temperature in Pearson correlation analysis (r=0.41; P=0.1251; N=15; fall forage fish numbers log-transformed) (Figure 16). Among individual forage fish sampling zones, a significant, positive Pearson correlation was detected between fall forage fish density and maximum zonal summer surface temperature in data for Zone 1 (r=0.65; P=0.0063; N=16; fall forage fish density log-transformed) (Figure 17). No significant correlations were detected in data for Zones 2, 3, or 4.

Linear regression analysis relating fall forage fish densities in zones to zonal maximum summer surface temperature (Appendix Table 36) produced the following significant model relating fall forage fish density in Zone 1 to zonal maximum summer surface temperature (Figure 17):

(2)
logFallDens = -7.00535 + 0.37418 MaxTempZ1
R2 = 0.4244
Pr>F = 0.0063
N = 16
Prob>|t| for intercept = 0.0407
Prob>|t| for temperature = 0.0063
Data set: 1997-2012
Outlying or highly influential observations: (none)
where logFallDens = log Fall forage fish density in Zone 1, no/ha
MaxTempZ1 = maximum summer surface temperature in Zone 1, °C

This model detected a significant tendency for fall forage fish density in Zone 1 to be higher following warmer summers. Maximum summer surface temperature potentially explained 42% of variance in fall forage fish density in Zone 1.

Initial linear regression analysis of total forage fish numbers lakewide on maximum summer surface temperature did not produce significant results (Appendix Table 35). The observation for 2012 was identified as outlying in this analysis (Figure 16). The regression was repeated excluding data for 2012, producing the following model:

(3)
logFallFish = 3.32467 + 0.12052 MaxLWTemp
R2 = 0.3425
Pr>F = 0.0279
N = 14
Prob>|t| for intercept = 0.0256
Prob>|t| for temperature = 0.0279
Data set: 1997-2012, excluding 2012
Outlying or highly influential observations: (none)
where logFallFish = log Total number of forage fish lakewide in fall
MaxLWTemp = maximum summer surface temperature lakewide, °C

There is no known reason to exclude data for 2012 from this analysis; exclusion of outliers without evidence of measurement or other error is not recommended as these observations contain information regarding variability in regression variables (Kleinbaum et al. 1998).

Late summer temperature-oxygen constraints – Examination of vertical temperature and oxygen profiles for July through October at locations on Lake Jocassee indicated that habitat within the ranges preferred by blueback herring was available during the warmer months in all years of the forage fish study. Based on habitat preferences of temperature ≤ 25°C and dissolved oxygen ≥ 2.5 mg/L at Location 558, blueback herring habitat was present in a vertical layer no less than 38 meters thick in all years, 1997-2012. As noted above, threadfin shad tolerate surface temperatures above 30°C; thus ample well-oxygenated habitat was available during the warmer months.

Lake level

Lake level characterization – Daily lake levels recorded on Lake Jocassee 1997-2012 ranged from 0.03 to 8.78 meters below full pool, exhibiting a mean of 3.46 meters below full pool and a median of 2.74 meters below full pool. Mean annual lake levels are listed in Table 7. Long-term variation in monthly mean lake level January 1997 through May 2013 is plotted in Figure 18.

Over the study period, mean lake levels observed during the winter (December-February) ranged from 0.36 to 7.56 meters below full pool, while mean lake levels observed during the months between forage fish spawning and fall forage fish sampling (May-October) ranged from 0.45 to 7.89 meters below full pool (Table 8; Figure 19). Substantial variation in lake level was commonly observed during both the winter and the warmer months. Annually, the range over which lake level varied was as high as 5.45 meters in winter, and as high as 8.42 meters during the warmer months (Table 8). Forage fish abundance was investigated in relation to the mean, lowest daily, and lowest 30-day average lake level observed during the period prior to forage fish sampling.

Relationship of winter lake level to spring forage fish abundance – Total lakewide numbers of forage fish in spring and spring forage fish densities in zones are plotted against mean winter lake level in Figures 20 and 21.

Relationships of spring forage fish abundance to winter lake level were initially investigated with Spearman correlation analysis. Spring forage fish lakewide numbers and densities in zones were subjected to correlation analysis with mean, lowest 30-day average, and lowest daily lake level observed December-February. No significant correlations were detected in these analyses.

Linear regression analysis was also employed to investigate relationships between spring forage fish abundance and winter lake level. Spring forage fish lakewide numbers and densities in zones were regressed on the mean, lowest 30-day average, and lowest daily lake level observed December-February. No significant relationships were detected in these analyses (Appendix Table 1).

Relationship of May-October lake level to fall forage fish abundance – Lakewide forage fish numbers in fall and fall forage fish densities in zones are plotted against mean May-October lake levels in Figures 22 and 23.

Relationships of fall forage fish abundance to lake level were initially investigated with Spearman correlation analysis. No significant relationships were detected between total numbers of forage fish lakewide in fall and mean, lowest daily, or lowest 30-day average lake level observed May-October. Among forage fish sampling zones, fall forage fish density in Zone 1 wase significantly correlated with mean lake level observed May-October (r_s=0.57; P=0.0218; N=16), as well as with lowest daily lake level (r_s=0.55; P=0.0283; N=16) and lowest 30-day average lake level observed May-October (r_s=0.58; P=0.0187; N=16). The positive nature of these correlations indicated that forage fish density in Zone 1 tended to be higher when lake levels were lower, suggesting a possible impact of declining lake level on fish distribution within Lake Jocassee. Fall forage fish densities in Zones 2, 3, and 4 exhibited no relationship to lake level.

Relationships of fall forage fish abundance to May-October lake levels were further investigated with linear regression analysis. As with Spearman correlation analysis, no significant relationships were detected between any measure of May-October lake level and either total numbers of forage fish in fall or fall forage fish densities in Zones 2, 3, or 4 (Appendix Table 2). Again consistent with Spearman correlation results, linear regression analysis detected significant relationships between fall forage fish density in Zone 1 and mean, maximum daily, and maximum 30-day average lake levels observed May-October, as follows.

(4)
logFallDensZ1 = 2.68564 + 0.08596 MeanMayOctLL
R^2 = 0.3155
Pr>F = 0.0236
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for lake level = 0.0236
Data set: 1997-2012
Outlying or highly influential observations: (none)
where logFallDensZ1 = log Fall forage fish density (no/ha) in Zone 1
MeanMayOctLL = mean lake level observed May-October, meters below full pool

(5)
logFallDensZ1 = 2.56586 + 0.07394 MaxDailyMayOctLL
R^2 = 0.2928
Pr>F = 0.0304
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for lake level = 0.0304
Data set: 1997-2012

Outlying or highly influential observations: (none)

where logFallDensZ1 = log Fall forage fish density (no/ha) in Zone 1
MaxDailyMayOctLL = lowest daily lake level observed May-October, meters below full pool

(6)
logFallDensZ1 = 2.58207 + 0.07884 Max30dayMayOctLL
$R^2 = 0.3192$
Pr>F = 0.0226
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for lake level = 0.0226
Data set: 1997-2012
Outlying or highly influential observations: (none)

where logFallDensZ1 = log Fall forage fish density (no/ha) in Zone 1
Max30dayMayOctLL = lowest 30-day moving average lake level observed May-October, meters below full pool

Again, the positive parameter estimates for lake level indicate that forage fish densities in Zone 1 exhibited some tendency to be higher at lower May-October lake levels. In light of the fact that no relationship was evident between total forage fish numbers and May-October lake level, the observation of a relationship in Zone 1 is consistent with the idea that lake level may have been influencing forage fish distribution in Lake Jocassee.

The possibility that forage fish abundance in Lake Jocassee was influenced by combined effects of lake level and BCPSS pumping or lake level and JPSS generation is examined in later in this report.

Chlorophyll

Chlorophyll data were analyzed in relation to forage fish on Lake Jocassee in an attempt to assess the influence of reservoir fertility on forage fish abundance. Quarterly surface (0.3 m) chlorophyll data were collected in 1997, 2007-2010, and 2012 at Locations 556, 557, 558, 558.7, and 560 (limited data were available for 1999 as well). For analysis of relationships with total forage fish numbers on Lake Jocassee, lakewide mean chlorophyll concentrations were calculated based on data from these five locations. In addition, in 2012 only, monthly chlorophyll data were collected at depths of 0.3, 5, and 10 meters at Locations 554.8, 556, 557, 558, 558.7, 559, 560, and 562.

Chlorophyll characterization – Based on monthly data collected at 8 locations on Lake Jocassee in 2012, mean annual chlorophyll concentrations in the top ten meters of the water column averaged 1.79 mg/m^3 in Zone 1 (Locations 558, 558.7); 2.18 mg/m^3 in Zone 2 (Locations 559, 560, 562); 2.37 mg/m^3 in Zone 3 (Location 557); and 3.10 mg/m^3 in Zone 4 (Locations 554.8, 556) (Figure 24). Nonparametric analysis of variance of monthly data from 2012 detected significant spatial variation in chlorophyll concentrations. Concentrations in Zone 4 were significantly higher than those in all other zones, while concentrations in Zone 1 were significantly lower than those in all other zones. Among individual locations sampled in 2012, highest chlorophyll concentrations were observed at Location 554.8, in the Horsepasture River arm of Zone 4 (Figure 24); concentrations at Location 554.8 were significantly higher than observed at any other location. Spatial patterns in 2012 data were consistent seasonally, in that highest mean winter (January-February) and growing season (May-October) chlorophyll concentrations in the top ten meters of the water column were observed in Zone 4, and lowest in Zone 1.

Seasonal variation in chlorophyll concentrations as observed in 2012 is plotted in Figure 25. Lakewide in 2012, mean chlorophyll concentrations were highest in May, averaging 3.07 mg/m^3 over 8 locations; and lowest in December, averaging 1.65 mg/m^3.

Few data were available to assess long-term variation in chlorophyll concentrations in Lake Jocassee over the forage fish study period. Based on time series analysis of zonal surface (0.3 m) data collected quarterly in 1997, 1999, 2007-2010, and 2012 at Locations 558 (Zone 1), 560 (Zone 2), 557 (Zone 3), and 556 (Zone 4), mean annual chlorophyll concentrations did not exhibit long-term upward or downward linear trends over the forage fish study period (1997-2012) (Figure26).

Comparison of pelagic forage fish-chlorophyll relationship to Catawba-Wateree reservoirs – Rodriguez (2005) investigated relationships of fall standing stocks of pelagic forage fish to reservoir fertility in reservoirs of the Catawba-Wateree Hydroelectric Project, in North and South Carolina. Based on data collected at 18 sites on nine reservoirs, variation in spring chlorophyll concentrations could explain 63% of variation in fall densities of forage fish. To examine whether Lake Jocassee maintained fall standing stocks of pelagic forage fish consistent with those of Catawba-Wateree reservoirs of similar fertility, forage fish and chlorophyll data for Lake Jocassee were superimposed on a plot of the Catawba-Wateree regression. Because substantial, statistically significant spatial variation in fall forage fish densities was evident on Lake Jocassee, data for each individual forage fish sampling zone were plotted. Observations consisted of zonal surface (0.3 m) chlorophyll concentrations measured in May and fall zonal forage fish densities, with both variables averaged over the years for which chlorophyll data were available (1997, 2007-2010, 2012). Observations for all zones fell within the 95% confidence limits of the Catawba-Wateree regression (Figure 27). In 2012, chlorophyll samples were collected on Lake Jocassee at greater frequency and at more depths than in previous years, allowing calculation of spring chlorophyll concentrations directly analogous to those utilized for the Catawba-Wateree regression (mean of chlorophyll values measured at 0.3 and 5 meters in April and May). To further examine whether relationships between reservoir fertility and fall forage fish density on Lake Jocassee were consistent with those observed for the Catawba-Wateree reservoirs, spring chlorophyll and fall forage fish data measured in 2012 in individual forage fish sampling zones of Lake Jocassee were superimposed on the Catawba-Wateree regression. Observations for all forage fish sampling zones on Lake Jocassee once again fell well within the 95% confidence limits of the Catawba-Wateree regression (Figure 28). These results indicate that fall forage fish stocks on Lake Jocassee were consistent with those of other southeastern reservoirs of similar fertility.

Relationships of spring forage fish abundance to winter chlorophyll concentration – Data available to analyze relationships of spring forage fish abundance to winter chlorophyll data were limited to the years 2007-2010 and 2012. Spring forage fish lakewide numbers were subjected to correlation analysis with mean lakewide surface (0.3 m) chlorophyll concentrations measured in February. No significant relationships were detected in these analyses. Zonal spring forage fish density data were subjected to Spearman and Pearson correlation analysis and linear regression analysis with February zonal surface chlorophyll data, yielding no significant relationships in data for individual zones. However, analysis of data for all zones together, allowing both spatial and temporal variation in chlorophyll to factor into explaining variability in forage fish density, produced the following regression model (Figure 29):

(7)
logSprDens = 2.49875 + 1.26543 logFebZoneChl
$R^2 = 0.2956$
Pr>F = 0.0132
N = 20
Prob>|t| < 0.0001 for intercept
Prob>|t| = 0.0132 for chlorophyll
Data set: 2007-2010, 2012 (all zones)
Outlying observation: 2007-Zone 4 (Studentized residual = 2.643)
where logSprDens = log Spring forage fish density, no/ha
logFebZoneChl = log February zonal surface (0.3m) chlorophyll

When this regression analysis was repeated, excluding the outlying observation, the relationship between February chlorophyll concentration and spring forage fish densities was stronger (R^2 = 0.4065; Pr>F = 0.0033; N=19), although there is not a known reason for excluding this observation.

These analyses suggest that food availability during the winter may have influenced spring forage fish abundance on Lake Jocassee, as winter chlorophyll concentration potentially explained 30% of variation in spring forage fish densities in zones.

Relationships of fall forage fish abundance to chlorophyll concentrations – Lakewide numbers of forage fish measured in fall exhibited no relationship to lakewide surface (0.3 m) chlorophyll concentrations measured in May or August, or to mean May-August chlorophyll concentration, based on correlation and linear regression analysis of data collected 1997, 2007-2010, and 2012. Similarly, correlation analysis detected no significant relationships between fall forage fish density in any zone and May, August, or mean May-August zonal chlorophyll concentrations. Over all zones, a very weak, but statistically significant, relationship was detected in correlation and linear regression analysis relating zonal fall forage fish densities to mean zonal surface chlorophyll concentrations averaged over May and August, using data collected 1997, 2007-2010, and 2012 (Figure 30):

(8)
logFallDens = 2.74393 + 0.18392 MayAugChl
$R^2 = 0.1912$
Pr>F = 0.0326
N = 24
Prob>|t| < 0.0001 for intercept
Prob>|t| = 0.0326 for chlorophyll
Data set: 1997, 2007-2010, 2012, for all zones
Outlying or highly influential observations: (none)
where logFallDens = log Fall forage fish density, no/ha
MayAugChl = mean of May and August surface (0.3 m) chlorophyll concentrations in forage fish sampling zone

This relationship, although weak, is consistent with the idea that fall forage fish densities in Lake Jocassee may have been influenced by food availability among other factors. Variation in chlorophyll concentrations potentially explained 19% of variation in fall forage fish densities in zones.

Zooplankton

Zooplankton data for Lake Jocassee were available only in 2012. Zooplankton were sampled quarterly in 2012 with 20 m-to-surface net tows at four locations, one within each forage fish sampling zone (Table 9).

Zooplankton characterization – Over all locations and dates sampled in 2012, densities of total zooplankton averaged 47,053 organisms/m^3, ranging from 10,601 to 89,377 organisms/m^3. Densities of copepods averaged 11,094 organisms/m^3; cladocerans 5,607 organisms/m^3; and rotifers 30,353 organisms/m^3 (Table 9). Based on nonparametric analysis of variance, seasonal variation in zooplankton densities was significant for all major taxonomic groups. Densities of total zooplankton and rotifers were lowest in February and highest in May and November. Copepod densities were lowest in February, and did not vary substantially among May, August, and November. Cladoceran densities were highest in August (Figure 31). Spatial variation in zooplankton densities was not statistically significant based on quarterly data from 2012, and tended to be outweighed by seasonal variation (Figure 32). In 2012, total zooplankton densities averaged 51,266 organisms/m^3 in Zone 1; 43,254 organisms/m^3 in Zone 2; 46,176 organisms/m^3 in Zone 3; and 47,516 organisms/m^3 in Zone 4.

Based on data collected in 2012, the cladocerna community of Lake Jocassee was dominated by *Bosmina longirostris* in February, August, and November; *Bosminopsis deitersi* was important in August. The copepod community was numerically dominated by immature forms year-round; in May *Tropocyclops prasinus* was important as well. The rotifer community was dominated by *Keratella cochlearis* in February; *Keratella taurocephala* in May; *Ptygura libra* in August (*Keratella taurocephala* in Zone 4); and *Keratella taurocephala* in November.

Relationships of spring forage fish abundance to winter zooplankton – As zooplankton data were collected in 2012 only, too few observations were available to allow statistical analysis of relationships between forage fish abundance and zooplankton densities. Plots of February zooplankton densities in forage fish sampling zones vs. spring forage fish densities for the year 2012 (Figure 33) provide a very preliminary indication that zooplankton abundance may be important in determining forage fish distribution in Lake Jocassee.

Relationships of fall forage fish abundance to spring/summer zooplankton – As with spring data, too few zooplankton observations were available to allow statistical analysis of relationships between fall forage fish abundance and zooplankton densities in spring and summer. Plots of fall forage fish densities in zones vs. densities of zooplankton measured in May and August provided no evidence of relationships between fall forage fish zonal densities and zooplankton abundance in 2012 (Figure 34).

Predation

Both threadfin shad and blueback herring are of major importance as prey for game fish in South Carolina reservoirs (SCDNR 2009). Brown trout, rainbow trout, redeye bass, and largemouth bass have been identified as major predators on blueback herring and threadfin shad in Lake Jocassee (Barwick and Moore 1983; Vaughan 1983; Taylor and Bulak 2011). Brown trout in Lake Jocassee foraged primarily on threadfin shad and blueback herring, with threadfin shad relatively more important in the diet of smaller brown trout, and blueback herring more important in the diet of larger brown trout; a substantial percentage of the fall-to-spring decline in abundance of threadfin shad and blueback herring in Lake Jocassee could be attributed to predation by brown trout (Taylor and Bulak 2011). Manooch and Raver (1988) and SCDNR (2009) documented that threadfin shad were a major part of the diet of largemouth bass in large reservoirs.

Because of the mutual pressures exerted between predator and prey, and the wide array of factors potentially influencing both predators and forage fish, relationships of the abundance of predators to prey are complex and detection of relationships may require a very large data set (Vatland et al. 2008). Forage fish numbers are influenced by both bottom-up factors related to food availability, and by top-down pressures of predation. Predator numbers are potentially influenced not only by food availability but by other factors, such as, stocking rates, habitat, competition, and fishing pressure, complicating detection of predator-prey relationships.

Indirect evidence for the importance of predation in regulating the fall population of threadfin shad lies in the fact that 100% of threadfin shad in fall purse seine samples consisted of YOY, for every year of this study (1997-2012) (Table 4), despite the fact that this species has a reported life span of up to three years (Etnier and Starnes 1993). For comparison, 72% of blueback herring in purse seine samples were YOY, on average (Table 4). Virtually 100% of both threadfin shad and blueback herring in fall purse seine samples on Lake Jocassee fell within the size range identified by Cyterski and Ney (2005) as vulnerable to predation (40 to 160 mm). In addition, in the current study, forage fish numbers declined 54% from fall to spring on average, presumably due at least in part to predation pressure during the winter.

Predation as a factor potentially influencing forage fish abundance on Lake Jocassee was investigated utilizing both gill net and electrofishing data to assess the abundance of potential predators.

Trends in predator abundance, gill net data – Rankin (2013) provided gill net data for Lake Jocassee for the years 1999 through 2012 (Table 10). Over the period 1999-2012, numbers and biomass of brown trout averaged 87 fish and 115.6 kg per 40 gill net sets. Numbers and biomass of rainbow trout averaged 7 fish and 3.7 kg per 40 gill net sets, although rainbow trout may not have been efficiently sampled with gill nets (Taylor and Bulak 2011). Numbers and biomass of total black basses averaged 110 fish and 84.1 kg per 40 gill net sets. Redeye bass accounted for 87% of black bass numbers and 77% of black bass biomass, with the remainder consisting of largemouth bass and smallmouth bass (*Micropterus dolomieu*). Numbers and biomass of white catfish (*Ictalurus catus*) averaged 40 fish and 10.7 kg per 40 gill net sets (Table 10).

Biomass of brown trout exhibited some tendency to decline over the years 1999-2012, based on time series analysis (R^2=0.42; Pr>F=0.0117; N=14) (Figure 35), while biomass of white catfish tended to increase (R^2=0.44; Pr>F=0.0097; N=14) (Table 10). No long-term upward or downward linear trends were evident in biomass of black basses over the study period (Figure 35).

Predator-prey interactions, gill net data – Total fall forage fish numbers lakewide are plotted against biomass of trout (Figure 36) and black basses (Figure 37) for the years 1999-2012. Spearman correlation analysis was carried out for initial examination of relationships of spring and fall total forage fish numbers to numbers and biomass of individual predator species in gill net data. Correlations were also carried out between forage fish numbers and the sums of black bass biomass; trout biomass; and total biomass of all predators in gill nets. These analyses yielded significant, positive correlations between fall lakewide numbers of forage fish and largemouth bass numbers (r_s=0.61; P=0.0207; N=14) and biomass (r_s=0.55; P=0.0436; N=14). The positive nature of these correlations suggests that both fall forage fish and largemouth bass were exhibiting a response to food availability to some degree. No other significant relationships were detected in these analyses.

Linear regression analyses were also performed, regressing lakewide numbers of forage fish in fall on numbers and biomass of brown trout; brown plus rainbow trout; redeye bass; largemouth bass; total black basses; and white catfish (Appendix Table 3). None of these analyses produced significant regression models. Following exclusion of data for 2012, identified as an outlier in several regressions, a weak but significant, positive relationship was detected between fall forage fish numbers and numbers of largemouth bass (R^2=0.3620; Pr>F=0.0296; N=13) (Appendix

Table 4); however there is no known justification for exclusion of data for 2012. No other significant relationships were detected.

Fall population numbers of blueback herring and threadfin shad individually were also regressed on biomass of brown trout; brown plus rainbow trout; redeye bass; largemouth bass; and total black basses. None of these regressions produced significant results. A regression model relating fall numbers of threadfin shad to total trout biomass approached, but did not attain, the reference probability for significance (R^2=0.28; Pr>F=0.0503; N=14). The parameter estimate for trout biomass was positive in this analysis (Figure 38).

The fact that no significant relationships were detected between the abundance of brown trout, a major predator on pelagic forage fish in Lake Jocassee, and fall forage fish abundance may be attributable in part to differences in the thermal preferences of threadfin shad and brown trout. Taylor and Bulak (2011) examined relationships between brown trout abundance and pelagic forage fish abundance on Lake Jocassee, based on field data and simulation results. They concluded that abundant forage was available for brown trout in spring and potentially in early summer, but that brown trout were not likely to take advantage of the abundant forage present in late summer due to thermal habitat constraints. Brown trout in southeastern reservoirs prefer temperatures of 20°C and below (Barwick et al. 2004). In the current study, mean temperature lakewide in the top ten meters of the water column exceeded 20°C from June through October in all years of the forage fish study period. As previously stated, threadfin shad typically congregate in surface waters, even at temperatures exceeding 30°C. The difference in thermal preferences of brown trout and threadfin shad reduced the likelihood of observing significant relationships between brown trout abundance and fall abundance of forage fish.

Spring forage fish numbers, as well as the percent and absolute magnitude of the decline in forage fish numbers from fall to spring, were subjected to Spearman correlation analysis with numbers and biomass of brown trout, total trout, largemouth bass, redeye bass, total black basses, white catfish, and total predators from gill net data the year previous to spring forage fish sampling. These analyses yielded significant, though weak, Spearman correlations between largemouth bass numbers and the percent decline in forage fish numbers from fall to spring

(r_s=0.54; P=0.0480; N=14). In addition, the absolute magnitude of the decline in forage fish numbers from fall to spring was significantly correlated with both largemouth bass numbers (r_s=0.54; P=0.0478; N=14); and largemouth bass biomass (r_s=0.57; P=0.0327; N=14). These results provide some indication that the greater the abundance of largemouth bass in a given year, the greater the decline in forage fish abundance observed from fall to the following spring.

Trends in predator abundance, electrofishing data – Electrofishing was carried out on Lake Jocassee at 3-year intervals during the forage fish study period (1999, 2002, 2005, 2008, 2011), in two zones. The upper zone was located in the upper reaches of the reservoir, corresponding to hydroacoustics Zone 4 and the upper reaches of Zone 2, while the lower zone corresponded with hydroacoustics Zones 1 and 3 and the lacustrine region of Zone 2.

Among species likely to prey on clupeids, density and biomass of electrofishing samples were dominated by redeye and largemouth bass. Redeye bass littoral density averaged 26.7 fish/km in the upper zone and 17.1 fish/km in the lower zone, while largemouth bass littoral density averaged 14.6 fish/km in the upper zone and 3.1 fish/km in the lower zone. In terms of biomass, redeye bass averaged 3.26 kg/km in the upper zone and 2.11 kg/km in the lower zone, while largemouth bass averaged 4.61 kg/km in the upper zone and 1.92 kg/km in the lower zone (Table 11). Based on nonparametric analysis of variance, littoral density and biomass of redeye bass, largemouth bass, and total black basses were all significantly higher in the upper zone as compared to the lower zone (Figures 39 and 40). The spatial heterogeneity observed in distribution of these predators is similar to that noted previously for chlorophyll concentrations and forage fish densities, both of which were highest in Zone 4, a component of the upper electrofishing zone.

No significant temporal upward or downward trends in the density or biomass of redeye bass, largemouth bass, or total black basses were detected in time series analysis of data collected 1999, 2002, 2005, 2008, and 2011.

Predator-prey interactions, electrofishing data – Forage fish density data from hydroacoustics sampling were averaged over hydroacoustics Zones 1 and 3 to estimate forage fish density in the lower electrofishing zone, and over Zones 2 and 4 to estimate forage fish density in the upper electrofishing zone. Fall forage fish density was subjected to Spearman correlation analysis with littoral density (fish/km) and biomass (kg/km) of redeye bass, largemouth bass, and total black basses measured in electrofishing, based on data from 1999, 2002, 2005, 2008, and 2011. In the lower electrofishing zone, fall forage fish density was positively correlated with largemouth bass biomass (r_s=0.90; P=0.0374; N=5), and over both electrofishing zones, fall forage fish density was positively correlated with littoral density of redeye bass (r_s=0.64; P=0.0443; N=10). These relationships are plotted in Figure 41. These results, though based on few observations, are consistent with the observations of predator-prey relationships seen in gill net data discussed above: relationships between abundance of predators and forage fish, where detected, were positive in nature, suggesting that over the study period, both forage fish and predators tended to exhibit responses to food availability to some degree.

Relationships of littoral black bass abundance and forage fish density were further examined with the more rigorous Pearson correlation analysis, with variables log-transformed as necessary to allow assumption of a normal distribution. None of the Pearson correlations produced statistically significant results.

Jocassee Pumped Storage Station Generation Flow

JPSS generation flow characterization – Mean daily generation flows at Jocassee Pumped Storage Station ranged from 0 to 628.8 m^3/sec, averaging 137.3 m^3/sec (4,849 cfs) over the period 1997 through 2012. Monthly mean JPSS generation flows are plotted for the study period in Figure 42. Mean annual generation flows (Table 12; Figure 43) did not exhibit significant upward or downward linear trends, in time series analysis of data from 1997-2012.

Seasonal variation in JPSS generation flows was statistically significant based on nonparametric analysis of variance comparing monthly mean data, 1997-2012 (prob > chi-square < 0.0001). Generation and pumping flows were highest in July and August and lowest during the colder months (Figure 44).

Operations at JPSS to generate electricity could potentially impact forage fish abundance on Lake Jocassee through flushing of fish during generation (e.g., Walburg 1971; Garvey et al. 2000). Spring forage fish lakewide numbers and densities in zones were analyzed in relation to mean, maximum daily, and maximum 30-day average generation flows observed December-February. Fall forage fish abundance was analyzed in relation to mean, maximum daily, and maximum 30-day average generation flows observed May-October. Generation flow variables were chosen to investigate effects of seasonal mean flows, short-term high flows, and sustained high flows.

Relationships of spring forage fish abundance to winter JPSS generation flow – Mean generation flow observed at JPSS in winter (December-February) ranged from 43.8 m^3/sec in 2001, to 159.6 m^3/sec in 2003 (Table 13; Figure 45). The potential influence of winter JPSS generation flow on spring forage fish total numbers and zonal densities was initially examined graphically (Figures 46 and 47) and with Spearman correlation analysis. Spearman correlation analysis detected no significant relationships between total forage fish lakewide in spring and mean, maximum daily, or maximum 30-day average Jocassee generation flow observed December-February.

The influence of JPSS generation on spring forage fish abundance was further examined with linear regression analysis. Total lakewide forage fish numbers in spring, as well as spring forage fish densities in zones, were regressed on mean, maximum daily, and maximum 30-day average JPSS generation flow observed December-February. No significant models resulted from these analyses (Appendix Table 5). Thus, no evidence was detected that JPSS generation flow influenced spring forage fish abundance or distribution on Lake Jocassee.

Relationships of fall forage fish abundance to May-October JPSS generation flow – Mean May-October JPSS generation flow ranged from 114.0 m^3/sec in 2000, to 196.4 m^3/sec in 2005 (Table 13; Figure 43). Fall forage fish lakewide numbers and zonal densities are plotted against mean JPSS generation flows observed May-October in Figures 48 and 49.

Relationships of fall forage fish abundance to mean, maximum daily, and maximum 30-day average JPSS generation flow observed May-October were initially investigated with Spearman correlation analysis. Three significant relationships were detected in these analyses. The total number of forage fish lakewide in fall was significantly, negatively correlated with both mean May-October generation flow (r_s= -0.55: P=0.0273; N=16) (Figure 48) and maximum daily May-October generation flow (r_s= -0.56; P=0.0235; N=16) (Figure 50). In addition, fall forage fish density in Zone 1, which encompasses the forebay area of the Jocassee dam, was negatively correlated with maximum daily generation flow observed May-October (r_s= -0.67; P=0.0047; N=16) (Figure 50). No significant Spearman correlations were detected between fall forage fish densities in Zones 2, 3, or 4 and any measure of May-October JPSS generation flow.

Relationships of fall forage fish abundance and May-October JPSS generation flow were further investigated with the more-rigorous linear regression analysis (Appendix Table 6). Fall forage fish total numbers lakewide and forage fish densities in zones were regressed on mean, maximum daily, and maximum 30-day average JPSS generation flow observed May-October. Regression results detected no relationships between fall forage fish abundance (lakewide numbers and densities in zones) and mean May-October JPSS generation flow. Similarly, fall forage fish abundance variables exhibited no relationship to sustained periods of high generation flow observed May-October, as quantified by the maximum 30-day average generation flow. Regression analysis detected a statistically significant relationship between fall forage fish density in Zone 1 and short-term high generation flows quantified as maximum daily JPSS generation flow observed May-October:

(9)
logFallDensZ1 = 4.49088 – 0.00359 MaxDailyMayOctJocGen
R^2 = 0.3682
Pr>F = 0.0127
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for Jocassee generation flow = 0.0127
Data set: 1997-2012
Outlying or highly influential observations: 2004 (highly influential, Cook's D = 3.869)
where logFallDensZ1 = log Fall forage fish density in Zone 1, no/ha
MaxDailyMayOctJocGen = Maximum daily JPSS generation flow May-October, m^3/sec

This relationship is plotted in Figure 51.

Regression (9) was re-analyzed, excluding data for 2004, identified as highly influential in regression diagnostics (above); there is no known reason for excluding this observation other than its statistical identification as highly influential. The resulting model was also significant:

(10)
logFallDensZ1 = 5.84017 – 0.00693 MaxDailyMayOctJocGen
$R^2 = 0.4347$
Pr>F = 0.0075
N = 15
Prob>|t| for intercept < 0.0001
Prob>|t| for Jocassee generation flow = 0.0075
Data set: 1997-2012 excluding 2004
Outlying or highly influential observations: (none)
where logFallDensZ1 = log Fall forage fish density in Zone 1, no/ha
MaxDailyMayOctJocGen = Maximum daily JPSS generation flow May-October, m^3/sec

The negative parameter estimates for maximum daily generation flow in these models indicate that distribution of forage fish in Lake Jocassee may have been influenced by JPSS generation, in that fall forage fish densities in Zone 1 exhibited some tendency to be lower when the maximum daily generation flow observed May-October was higher (Figure 51). Maximum daily May-October JPSS generation flow potentially explained 37% of variance in fall forage fish density in Zone 1 over the period 1997-2012.

It should be noted that maximum daily JPSS generation flow observed May-October was negatively correlated with maximum summer surface temperature in Zone 1 (rs= -0.59; P=0.0151; N=16) (Figure 52); maximum summer surface temperature in Zone 1 was positively correlated with Zone 1 fall forage fish density, potentially explaining 42% of variance in fall forage fish density in Zone 1 (see Regression (2)). The possibility of spurious relationships should be considered in interpreting the significance of the above regression results.

The total number of forage fish lakewide in fall was unrelated to mean, maximum daily, or maximum 30-day average May-October JPSS generation flows in initial linear regression analyses. Data for 2012 were identified as outlying in all regressions of total fall forage fish number (Appendix Table 6). When linear regressions of total fall forage fish number on mean, maximum daily, and maximum 30-day average JPSS May-October generation flows were repeated, excluding data for 2012 (Appendix Table 6), one significant model resulted:

(11)
logFallFish = 7.14429 – 0.00333 MeanMayOctJocGen
$R^2 = 0.3202$
Pr>F = 0.0279
N = 15
Prob>|t| for intercept < 0.0001
Prob>|t| for Jocassee generation flow = 0.0279
Data set: 1997-2012 excluding 2012
Outlying or highly influential observations: (none)
where logFallFish = log Fall forage fish lakewide numbers
MeanMayOctJocGen = mean JPSS generation flow observed May-October, m^3/sec

This regression model is plotted in Figure 53.

With data for 2012 excluded, the above model detected some tendency for total forage fish numbers in fall to be lower at higher mean rates of JPSS generation flow for May through October, potentially accounting for up to 32% of variance in fall forage fish numbers. However, no factors have been identified which would justify exclusion of the observation for 2012 from the complete data set characterizing relationships between variation in fall forage fish abundance and May-October JPSS generation flow. Due to the loss of potentially important information regarding the relationship between dependent and independent variables, Kleinbaum et al. (1998) recommended against excluding outlying observations unless an obvious source of error has been identified (see Methods). As noted above, when the entire data set (1997-2012) is analyzed, no relationships were detected between fall forage fish numbers lakewide and any measure of May-October JPSS generation flow.

Possible interactions of JPSS generation flow, BCPSS pumping flow, and lake level are investigated later in this report.

Bad Creek Pumped Storage Station Pumping Flow

BCPSS pumping flow characterization – Bad Creek Pumped Storage Station is located on the western arm of Lake Jocassee (Figure 1). Pelagic forage fish in Lake Jocassee are subject to entrainment during pumping operations at BCPSS (Barwick et al. 1994, 2005).

From 1997 through 2012, daily mean BCPSS pumping flows ranged from 0 to 332.0 m^3/sec, averaging 120.9 m^3/sec and exhibiting a median of 121.5 m^3/sec. Monthly mean Bad Creek pumping flows are plotted for January 1997 through May 2013 in Figure 54. Mean annual pumping flows ranged from 99.3 m^3/sec in 1997 to 145.1 m^3/sec in 2008 (Table 14). Mean annual pumping flows did not exhibit significant, long-term upward or downward linear trends over the study period, based on time series analysis (Figure 55).

Seasonal variation in Bad Creek pumping flow was significant, based on nonparametric analysis of variance comparing data for months of the year, using data from 1997-2012 (prob>chi-square<0.0001). Bad Creek pumping flows were typically highest in July and August, and lowest during the cooler months (Figure 56).

Spring zonal densities and total lakewide numbers of pelagic forage fish were examined in relation to the mean, maximum daily, and maximum 30-day average Bad Creek pumping flows observed December-February. Fall forage fish abundance variables were examined in relation to the mean, maximum daily, and maximum 30-day average Bad Creek pumping flow observed between spring spawning and fall hydroacoustics sampling (May-October). Pumping variables were chosen to investigate potential impacts of season-long mean flows; short-term high-flow events; and periods of sustained high flows.

Relationship of spring forage fish abundance to winter BCPSS pumping flow – Mean Bad Creek pumping flows observed December-February 1998-2013 ranged from 74.2 m^3/sec, observed in 2013, to 146.4 m^3/sec, observed in 2008 (Table 15; Figure 57). Spring lakewide forage fish numbers and forage fish densities in zones are plotted against mean December-February BCPSS pumping flows in Figures 58 and 59.

Spearman correlation analysis detected no significant relationships between the total number of forage fish lakewide in spring and mean, maximum daily, or maximum 30-day average BCPSS pumping flows observed December-February, based on data collected 1998-2013. Similarly, spring forage fish densities in zones were not significantly correlated with any measure of December-February BCPSS pumping flow (mean, maximum daily, or maximum 30-day average).

Relationships of spring forage fish abundance to winter BCPSS pumping flows were also investigated with linear regression analysis. Total numbers of forage fish lakewide in spring, as well as spring forage fish densities in individual zones, were regressed on mean, maximum daily, and maximum 30-day average pumping flows observed December-February. No relationships were detected between the total number of forage fish lakewide in spring or spring forage fish densities in zones and any measure of BCPSS pumping flows observed December-February (Appendix Table 7). Where outlying observations were identified, regressions were repeated excluding the outlying observations; these regressions produced no significant models (Appendix Table 7a). Thus, these analyses produced no evidence that winter pumping flows were influencing spring forage fish numbers lakewide or distribution of forage fish in Lake Jocassee.

Relationship of fall forage fish abundance to May-October BCPSS pumping flow – Mean Bad Creek pumping flows observed May-October 1997-2012 ranged from 116.7 m^3/sec, observed in 2012, to 163.2 m^3/sec, observed in 2007 (Table 15; Figure 57). Total lakewide number of forage fish in fall and fall forage fish densities in zones are plotted against mean Bad Creek pumping flows observed May-October in Figures 60 and 61.

Relationships between fall forage fish abundance in Lake Jocassee and pumping at BCPSS between spring spawning and fall hydroacoustics sampling (May-October) were initially investigated with Spearman correlation analysis. Total number of forage fish lakewide in fall was subjected to correlation analysis with mean, maximum daily, and maximum 30-day average Bad Creek pumping flows observed May-October, 1997-2012. No significant correlations were detected. Spearman correlation analyses were also carried out relating fall forage fish density in each zone to mean, maximum daily, and maximum 30-day average Bad Creek pumping flow observed May-October. Again, no significant correlations were detected.

Relationships of fall forage fish abundance to May-October Bad Creek pumping were investigated with linear regression analysis as well (Appendix Table 8). Fall forage fish lakewide numbers, as well as densities in zones, were regressed on mean, maximum daily, and maximum 30-day average Bad Creek pumping flows observed May-October, 1997-2012. No relationship was detected between the total number of forage fish lakewide in fall and any measure of BCPSS pumping flow observed during the growing season (May-October). One significant model resulted from linear regressions of fall forage fish densities in zones on BCPSS pumping flows (Figure 62):

(12)
logFallDensZ4 = 4.58616 – 0.00437 MaxDailyMayOctBadPump
$R^2 = 0.3727$
Pr>F = 0.0120
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for Bad Creek pumping = 0.0120
Data set: 1997-2012
Outlying or highly influential observations: (none)
where logFallDensZ4 = log Fall forage fish density (no/ha) in Zone 4
MaxDailyMayOctBadPump = maximum daily BCPSS pumping flow observed May-October, m^3/sec

This model detected a significant tendency for forage fish density in Zone 4, the furthest zone from Bad Creek Pumped Storage Station, to be lower in years when higher maximum daily May-October pumping rates occurred, perhaps suggesting a relationship between Bad Creek pumping and forage fish distribution in Lake Jocassee. Based on this model, 37% of variance in fall forage fish density in Zone 4 could potentially be explained by rates of Bad Creek pumping observed May-October.

Potential combined influences of Bad Creek pumping, lake level, and Jocassee generation on forage fish abundance and distribution are examined later in this report.

Responses of forage fish variables to multiple predictor variables

Forage fish abundance and distribution on Lake Jocassee were undoubtedly influenced by multiple factors, including food availability, predation, and physical factors related to habitat, as well as operational factors. In an attempt to detect combined influences of environmental and operational parameters on forage fish abundance and distribution in Lake Jocassee, multiple regression analyses were performed. Spring and fall forage fish total numbers and densities in zones were regressed on combinations of variables related to JPSS generation flow, BCPSS pumping flow, lake level, winter temperature, and predation. Too few observations of fertility-related factors (chlorophyll, zooplankton) were available to include these parameters in multiple regression analysis. Lack of a term related to food availability may produce specification error in multiple regression models.

Multiple regression analyses were carried out to detect potential combined influences, in which both independent variables exert an influence on the dependent variable; and to detect potential interactive effects of the independent variables, in which the influence of a given independent variable changes at different levels of the other independent variable. Regressions intended to detect interacting influences utilized an interaction term, calculated as the product of the centered independent variables (see Methods).

Spring forage fish in relation to winter BCPSS pumping flow and lake level – To summarize results reported above, linear regression analyses of total forage fish numbers in spring on winter BCPSS pumping flows produced no evidence that winter BCPSS pumping rates influenced spring forage fish numbers lakewide. Similarly, linear regression analysis of spring forage fish numbers on winter lake levels did not detect any influence of winter lake level on spring forage fish numbers lakewide.

To assess the combined influence of winter BCPSS pumping and winter lake level, total numbers of forage fish lakewide in spring were regressed on combinations of two independent variables for December-February BCPSS pumping flow (mean, maximum daily, and maximum 30-day average); and December-February Lake Jocassee lake level (mean, lowest daily, lowest 30-day average). No significant models were produced by these analyses (Appendix Table 9). To investigate whether BCPSS pumping flows and low winter lake levels may have interacted to impact spring forage fish numbers, multiple regression analyses were repeated with the addition of an interaction term. Again, no significant models resulted from these analyses (Appendix Table 10). Thus, no evidence was detected that the combined or interacting influences of winter BCPSS pumping and lake level influenced spring forage fish numbers in Lake Jocassee.

To investigate whether the combined influence of BCPSS pumping and lake level in winter may have exerted localized impacts on forage fish, spring forage fish density in the western arm of Lake Jocassee (Zone 2), on which BCPSS is located, was regressed on combinations of two independent variables for December-February BCPSS pumping flow (mean, maximum daily, and maximum 30-day average); and December-February Lake Jocassee lake level (mean, lowest daily, lowest 30-day average). No significant models were produced by these analyses (Appendix Table 11). Thus, no evidence of localized combined impacts of winter BCPSS pumping and lake level was detected in spring forage fish density data for Zone 2.

Spring forage fish in relation to winter BCPSS pumping flow and temperature –As described previously, Spearman correlation analysis detected a significant, positive relationship between mean January-February temperature and spring total lakewide forage fish numbers, suggesting a tendency for spring forage fish numbers to be lower following colder winters. Because threadfin shad may experience reduced mobility and thus increased susceptibility to entrainment at low temperatures, multiple regression analyses were carried out to investigate whether BCPSS pumping and low winter temperatures may have exerted combined influences on spring total forage fish numbers. Spring forage fish numbers were regressed on combinations of independent variables for December-February BCPSS pumping flows (mean, maximum daily, maximum 30-day average); and winter temperature (minimum winter temperature, mean January-February temperature). Initial regressions did not produce any significant models (Appendix Table 12). Data for 2013 were identified as outlying in four of the six regressions. These analyses were repeated, excluding data for 2013 although there are no known reasons why these data should be excluded (Appendix Table 12). When data for 2013 were excluded, regression models indicated that up to 54% of variation in spring forage fish numbers could be explained by the combined influence of winter temperature and BCPSS pumping flow (Appendix Table 12). The model with the highest R^2 value is listed below:

(13)
logSprFish = 2.89803 + 0.00452 MaxDailyDecFebBCPump + 0.20059 LWJanFebTemp
$R^2 = 0.5411$
Pr>F = 0.0093
N = 15
Prob>|t| for intercept = 0.0072
Prob>|t| for Bad Creek pumping = 0.0178
Prob>|t| for mean temperature = 0.0178
Data set: 1998-2013 excluding 2013
Outlying or highly influential observations: (none)

where logSprFish = log Spring total forage fish numbers lakewide
MaxDailyDecFebBCPump = maximum daily BCPSS pumping flow observed December-February, m^3/sec
LWJanFebTemp = mean surface (0-4 m) temperature observed lakewide in January-February, °C

The parameter estimates for both winter BCPSS pumping flow and winter temperature were positive in all of these models (Appendix Table 12), suggesting that spring forage fish numbers were higher following winters with higher temperature and higher rates of BCPSS pumping. Thus, these models detected no negative impact of the combined influence of cold temperature and winter BCPSS pumping on spring forage fish total numbers, regardless of whether data for 2013 were included in the regression analyses.

To further investigate whether winter BCPSS pumping rates and winter temperature interacted to influence spring forage fish numbers, the above multiple regression analyses were repeated with the addition of an interaction variable. No significant models resulted from these analyses (Appendix Table 13). The interaction variable did not contribute significantly to explaining variance in spring forage fish total numbers; therefore no evidence was detected that interacting effects of winter pumping and winter temperature were influencing forage fish numbers in spring. Data for 2013 were again identified as outlying in some regressions (Appendix Table 13), and these regressions were repeated, excluding data for 2013. Again, the interaction variable did not contribute significantly to explaining variance in spring forage fish numbers in any of these regressions (Appendix Table 13).

Based on the above, multiple regression analysis yielded no evidence that either combined or interacting influences of winter BCPSS pumping and winter temperature were adversely affecting lakewide forage fish numbers in spring.

To assess possible localized impacts of the combined effects of winter BCPSS pumping and low temperature, spring forage fish density in the western arm of Lake Jocassee (Zone 2) was regressed on combinations of variables for December-February BCPSS pumping flows (mean, maximum daily, maximum 30-day average) and winter temperature (minimum winter temperature, mean January-February temperature). None of these regressions explained significant variance in spring forage fish density in Zone 2 (Appendix Table 14); thus no localized impacts were detected.

Spring forage fish in relation to winter JPSS generation flow and lake level – As previously described, linear regression analyses of total forage fish numbers in spring on winter JPSS generation flows produced no evidence that winter generation flows influenced spring forage fish numbers lakewide. Similarly, linear regression analysis of spring forage fish numbers on winter lake levels did not detect any influence of winter lake level on spring forage fish numbers lakewide.

Multiple regression analyses were employed to investigate combined or interactive influences of winter JPSS generation and lake level. The total number of forage fish lakewide in spring was regressed on combinations of two independent variables for December-February JPSS generation flow (mean, maximum daily, maximum 30-day average) and December-February lake level (mean, lowest daily, lowest 30-day average). No significant models were produced in these analyses (Appendix Table 15), consistent with the lack of influence of these parameters on spring forage fish numbers in linear regression analysis.

To determine whether the effects of winter JPSS generation and lake level may have interacted to influence spring forage fish numbers, multiple regressions were repeated, including an interaction term. Independent variables were centered for these analyses, and the interaction term was calculated as the product of the centered independent variables. None of these analyses produced significant results. In addition, the interaction variable was not identified as significantly influencing spring forage fish numbers in any of these analyses, based on significance probability associated with the parameter estimate for the interaction variable (prob>|t|) (Appendix Table 16).

Thus, multiple regression analyses produced no evidence that winter JPSS generation and winter lake level combined or interacted to influence spring forage fish numbers.

To investigate possible localized effects of winter JPSS generation and winter lake level, spring forage fish density in Zone 1, which encompasses the forebay area, was regressed on combinations of two independent variables for December-February JPSS generation flow (mean, maximum daily, maximum 30-day average) and December-February lake level (mean, lowest daily, lowest 30-day average). None of these models explained significant variance in spring forage fish density in Zone 1 (Appendix Table 17); thus, no localized combined effects of winter JPSS generation and winter lake level were detected.

Spring forage fish in relation to winter JPSS generation flow and temperature – As noted above, linear regression analyses did not detect any relationship between spring forage fish lakewide numbers on Lake Jocassee and winter JPSS generation. A significant tendency for spring forage fish numbers to be lower following colder winters was evident in Spearman correlation analysis, though not in linear regression analysis. Multiple regression analyses were performed to investigate whether combined or interacting influences of winter JPSS generation and winter temperature may have influenced spring forage fish numbers, potentially through increased susceptibility of threadfin shad to entrainment at low temperatures.

To detect combined influences of winter JPSS generation and winter temperature, total forage fish numbers lakewide in spring were regressed on combinations of two independent variables for December-February JPSS generation (mean, maximum daily, maximum 30-day average) and winter temperature (minimum, mean January-February). None of these analyses explained significant variance in total lakewide spring forage fish numbers (Appendix Table 18).

To detect whether winter generation at JPSS and winter temperature may have interacted to influence spring forage fish numbers on Lake Jocassee, multiple regressions were repeated, after centering the independent variables and adding an interaction term (product of the centered independent variables). None of these analyses produced significant models. In addition, the interaction term did not contribute significantly to explaining variation in spring forage fish numbers based on prob>|t| (Appendix Table 19).

The multiple regression analyses described above detected no evidence that winter generation at JPSS and winter temperature exerted combined or interactive influences on total forage fish numbers on Lake Jocassee in spring.

To assess whether the combined influence of winter JPSS generation and winter temperature may have had localized effects, spring forage fish density in the main lake/forebay area of Lake Jocassee (Zone 1) was regressed on combinations of variables for December-February JPSS generation (mean, maximum daily, maximum 30-day average) and winter temperature (minimum, mean January-February). These models did not explain significant variance in spring forage fish density in Zone 1 (Appendix Table 20); thus, no localized combined impacts of winter JPSS generation and temperature were detected.

Spring forage fish in relation to winter JPSS generation and BCPSS pumping – As described previously, linear regression analysis detected no relationships between total numbers of forage fish in spring and either JPSS generation flow or BCPSS pumping flow in winter. To investigate whether spring forage fish numbers may have been subject to combined influences of JPSS generation and BCPSS pumping in winter, multiple regression analyses were carried out. Spring total numbers of forage fish lakewide were regressed on combinations of independent variables for December-February JPSS generation flow (mean, maximum daily, maximum 30-day average) and December-February BCPSS pumping flow (mean, maximum daily, maximum 30-day average). These analyses produced no significant models (Appendix Table 21), consistent with the idea that combined winter operations did not influence spring forage fish numbers in Lake Jocassee.

To investigate potential interacting influences of winter JPSS generation and BCPSS pumping on spring forage fish numbers, multiple regressions were repeated after centering the independent variables and adding an interaction term. None of these regressions produced significant models, and the interaction term did not explain significant variance in spring forage fish numbers in any of these regressions (Appendix Table 22).

Based on these multiple regression analyses, no combined or interactive effects of winter JPSS generation and BCPSS pumping on spring forage fish numbers were detected.

Spring forage fish in relation to winter JPSS generation, BCPSS pumping, and lake level – In addition to the regressions described above, spring total numbers of forage fish in Lake Jocassee were subjected to multiple regression analysis on combinations of three independent variables, one each for December-February JPSS generation flow (mean, maximum daily, maximum 30-day average); December-February BCPSS pumping flow (mean, maximum daily, maximum 30-day average); and December-February lake level (mean, lowest daily, and lowest 30-day average). None of these regressions produced significant models (Appendix Table 23).

Spring forage fish in relation to winter JPSS generation, BCPSS pumping, and winter temperature – Spring total numbers of forage fish in Lake Jocassee were subjected to multiple regression analysis on combinations of three independent variables, one each for December-February JPSS generation flow (mean, maximum daily, maximum 30-day average); December-February BCPSS pumping flow (mean, maximum daily, maximum 30-day average); and temperature (minimum winter lakewide temperature, mean January-February lakewide temperature). None of these regressions explained significant variance in spring forage fish numbers on Lake Jocassee (Appendix Table 24).

Fall forage fish in relation to May-October BCPSS pumping flow and lake level – As described previously, linear regression analyses of total forage fish numbers in fall detected no significant relationships with either May-October BCPSS pumping flow variables or May-October lake level variables. Multiple regression analyses were carried out to determine whether any variation in fall forage fish numbers could potentially be explained by combined or interacting effects of May-October Bad Creek pumping and lake level.

To investigate potential combined influences of May-October BCPSS pumping and lake level, total fall forage fish numbers lakewide were regressed on combinations of variables for May-October BCPSS pumping (mean, maximum daily, maximum 30-day average) and lake level (mean, lowest daily, lowest 30-day average). None of these regressions produced significant results, consistent with the lack of evidence from linear regression analyses that either of these factors significantly influenced numbers of fall forage fish in Lake Jocassee (Appendix Table 25).

These regression analyses were repeated after centering the independent variables and adding an interaction term to the analyses, to investigate whether rates of BCPSS pumping may have interacted with lake level to influence fall numbers of forage fish on Lake Jocassee. None of these regressions produced significant models, and the interaction term did not explain significant variance in fall forage fish numbers (Appendix Table 26). Thus, multiple regression analyses yielded no evidence that May-October BCPSS pumping rates and lake level exerted combined or interacting influences on total fall forage fish numbers on Lake Jocassee based on data collected 1997-2012.

To investigate possible localized effects of combined influences of May-October lake level and BCPSS pumping, fall forage fish density in the western arm of Lake Jocassee (Zone 2), where BCPSS is located, was regressed on combinations of variables for lake level and BCPSS pumping flow observed May-October. None of these regressions produced significant results, yielding no evidence that combined influences of lake level and BCPSS pumping influenced fall forage fish density in Zone 2 (Appendix Table 27).

Fall forage fish in relation to May-October JPSS generation flow and lake level – As documented in an earlier section of this report, linear regression analyses detected no significant relationships between total forage fish numbers in fall and either JPSS generation flows or lake levels measured May-October.

Multiple regression analysis was employed to assess the likelihood that May-October JPSS generation and lake level exerted combined effects on total forage fish numbers on Lake Jocassee in fall. Lakewide numbers of forage fish in fall were regressed on combinations of variables for JPSS generation flow (mean, maximum daily, maximum 30-day average) and lake level (mean, lowest daily, lowest 30-day average) observed May-October, 1997-2012 (Appendix Table 28). These analyses produced one significant model:

(14)
logFallFish = 7.16316 + 0.03649 MeanMayOctLL – 0.00398 MeanMayOctJocGen
$R^2 = 0.4251$
Pr>F = 0.0274
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for lake level = 0.0423
Prob>|t| for JPSS generation = 0.0381
Data set: 1997-2012
Outlying or highly influential observations: (none)
where logFallFish = log Total number of forage fish lakewide in fall
MeanMayOctLL = mean lake level observed May-October, meters below full pool (positive number)
MeanMayOctJocGen = mean JPSS generation flow observed May-October, m^3/sec

Based on this model, the combined influences of mean lake level and JPSS generation flow observed May-October could potentially explain 43% of variance in total lakewide numbers of forage fish in fall, in data collected 1997-2012. The parameter estimate for lake level is positive, indicating that fall forage fish numbers tended to be higher when May-October lake levels were lower (lake level is expressed as a positive number equal to meters below full pool). The parameter estimate for JPSS generation flow is negative, indicating a tendency for fall forage fish numbers to be lower at higher May-October mean JPSS generation flows. Prob>|t| values indicate that both independent variables contributed significantly to explaining variance in fall forage fish numbers. Neither of these tendencies was significant in linear regression analysis, as documented earlier in this report.

To examine whether the influence of May-October JPSS generation flow on fall forage fish numbers changed at different lake levels or vice versa, multiple regression analyses were repeated after centering the independent variables and adding an interaction term as an independent variable. None of the models produced by these analyses explained significant variance in fall forage fish numbers (Appendix Table 29), nor did the interaction term in any model contribute significantly to explaining variance in fall forage fish numbers. These results suggest that the potential effects of JPSS generation flow and lake level were not interdependent.

To investigate possible localized combined effects of lake level and JPSS generation, forage fish density in Zone 1 was regressed on combinations of variables for May-October lake level (mean, lowest daily, lowest 30-day average) and JPSS generation flow (mean, maximum daily, maximum 30-day average). With one exception, all of these analyses produced models which explained significant variation in fall forage fish density in Zone 1 (Appendix Table 30). Parameter estimates were positive for lake level and negative for JPSS generation flow in all models. The following model explained the highest degree of variation in Zone 1 fall forage fish density over the period 1997-2012:

(15)
logFallDensZ1 = 4.10702 + 0.09250 MeanMayOctLL – 0.00856 MeanMayOctJocGen
$R^2 = 0.5905$
Pr>F = 0.0030
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for lake level = 0.0048
Prob>|t| for Jocassee generation = 0.0112
Data set: 1997-2012
Outlying or highly influential observations: (none)

where logFallDensZ1 = log Fall forage fish density (no/ha) in Zone 1
MeanMayOctLL = mean lake level observed May-October, meters below full pool (positive number)
MeanMayOctJocGen = mean JPSS generation flow observed May-October, m^3/sec

These results indicate that the influences of lake level and JPSS generation combined to potentially explain 59% of variation in fall forage fish densities in Zone 1, 1997-2012. The parameter estimate associated with lake level was positive, indicating that Zone 1 fall forage fish density tended to be higher at lower lake levels. The parameter estimate for JPSS generation flow was negative, indicating a tendency for Zone 1 fall forage fish density to be lower at higher mean JPSS generation flows observed May-October. Both independent variables contributed significantly to explaining variation in the dependent variable. The significance of mean lake level in explaining variance in fall forage fish density in Zone 1 is consistent with linear regression analysis, in which mean lake level observed May-October could explain 32% of variance. Mean May-October JPSS generation flow did not explain significant variance in fall forage fish density in Zone 1 in linear regression analysis (R^2=0.2276; Pr>F=0.0617; N=16).

Fall forage fish in relation to May-October JPSS generation and BCPSS pumping – As reported above, linear regression analyses of total forage fish in fall did not detect significant relationships with JPSS generation flows observed May-October, or with Bad Creek pumping flows observed May-October in data collected 1997-2012. Multiple regression analysis was carried out to investigate whether combined effects of JPSS generation and BCPSS pumping potentially influenced fall forage fish numbers. The total number of forage fish lakewide in fall was regressed on combinations of two independent variables for May-October JPSS generation flows (mean, maximum daily, maximum 30-day average) and May-October BCPSS pumping flows (mean, maximum daily, maximum 30-day average). None of these analyses produced significant regression models (Appendix Table 31).

To examine whether May-October JPSS generation flows and BCPSS pumping flows may have interacted to influence fall forage fish numbers, regression analyses were repeated, centering the independent variables and adding a term for interaction to the models. None of these models explained significant variance in total numbers of forage fish lakewide in fall, and the interaction term did not contribute significantly to explaining variance in any model (Appendix Table 32).

Thus, multiple regression analyses detected no evidence of combined or interactive influences of May-October JPSS generation flows and BCPSS pumping flows on total numbers of forage fish in Lake Jocassee in fall.

Fall forage fish in relation to May-October JPSS generation, BCPSS pumping, and lake level – To investigate whether fall forage fish abundance was influenced by combined effects of JPSS generation, BCPSS pumping, and lake level, fall total forage fish numbers were subjected to multiple regression analysis on combinations of three independent variables, one each for May-

October JPSS generation flow (mean, maximum daily, maximum 30-day average); May-October BCPSS pumping flow (mean, maximum daily, maximum 30-day average); and May-October lake level (mean, lowest daily, and lowest 30-day average). Two significant results were obtained in these analyses (Appendix Table 33):

(16)
logFallFish = 7.59114 – 0.00342 MeanMayOctJocGen – 0.00368 MeanMayOctBadPump + 0.03647 MeanMayOctLL

$R^2 = 0.5010$
Pr>F = 0.0342
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for JPSS generation = 0.0701
Prob>|t| for BCPSS pumping = 0.2017
Prob>|t| for lake level = 0.0387
Data set: 1997-2012
Outlying or highly influential observations: (none)

where logFallFish = total number of forage fish lakewide in fall
MeanMayOctJocGen = mean JPSS generation flow observed May-October, m^3/sec
MeanMayOctBadPump = mean BCPSS pumping flow observed May-October, m^3/sec
MeanMayOctLL = mean lake level May-October, meters below full pool

(17)
logFallFish = 7.69002 – 0.00362 MeanMayOctJocGen – 0.00321 Max30dayMayOctBadPump + 0.03317 MeanMayOctLL

$R^2 = 0.4772$
Pr>F = 0.0444
N = 16
Prob>|t| for intercept < 0.0001
Prob>|t| for JPSS generation = 0.0599
Prob>|t| for BCPSS pumping = 0.2954
Prob>|t| for lake level = 0.0656
Data set: 1997-2012
Outlying or highly influential observations: (none)

where logFallFish = total number of forage fish lakewide in fall
MeanMayOctJocGen = mean JPSS generation flow observed May-October, m^3/sec
Max30dayMayOctBadPump = maximum 30-day average BCPSS pumping flow observed May-October, m^3/sec
MeanMayOctLL = mean lake level May-October, meters below full pool

It is evident that these models did not explain substantially more variation in fall forage fish numbers than was explained in Regression (14), in which fall forage fish numbers were regressed on lake level and JPSS generation flow alone. In addition, prob>|t| for BCPSS pumping flow indicated that this variable did not contribute significantly to explaining variance in fall forage fish numbers. Thus, the significance of these models is apparently due to the combined influence of lake level and JPSS generation flow alone.

Fall forage fish in relation to predators, operational factors, and lake level – Multiple regression analyses with two independent variables were carried out relating total forage fish numbers in fall to selected variables including one variable for predator abundance in gill nets. Variables analyzed for possible effects of predation included total numbers and biomass of trout (sum of brown trout and rainbow trout); and total numbers and biomass of black basses (redeye, largemouth, and smallmouth bass). Independent variables quantifying measures of predator abundance were analyzed in combination with the following independent variables: mean May-October JPSS generation flow; mean May-October BCPSS pumping flow; and mean May-October lake level. The purpose of these analyses was to investigate whether combined effects of predation and other factors explained more variance in fall forage fish numbers than any variable alone. None of these analyses produced significant results (Appendix Table 34).

SUMMARY

Since the introduction of threadfin shad and blueback herring Lake Jocassee in the early 1970s (Prince and Barwick 1981), self-sustaining and reproducing populations have existed in the lake. Monitoring of these forage fish populations with purse seine collections and hydroacoustic techniques has been ongoing for decades. Based on data collected fall 1997 through spring 2013, lakewide pelagic forage fish densities on Lake Jocassee averaged 587 fish/ha in spring and 1,356 fish/ha in fall. Total numbers of forage fish on Lake Jocassee varied substantially among years in both spring and fall. Spring forage fish numbers ranged from 315,678 in 1998 to 7,055,096 in 2013; fall forage fish numbers ranged from 1,651,468 in 2005 to 13,082,248 in 2012. No consistent long-term upward or downward linear trends in forage fish numbers or zonal densities were evident over the study period. Interestingly, the total number of forage fish observed in fall 2012 was nearly twice the previous fall maximum, observed in 1999; similarly, the total number of forage fish observed in spring 2013 was nearly twice the previous spring maximum, also observed in 1999.

Spatial variation in pelagic forage fish distribution was significant in both spring and fall. Over the forage fish study period, spring forage fish density in the Horsepasture and upper Toxaway Rivers area (Zone 4) averaged 2,084 fish/ha, more than six times the average spring densities observed in the main lake forebay area (Zone 1) (304 fish/ha), the western arm (Zone 2) (170 fish/ha), and the main Toxaway River arm (Zone 3) (335 fish/ha). Fall forage fish density in Zone 4 averaged 2,744 fish/ha, more than twice the average fall densities observed in Zone 1 (1,360 fish/ha) and Zone 3 (1,077 fish/ha). Fall forage fish density in Zone 2 was significantly lower than in other areas of the reservoir, averaging 608 fish/ha.

The pelagic forage fish community of Lake Jocassee consisted on average of 75% blueback herring and 25% threadfin shad, based on purse seine sampling. Community composition varied considerably among years, with blueback herring constituting from 26.8 to 99.9% of the total population. Although no statistically significant long-term upward or downward linear trends were detected in the composition of the forage fish community or in total numbers of blueback herring or threadfin shad over the study period, it is interesting to note that blueback herring comprised greater than 90% of the fall forage fish community in the most recent four years of the study (2009-2012), and accounted for 99.9% of the unusually high forage fish numbers observed in fall 2012.

In terms of age structure, the percent of the fall blueback herring population consisting of YOY fish ranged from 14.8 to 99.5%, averaging 72.2% over the study period. Ninety-five percent of the blueback herring population observed in fall 2012 consisted of YOY fish. Threadfin shad populations in fall consisted of virtually 100% YOY fish every year.

Relationships of spring forage fish abundance to environmental and operational parameters – Spring forage fish abundance on Lake Jocassee was analyzed in relation to food-related factors (chlorophyll, zooplankton); predation; temperature; lake level; and operational factors (generation at JPSS, pumping at BCPSS).

Very few observations were available to assess relationships of spring forage fish abundance to chlorophyll. However, a statistically significant relationship was detected when spring zonal forage fish densities were regressed on chlorophyll concentrations measured in February, utilizing data from five years and four forage fish sampling zones. This analysis indicated that variation in winter zonal chlorophyll could potentially account for 30% of variation in spring zonal forage fish densities.

Zooplankton data were available for 2012 only. Graphical data relating February zooplankton density to spring forage fish density in forage fish sampling zones provided a very preliminary indication that zooplankton distribution may have influenced forage fish distribution in spring, in that both February zooplankton density and spring forage fish density were substantially higher in Zone 4.

The impact of predation on spring forage fish abundance was potentially evident in the decline in forage fish numbers from fall to spring, which averaged 54% over the study period. The magnitude of the decline in forage fish numbers from fall to spring, as well as the percent decline in forage fish numbers, was weakly but significantly correlated with largemouth bass numbers in gill net data for the year previous to spring forage fish sampling, revealing a weak tendency for the decline in forage fish number from fall to spring to be greater when the number of largemouth bass in gill nets was higher.

Thermal preferences of the two species comprising the pelagic forage fish community of Lake Jocassee differed markedly, in that threadfin shad are susceptible to impaired mobility at temperatures below about 14°C and may be subject to die-offs at temperatures below 9-12°C (Griffith 1978; Burgess 1980; McLean et al. 1982, 1985; Etnier and Starnes 1993). In contrast, blueback herring tolerate temperatures at least as low as 2°C (Lee et al. 1980; Page and Burr 1991). On Lake Jocassee, minimum winter temperature averaged over the top four meters of the water column ranged from 9.0°C in 2001 to 11.1°C in 1999. Species-specific abundance data were not available in spring for Lake Jocassee, preventing analysis of species-specific responses to low temperature. However, a weak but significant tendency was detected for total forage fish numbers in spring to be lower following colder winters as quantified by mean January-February temperature (r_s=0.53; P=0.0350; N=16). This tendency was also evident in data for forage fish Zone 4, in that spring forage fish density in the Horsepasture and upper Toxaway Rivers area tended to be lower following colder winters (r_s=0.59; P=0.0159; N=16); significant relationships were not detected in data for Zones 1, 2, or 3.

Mean winter lake level on Lake Jocassee varied from 0.4 meters below full pool in 2010 to 7.6 meters below full pool in 2009. Correlation and linear regression analysis detected no evidence that either spring forage fish lakewide numbers or spring forage fish densities in individual zones.

Average winter generation flows at Jocassee Pumped Storage Station ranged from 43.8 m^3/sec in winter 2001, to 159.6 m^3/sec in winter 2003. Correlation and regression analyses of spring forage fish total numbers and forage fish densities in zones in relation to mean, maximum daily, and maximum 30-day average winter JPSS generation flows detected no evidence that spring forage fish abundance or distribution were affected by rates of generation flow at JPSS in winter.

Mean winter pumping flows at Bad Creek Pumped Storage Station ranged from 74.2 m^3/sec in winter 2013, to 146.4 m^3/sec in winter 2008. Correlation and regression analyses of spring forage fish total numbers and forage fish densities in zones on mean, maximum daily, and maximum 30-day mean winter pumping flows at BCPSS produced no significant results, detecting no evidence that spring forage fish total numbers or densities in zones were influenced by winter pumping flows at BCPSS.

In order to assess whether total numbers of forage fish in spring were affected by combined influences of winter temperature, lake level, JPSS generation, and BCPSS pumping, multiple regression analyses with two and three independent variables were carried out. In addition, potential interacting effects of winter temperature, lake level, JPSS generation, and BCPSS pumping, where the influence of one factor on spring forage fish abundance changed at different levels of another factor, were assessed using multiple regression analysis with two independent variables and an interaction term. None of these analyses produced significant results, yielding no evidence that total spring forage fish numbers in Lake Jocassee were influenced by combined or interactive effects of temperature, lake level, JPSS generation, or BCPSS pumping.

To investigate any localized combined effects of winter environmental and operational variables, spring forage fish density in Zone 1 was regressed on combinations of variables for winter JPSS generation flow and lake level; and combinations of variables for winter JPSS generation flow and temperature. Similarly, spring forage fish density in Zone 2 was regressed on combinations of variables for winter Bad Creek pumping flow and lake level; and winter Bad Creek pumping flow and temperature. None of these analyses produced significant results. Thus, no evidence was detected that winter temperature or lake level and operations at JPSS or BCPSS combined to produce localized or lakewide effects on spring forage fish abundance on Lake Jocassee.

Relationships of fall forage fish abundance to environmental and operational parameters – Fall forage fish abundance in Lake Jocassee was analyzed in relation to food-related factors (chlorophyll, zooplankton); predation; summer temperature; lake level; and operational factors (generation at JPSS, pumping at BCPSS).

Relationships of fall forage fish abundance to food availability as manifested in chlorophyll concentration were examined using data from 1997, 2007-2010, and 2012 (years when chlorophyll data were available). To investigate whether Lake Jocassee maintained fall forage fish standing stocks similar to those observed in other regional reservoirs of similar fertility, chlorophyll forage fish relationships on Lake Jocassee were compared to those observed on Catawba-Wateree reservoirs. Regression analysis indicated that 63% of variance in fall forage fish density on Catawba-Wateree reservoirs could be explained by variation in spring chlorophyll concentrations (Rodriguez 2005). When mean spring chlorophyll concentrations and fall forage fish densities observed over the years 1997, 2007-2010, and 2012 were superimposed on a plot of the Catawba-Wateree regression, observations for all Lake Jocassee forage fish sampling zones fell within the 95% confidence limits. Lake Jocassee data for 2012, when more comprehensive chlorophyll data were available, were also plotted on the Catawba-Wateree regression, and again, observations for all forage fish zones fell within the 95% confidence limits. Based on these results, all forage fish zones of Lake Jocassee maintained fall forage fish standing stocks similar to those of other regional reservoirs of similar fertility.

The potential influence of fertility on fall forage fish abundance was also apparent in the spatial heterogeneity observed on Lake Jocassee in 2012, in that Zone 4 maintained both the highest May-October chlorophyll concentrations and the highest fall forage fish densities on Lake Jocassee. In addition, despite the small size of the chlorophyll data set over years, a weak but significant relationship between zonal chlorophyll concentrations and fall forage fish densities was detected. Zonal surface chlorophyll concentrations averaged over May and August could explain 19% of variation in zonal forage fish densities observed in fall, based on linear regression analysis. These results are consistent with the idea that food availability exerted some influence on fall forage fish abundance on Lake Jocassee. Too few zooplankton data were available to allow statistical analysis of relationships between zooplankton and fall forage fish abundance.

To investigate effects of predation on fall forage fish abundance, correlation and regression analyses were carried out relating total forage fish numbers in fall to numbers and biomass of predators. Predators analyzed included brown trout; the sum of brown plus rainbow trout; redeye bass; largemouth bass; total black basses; and white catfish. Potential effects of predation were also examined utilizing electrofishing data. Fall forage fish density in electrofishing sampling zones was analyzed in relation to numbers and biomass of redeye bass and largemouth bass as measured in electrofishing. Significant, positive Spearman correlations were detected between total fall forage fish numbers and the numbers and biomass of largemouth bass in gill nets. Similarly, positive Spearman correlations were detected between fall forage fish density and largemouth bass biomass in the lower electrofishing zone, and between fall forage fish density and redeye bass density over both electrofishing zones, suggesting that both forage fish and black bass varied along a fertility gradient. No other significant relationships were detected, potentially due to the complexity of predator-prey interactions and to the influence of other factors such as temperature on the abundance and distribution of both forage fish and game species.

No significant relationships were detected in correlation and regression analysis relating total numbers of forage fish in fall to Lake Jocassee lake levels observed May through October (mean, lowest daily, or lowest 30-day average). Lake level may have influenced forage fish distribution within Lake Jocassee in fall, in that fall forage fish density in the main lake/forebay area of Lake Jocassee (Zone 1) exhibited a significant tendency to be higher when May-October lake levels were lower.

Total forage fish numbers in fall and fall forage fish densities in Zone 1 were weakly, negatively correlated with May-October JPSS generation flows in initial Spearman correlation analysis. Linear regression analysis of data collected 1997-2012 detected no relationship between total fall forage fish numbers lakewide and May-October JPSS generation flows. A statistically significant tendency was detected for fall forage fish densities in Zone 1 to be lower when the maximum daily generation flow observed May-October was higher. This relationship potentially explained 37% of variance in fall forage fish density in Zone 1 over the study period. It should be noted that maximum daily May-October generation flow was also significantly, negatively correlated with maximum summer surface temperature in Zone 1. In light of the fact that maximum summer surface temperature in Zone 1 was positively correlated with fall forage fish density in Zone 1, the possibility of spurious relationships should be considered.

Multiple regression analysis indicated that May-October JPSS generation flow and lake level combined to potentially explain as much as 43% of variation in lakewide fall forage fish numbers. Similarly, these factors combined to potentially explain as much as 59% of variation in fall forage density in Zone 1, in the main lake forebay area. Parameter estimates for lake level in these models indicated that fall lakewide forage fish numbers and density in Zone 1 tended to be higher at lower lake levels, while parameter estimates for JPSS generation flow revealed a tendency for lakewide fall forage fish numbers and density in Zone 1 to be lower at higher generation flows. Based on regression analyses with interaction variables, no interactive effects of lake level and JPSS generation were detected; i.e., the effect of JPSS generation flow on fall forage fish abundance did not appear to be modified by lake level.

Total numbers of forage fish lakewide in fall were unrelated to BCPSS pumping flows measured May-October (mean, maximum daily, maximum 30-day average), in either Spearman correlation analysis or linear regression analysis. Similarly, no significant relationships were detected between May-October BCPSS pumping flows and fall forage fish density in Zone 2, the arm of the reservoir on which BCPSS is located. Linear regression analysis did detect a statistically significant tendency for forage fish density in Zone 4, the farthest zone from BCPSS, to be lower when maximum daily pumping flows observed May-October were higher (R2=0.37; P=0.0120; N=16).

Multiple regression analyses relating total numbers of forage fish in fall to combined and interactive influences of May-October BCPSS pumping and lake level produced no significant results. Similarly, no combined localized influences of BCPSS pumping and lake level were detected in fall forage fish density data for Zone 2.

Multiple regression analyses of total numbers of forage fish in fall on combinations of variables quantifying May-October JPSS generation flow and BCPSS pumping flows yielded no significant results. Thus no combined or interactive effects of JPSS generation flow and BCPSS pumping flow on fall forage fish numbers were detected based on data collected 1997-2012. Multiple regression analyses of total forage fish in fall on three independent variables for May-October JPSS generation flow, BCPSS pumping flow, and lake level explained no more variance in fall forage fish numbers than was explained by JPSS generation flow and lake level alone.

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Table 1. Morphometric characteristics of Lake Jocassee and hydroacoustics zones of Lake Jocassee (Figure 1). Surface area, volume, and mean depth data were provided by Duke Energy (personal communication, David Coughlan, 2008). Maximum depth and surface elevation are from Barwick et al. (1994). Watershed area is from Duke Power Company (1995).

Characteristic	**Lake Jocassee**	**Main lake (Zone 1)**	**Devils Fork (Zone 2)**	**Main Toxaway (Zone 3)**	**Toxaway & Horsepasture Rivers (Zone 4)**
Surface area at full pool, m^2	35.588×10^6	11.987×10^6	8.119×10^6	9.170×10^6	6.312×10^6
Volume, m^3	17.166×10^8	6.912×10^8	3.629×10^8	4.347×10^8	2.278×10^8
Mean depth, m	48.2	57.7	44.7	47.4	36.1
Maximum depth, m	107	-	-	-	-
Watershed area, km^2	383	-	-	-	-
Surface elevation at full pool, m above mean sea level	338.3	-	-	-	-

Table 2. Total number and lakewide density of pelagic forage fish in Lake Jocassee and densities of forage fish in sampling zones, spring and fall, based on hydroacoustics sampling carried out fall 1997 through spring 2013.

	Spring	**Spring forage fish density, no/ha**					**Fall**	**Fall forage fish density, no/ha**				
Year	**Total fish**	**Lakewide**	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Total fish**	**Lakewide**	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
1997	-	-	-	-	-	-	3,962,952	1117	1060	584	820	2348
1998	315,678	89	167	66	24	64	5,513,030	1573	649	763	1624	4341
1999	3,975,478	1135	844	681	983	2515	6,965,453	2083	4166	603	780	1764
2000	2,013,610	591	583	37	33	2183	4,326,627	1304	1191	387	1696	2173
2001	922,693	278	30	9	122	1388	4,450,912	1349	1604	639	1814	1062
2002	1,411,768	420	90	33	101	2092	3,347,684	1019	1430	102	283	2525
2003	1,554,639	438	120	73	415	1548	2,838,766	799	412	144	706	2520
2004	1,412,590	399	238	176	430	950	3,290,394	931	321	373	1160	2487
2005	1,033,312	292	42	41	36	1470	1,651,468	466	217	400	447	1057
2006	2,067,956	584	37	151	148	2822	3,281,054	979	353	646	362	3639
2007	2,893,373	829	96	70	360	3948	5,397,621	1618	1325	684	1857	3108
2008	3,145,009	952	935	237	695	2337	3,820,985	1150	1117	620	833	2409
2009	1,009,213	305	152	81	250	1010	3,378,974	957	390	663	1301	1924
2010	1,295,667	365	342	262	426	453	3,867,067	1147	1376	390	609	2501
2011	530,512	152	26	163	152	385	3,958,276	1207	1226	242	326	3820
2012	1,434,770	434	283	265	367	1073	13,082,248	3993	4917	2481	2610	6220
2013	7,055,096	2137	884	380	821	9108	-	-	-	-	-	-
Mean	**2,004,460**	**587**	**304**	**170**	**335**	**2084**	**4,570,844**	**1356**	**1360**	**608**	**1077**	**2744**
Median	1,423,680	427	159	116	305	1509	3,912,672	1148	1154	594	827	2494
Minimum	315,678	89	26	9	24	64	1,651,468	466	217	102	283	1057
Maximum	7,055,096	2137	935	681	983	9108	13,082,248	3993	4917	2481	2610	6220

Table 3. Percents which blueback herring and threadfin shad constituted of fall purse seine sample on Lake Jocassee, and lakewide number of blueback herring and threadfin shad on Lake Jocassee in fall, 1997-2012. Lakewide numbers were calculated as the product of percent of purse seine sample and total forage fish numbers lakewide in fall as measured in hydroacoustic sampling.

	Percent of purse seine sample		Lakewide number of fish in fall	
Year	**Blueback herring**	**Threadfin shad**	**Blueback herring**	**Threadfin shad**
1997	99.9	0.1	3,958,989	3,963
1998	74.7	25.3	4,118,233	1,394,797
1999	85.3	14.7	5,941,531	1,023,922
2000	26.8	73.2	1,159,536	3,167,091
2001	68.2	31.8	3,035,522	1,415,390
2002	51.5	48.5	1,724,057	1,623,627
2003	76.0	24.0	2,157,462	681,304
2004	76.1	23.9	2,503,990	786,404
2005	69.1	30.9	1,141,164	510,304
2006	81.8	18.2	2,683,902	597,152
2007	68.1	31.9	3,675,780	1,721,841
2008	42.9	57.1	1,639,203	2,181,782
2009	91.2	8.8	3,081,624	297,350
2010	94.4	5.6	3,650,511	216,556
2011	96.9	3.1	3,835,570	122,707
2012	99.9	0.1	13,069,166	13,082
Mean	**75.2**	**24.8**	**3,586,015**	**984,830**
Median	76.1	24.0	3,058,573	733,854
Minimum	26.8	0.1	1,141,164	3,963
Maximum	99.9	73.2	13,069,166	3,167,091

Table 4. Median lengths of YOY blueback herring and threadfin shad in fall and percent of total population consisting of YOY fish in fall, based on purse seine sampling on Lake Jocassee, 1997-2012.

Year	Blueback herring			Threadfin shad		
	Number of YOY fish measured	**Median length YOY fish, mm**	**Percent of population consisting of YOY fish**	**Number of YOY fish measured**	**Median length YOY fish, mm**	**Percent of population consisting of YOY fish**
1997	57	67	27.4	1	-	100
1998	110	76	98.2	38	67.5	100
1999	51	92	63.0	14	67.5	100
2000	44	88.5	73.3	191	66	100
2001	179	71	71.9	103	63	100
2002	93	77	61.2	143	65	100
2003	189	75	99.5	60	70	100
2004	130	91	68.1	60	76.5	100
2005	114	89.5	67.1	76	81	100
2006	16	73	14.8	24	75	100
2007	91	80	83.5	51	60	100
2008	113	68	81.3	185	59	100
2009	343	72	96.9	34	57	100
2010	194	86	76.7	15	65	100
2011	401	85	76.8	10	70.5	100
2012	400	74.5	95.0	1	-	100
Mean		**79.1**	**72.2**		**67.4**	**100**
Median		76.5	75.0		66.75	100
Minimum		67	14.8		57	100
Maximum		92	99.5		81	100

Table 5. Winter minimum and summer maximum surface (0.3 to 4-m mean) temperature (C) in forage fish sampling zones on Lake Jocassee, 1997-spring 2013.

	Zone 1		Zone 2		Zone 3		Zone 4	
Year	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
1997	-	26.3	-	26.5	-	26.3	-	27.1
1998	9.6	26.9	9.8	27.5	9.8	27.6	9.8	27.8
1999	10.9	27.9	11.3	27.8	11.1	28.3	11.2	28.1
2000	9.8	26.9	10.4	27.3	10.0	27.0	10.1	27.1
2001	9.0	26.3	9.1	27.1	9.0	26.7	8.8	27.1
2002	-	27.4	-	27.9	-	27.5	-	27.7
2003	9.3	26.0	9.4	27.2	9.3	26.5	9.2	26.8
2004	9.4	25.1	9.5	25.7	9.5	25.4	9.3	25.7
2005	10.6	26.0	10.7	26.4	11.2	26.7	10.9	26.2
2006	10.6	26.8	11.0	-	11.5	-	11.5	-
2007	9.7	27.0	10.0	27.7	9.9	27.8	9.7	28.2
2008	10.5	26.8	10.6	27.3	10.7	26.8	10.6	27.0
2009	10.1	26.7	10.3	27.3	10.3	27.7	10.0	27.7
2010	9.0	27.4	9.1	27.9	9.1	28.7	8.8	28.3
2011	9.5	26.6	10.0	27.2	10.5	27.3	10.3	27.3
2012	10.7	26.9	10.9	27.0	11.0	27.0	11.0	27.6
2013	10.3	-	10.4	-	10.4	-	10.3	-
Mean	**9.9**	**26.7**	**10.2**	**27.2**	**10.2**	**27.2**	**10.1**	**27.3**
Median	9.8	26.8	10.3	27.3	10.3	27.0	10.1	27.3
Minimum	9.0	25.1	9.1	25.7	9.0	25.4	8.8	25.7
Maximum	10.9	27.9	11.3	27.9	11.5	28.7	11.5	28.3

Table 6. Winter minimum, January-February mean, and summer maximum surface (0.3 to 4-m mean) lakewide temperatures on Lake Jocassee, calculated from monthly mean temperatures measured in forage fish sampling zones, 1997 through spring 2013.

Surface lakewide mean temperature, C			
Year	**Winter minimum**	**January-February mean**	**Summer maximum**
1997	-	-	26.6
1998	9.8	10.3	27.4
1999	11.1	11.9	28.0
2000	10.1	10.6	27.0
2001	9.0	9.3	26.8
2002	-	10.8	27.6
2003	9.3	9.4	26.6
2004	9.4	10.1	25.5
2005	10.9	11.4	26.2
2006	10.8	11.2	-
2007	9.8	11.1	27.7
2008	10.6	10.7	27.0
2009	10.2	10.2	27.3
2010	9.0	9.7	28.1
2011	9.5	9.8	27.0
2012	10.9	11.2	27.0
2013	10.3	10.9	-
Mean	**10.0**	**10.5**	**27.1**
Median	10.1	10.7	27.0
Minimum	9.0	9.3	25.5
Maximum	11.1	11.9	28.1

Table 7. Annual mean, median, minimum (highest) and maximum (lowest) lake levels observed on Lake Jocassee, based on daily lake level data. Range is the difference between minimum and maximum daily lake levels observed for each year, 1997-2012.

Lake level, meters below full pool					
Year	Mean	Median	Minimum (Highest)	Maximum (Lowest)	Range, meters
1997	0.4	0.4	0.0	1.0	1.0
1998	0.6	0.6	0.1	1.9	1.8
1999	2.9	2.2	0.2	6.2	6.0
2000	4.3	4.7	0.1	7.9	7.8
2001	5.8	6.1	2.7	7.5	4.8
2002	6.4	6.7	4.0	7.9	3.8
2003	1.1	0.6	0.1	5.0	4.9
2004	0.9	0.7	0.1	2.7	2.5
2005	1.0	0.7	0.1	2.8	2.7
2006	2.8	2.0	0.2	6.9	6.7
2007	4.3	4.4	0.3	8.7	8.5
2008	7.6	7.6	6.2	8.8	2.6
2009	4.0	3.8	0.1	8.6	8.5
2010	1.7	0.7	0.1	5.0	4.9
2011	4.2	4.4	0.6	8.0	7.5
2012	7.3	7.4	5.9	8.2	2.3
Mean	**3.5**				**4.8**
Median	3.5				4.9
Minimum	0.4				1.0
Maximum	7.6				8.5

Table 8. Mean, lowest daily, and lowest 30-day average lake levels observed on Lake Jocassee December-February and May-October, 1997-2013, based on daily lake level data. Range is the difference between maximum and minimum lake levels observed during the period.

	Dec-Feb lake level, meters below full pool				May-Oct lake level, meters below full pool			
Year	**Mean**	**Lowest daily**	**Lowest 30-day average**	**Range, meters**	**Mean**	**Lowest daily**	**Lowest 30-day average**	**Range, meters**
1997	-	-	-	-	0.45	0.95	0.57	0.84
1998	0.37	1.04	0.52	0.98	0.67	1.50	1.14	1.38
1999	1.92	3.84	2.75	3.20	2.73	6.16	5.77	6.01
2000	5.30	6.13	5.71	2.13	3.88	7.44	6.68	6.95
2001	6.72	7.50	6.84	1.31	5.11	7.53	6.58	4.82
2002	5.30	6.88	6.28	2.87	6.87	7.75	7.33	2.21
2003	4.71	7.72	6.44	5.45	0.46	1.13	0.86	1.04
2004	0.61	1.10	0.70	0.88	0.95	2.67	2.14	2.53
2005	1.67	2.71	2.34	2.24	0.77	2.80	2.08	2.66
2006	0.69	1.65	0.86	1.43	3.22	6.26	5.62	5.72
2007	4.93	6.88	6.47	3.76	4.58	8.68	7.97	8.42
2008	7.31	8.71	7.73	2.72	7.89	8.78	8.49	2.59
2009	7.56	8.73	7.86	2.26	3.24	5.93	5.17	5.23
2010	0.36	0.94	0.45	0.85	1.68	4.89	4.27	4.74
2011	4.17	5.42	4.86	2.42	3.69	7.78	7.18	7.21
2012	6.89	7.78	7.14	1.91	7.43	8.04	7.64	1.55
2013	7.00	8.05	7.59	2.54	-	-	-	-
Mean	**4.10**			**2.31**	**3.35**			**3.99**
Median	4.82			2.25	3.23			3.70
Minimum	0.36			0.85	0.45			0.84
Maximum	7.56			5.45	7.89			8.42

Table 9. Densities of zooplankton on Lake Jocassee, based on net tows from 20 meters to surface carried out in forage fish sampling zones quarterly in 2012.

			Zooplankton, organisms/m^3			
Date	**Location**	**Zone**	**Copepoda**	**Cladocera**	**Rotifera**	**Total**
2/20/2012	558.7	1	3,371	3,201	6,595	13,167
2/20/2012	560	2	3,690	3,678	3,233	10,601
2/20/2012	557	3	5,238	5,239	8,898	19,374
2/20/2012	556	4	6,391	4,808	9,815	21,014
		Mean	**4,672**	**4,232**	**7,135**	**16,039**
5/16/2012	558.7	1	9,679	4,134	57,125	70,938
5/16/2012	560	2	12,924	3,004	73,449	89,377
5/16/2012	557	3	7,380	3,355	39,253	49,989
5/16/2012	556	4	15,595	2,829	53,224	71,648
		Mean	**11,395**	**3,330**	**55,763**	**70,488**
8/21/2012	558.7	1	12,067	11,351	9,092	32,510
8/21/2012	560	2	9,939	9,172	16,531	35,641
8/21/2012	557	3	16,958	10,739	10,947	38,644
8/21/2012	556	4	14,988	8,353	15,755	39,096
		Mean	**13,488**	**9,904**	**13,081**	**36,473**
11/19/2012	558.7	1	13,598	7,693	67,158	88,448
11/19/2012	560	2	7,823	2,942	26,632	37,398
11/19/2012	557	3	18,073	4,365	54,258	76,697
11/19/2012	556	4	19,784	4,846	33,677	58,306
		Mean	**14,819**	**4,961**	**45,431**	**65,212**
Grand mean			**11,094**	**5,607**	**30,353**	**47,053**

Table 10. Number and biomass of selected species in gill net sampling conducted on Lake Jocassee, 1999-2012 (Rankin 2013).

Number per 40 gill net sets								
Year	**Brown trout**	**Bullhead catfish**	**Largemouth bass**	**Rainbow trout**	**Redeye bass**	**Smallmouth bass**	**White bass**	**White catfish**
1999	74	24	9	1	107	14	1	57
2000	124	6	5	3	111	3	2	20
2001	126	14	7	3	86	3	0	14
2002	139	17	5	0	85	5	0	17
2003	107	4	3	36	59	8	0	25
2004	80	2	4	4	64	2	0	9
2005	83	13	1	1	102	8	1	58
2006	49	28	2	5	127	8	1	3
2007	51	18	8	22	118	18	4	11
2008	85	7	13	6	120	7	0	23
2009	116	39	9	4	125	15	1	93
2010	53	33	8	3	76	9	0	60
2011	69	61	4	4	91	9	1	100
2012	68	38	6	2	63	8	0	66
Mean	**87**	**22**	**6**	**7**	**95**	**8**	**1**	**40**
Median	82	18	6	4	97	8	1	24
Minimum	49	2	1	0	59	2	0	3
Maximum	139	61	13	36	127	18	4	100

Biomass per 40 gill net sets, kg								
Year	**Brown trout**	**Bullhead catfish**	**Largemouth bass**	**Rainbow trout**	**Redeye bass**	**Smallmouth bass**	**White bass**	**White catfish**
1999	114.2	3.3	14.3	0.2	68.1	24.4	1.1	8.4
2000	172.6	0.6	8.6	0.8	69.8	5	2.9	3.8
2001	194.7	1.9	10.6	2.3	54.1	7.6	0	10.7
2002	167.8	1.3	8.1	0	53.4	4.9	0	6.6
2003	132.6	0.3	4.7	12.8	50.6	8.9	0	6.8
2004	89.4	0.1	6.9	1.9	42.3	2.6	0	4.6
2005	111.6	0.6	0.6	0.2	63.9	9	0.7	8.8
2006	80.9	3.8	5.1	4.2	85.3	8.7	1.6	1.1
2007	67.9	2.5	11	17.3	90.7	21.2	5.1	5.9
2008	113.1	2.5	30.4	2.7	86.4	5.7	0	20.7
2009	126.6	3.2	15.8	2.9	78.3	15.6	1	20.9
2010	60.9	2.6	11.4	2.4	53.3	8.4	0	12.7
2011	89.7	5.9	4.7	2	58.3	8.4	0.5	22.2
2012	95.7	3.3	10	1.9	39.9	10.1	0	17.1
Mean	**115.6**	**2.3**	**10.2**	**3.7**	**63.9**	**10.0**	**0.9**	**10.7**
Median	112.4	2.5	9.3	2.2	61.1	8.6	0.3	8.6
Minimum	60.9	0.1	0.6	0.0	39.9	2.6	0.0	1.1
Maximum	194.7	5.9	30.4	17.3	90.7	24.4	5.1	22.2

M.S. Rodriguez

Table 11. Littoral density and biomass of black basses in electrofishing zones on Lake Jocassee, 1999 through 2011.

Littoral density of black basses, fish/km						
Year	**Zone**	**Largemouth**	**Redeye**	**Smallmouth**	**Spotted**	**Hybrid**
1999	Lower	4.00	21.00	0.67	0	0
2002	Lower	4.33	25.67	8.00	0.67	0
2005	Lower	1.67	12.67	0	1.33	0
2008	Lower	2.67	7.67	1.33	1.33	2
2011	Lower	3.00	18.67	1.00	0	0.33
Mean		**3.13**	**17.13**	**2.20**	**0.67**	**0.47**
1999	Upper	12.33	27.00	0	0	0
2002	Upper	15.00	32.00	0.33	0	0
2005	Upper	12.67	16.67	0.33	0.33	0
2008	Upper	19.33	29.00	0.33	0.33	0.33
2011	Upper	13.67	29.00	1.67	0.67	0
Mean		**14.60**	**26.73**	**0.53**	**0.27**	**0.07**

Littoral biomass of black basses, kg/km						
Year	**Zone**	**Largemouth**	**Redeye**	**Smallmouth**	**Spotted**	**Hybrid**
1999	Lower	3.514	2.843	0.538	0	0
2002	Lower	2.806	2.404	0.382	0.006	0
2005	Lower	0.965	2.455	0	0.148	0
2008	Lower	1.281	0.765	0.124	0.350	0.472
2011	Lower	1.018	2.076	0.164	0	0.049
Mean		**1.917**	**2.109**	**0.242**	**0.101**	**0.104**
1999	Upper	3.381	3.468	0	0	0
2002	Upper	5.666	3.169	0.004	0	0
2005	Upper	5.315	2.341	0.242	0.003	0
2008	Upper	6.627	3.968	0.383	0.123	0.064
2011	Upper	2.038	3.339	0.475	0.010	0
Mean		**4.605**	**3.257**	**0.221**	**0.027**	**0.013**

Table 12. Annual mean, median, minimum, and maximum generation flows at Jocassee Pumped Storage Station based on daily mean data, 1997-2012.

	JPSS generation flow, m^3/sec			
Year	**Mean**	**Median**	**Minimum**	**Maximum**
1997	121.4	106.3	0	393.5
1998	139.4	137.4	0	430.3
1999	98.0	71.5	0	344.5
2000	101.7	89.7	0	362.4
2001	115.6	90.3	0	410.0
2002	146.6	133.8	0	416.1
2003	165.5	162.1	0	470.8
2004	160.0	140.8	0	628.8
2005	165.6	158.6	0	452.6
2006	143.4	127.4	0	419.6
2007	136.2	126.8	0	556.7
2008	166.2	163.1	0	422.2
2009	140.1	121.4	0	427.8
2010	132.9	109.6	0	390.4
2011	130.7	108.0	0	437.9
2012	132.1	120.6	0	375.2
Mean	**137.2**	**123.0**	**0**	**433.7**
Median	137.8	124.1	0	420.9
Minimum	98.0	71.5	0	344.5
Maximum	166.2	163.1	0	628.8

Table 13. Mean, maximum, and maximum 30-day average of daily Jocassee Pumped Storage Station generation flow observed December-February and May-October, 1997 through 2013. Year associated with December-February data is the year of January-February measurements. Values were calculated based on daily mean generation flows.

Year	December-February generation flow, m^3/sec			May-October generation flow, m^3/sec		
	Mean	Maximum	Maximum 30-day average	Mean	Maximum	Maximum 30-day average
1997	-	-	-	148.7	393.5	230.0
1998	97.1	400.7	107.7	173.2	430.3	210.4
1999	76.8	314.9	96.2	117.3	344.5	228.0
2000	70.6	316.8	101.8	114.0	337.3	142.3
2001	43.8	253.2	73.4	172.7	410.0	236.0
2002	59.9	218.4	74.7	183.0	416.1	226.4
2003	159.6	450.9	204.3	172.8	470.8	239.7
2004	149.6	428.8	181.2	183.8	628.8	251.2
2005	136.2	452.6	166.8	196.4	436.8	258.1
2006	121.3	387.2	135.1	172.2	419.6	266.8
2007	67.1	236.7	81.0	172.4	427.9	258.4
2008	134.4	556.7	161.3	192.3	418.2	251.5
2009	128.6	419.1	149.8	173.0	427.8	254.9
2010	122.1	353.2	134.7	174.4	390.4	264.3
2011	63.4	302.2	84.5	188.4	437.9	291.9
2012	95.8	340.4	107.8	163.3	375.2	220.6
2013	104.0	472.5	128.4	-	-	-
Mean	**101.9**	**369.0**	**124.3**	**168.6**	**422.8**	**239.4**
Median	100.6	370.2	118.1	172.9	418.9	245.4
Minimum	43.8	218.4	73.4	114.0	337.3	142.3
Maximum	159.6	556.7	204.3	196.4	628.8	291.9

Table 14. Annual mean, median, minimum, and maximum pumping flows at Bad Creek Pumped Storage Station, 1997-2012. Values were calculated based on daily mean data.

Year	**BCPSS pumping flow, m^3/sec**			
	Mean	**Median**	**Minimum**	**Maximum**
1997	99.3	99.2	0	272.7
1998	121.7	122.7	0	293.9
1999	119.3	120.8	0	271.8
2000	128.4	134.7	0	277.6
2001	111.8	110.5	0	332.0
2002	120.8	123.3	0	259.9
2003	139.1	141.3	0	274.6
2004	114.2	110.4	0	289.0
2005	130.9	127.6	0	324.3
2006	121.5	120.6	0	248.6
2007	141.0	148.5	0	294.1
2008	145.1	143.7	0	294.7
2009	109.5	108.0	0	227.3
2010	116.8	115.5	0	288.7
2011	114.7	114.9	0	262.9
2012	100.2	100.1	0	239.8
Mean	**120.9**	**121.4**	**0**	**278.2**
Median	120.1	120.7	0	276.1
Minimum	99.3	99.2	0	227.3
Maximum	145.1	148.5	0	332.0

Table 15. Mean, maximum daily, and maximum 30-day average Bad Creek Pumped Storage Station pumping flow observed December-February and May-October, 1997-2013. Year associated with December-February data is the year of January-February measurements. Values were calculated based on daily mean data.

Year	December-February pumping flow, m^3/sec			May-October pumping flow, m^3/sec		
	Mean	Maximum daily	Maximum 30-day average	Mean	Maximum daily	Maximum 30-day average
1997	-	-	-	122.9	272.7	165.2
1998	75.7	219.1	90.4	153.1	277.6	184.6
1999	74.3	253.3	97.4	145.6	271.8	196.7
2000	103.6	277.6	120.7	139.6	247.4	169.5
2001	99.7	255.8	114.6	126.4	332.0	159.4
2002	75.9	200.9	84.7	150.7	259.9	179.5
2003	132.6	274.6	151.3	144.4	273.1	191.2
2004	123.0	289.0	135.8	124.4	275.4	162.0
2005	93.3	207.1	119.0	162.8	315.6	198.6
2006	96.1	324.3	129.1	150.2	248.6	182.7
2007	111.1	255.9	126.9	163.2	294.1	189.8
2008	146.4	264.2	154.4	160.6	294.7	196.6
2009	112.4	227.2	120.1	128.3	227.3	172.4
2010	97.1	271.9	112.7	142.9	275.2	188.2
2011	96.7	213.2	108.7	135.6	262.9	182.1
2012	77.0	239.8	93.3	116.7	229.3	154.5
2013	74.2	215.2	86.4	-	-	-
Mean	**99.3**	**249.3**	**115.3**	**141.7**	**272.4**	**179.6**
Median	96.9	254.6	116.8	143.7	272.9	182.4
Minimum	74.2	200.9	84.7	116.7	227.3	154.5
Maximum	146.4	324.3	154.4	163.2	332.0	198.6

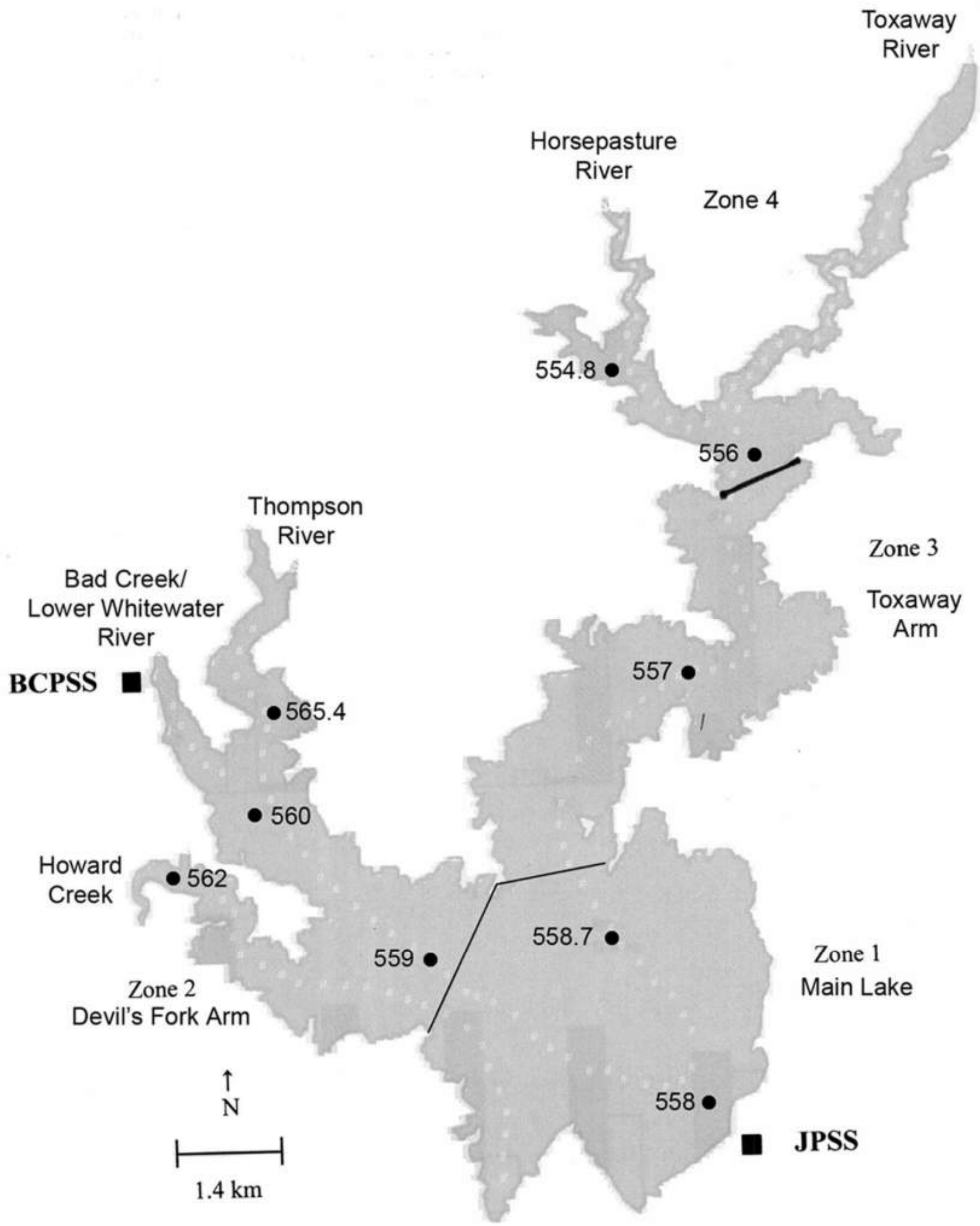


Figure 1. Lake Jocassee, North and South Carolina. Boundaries of hydroacoustics forage fish sampling zones are indicated by lines. Locations of Bad Creek Pumped Storage Station (BCPSS) and Jocassee Pumped Storage Station (JPSS) are indicated. Location numbers correspond to locations sampled for temperature, dissolved oxygen, nutrients, chlorophyll, and zooplankton.

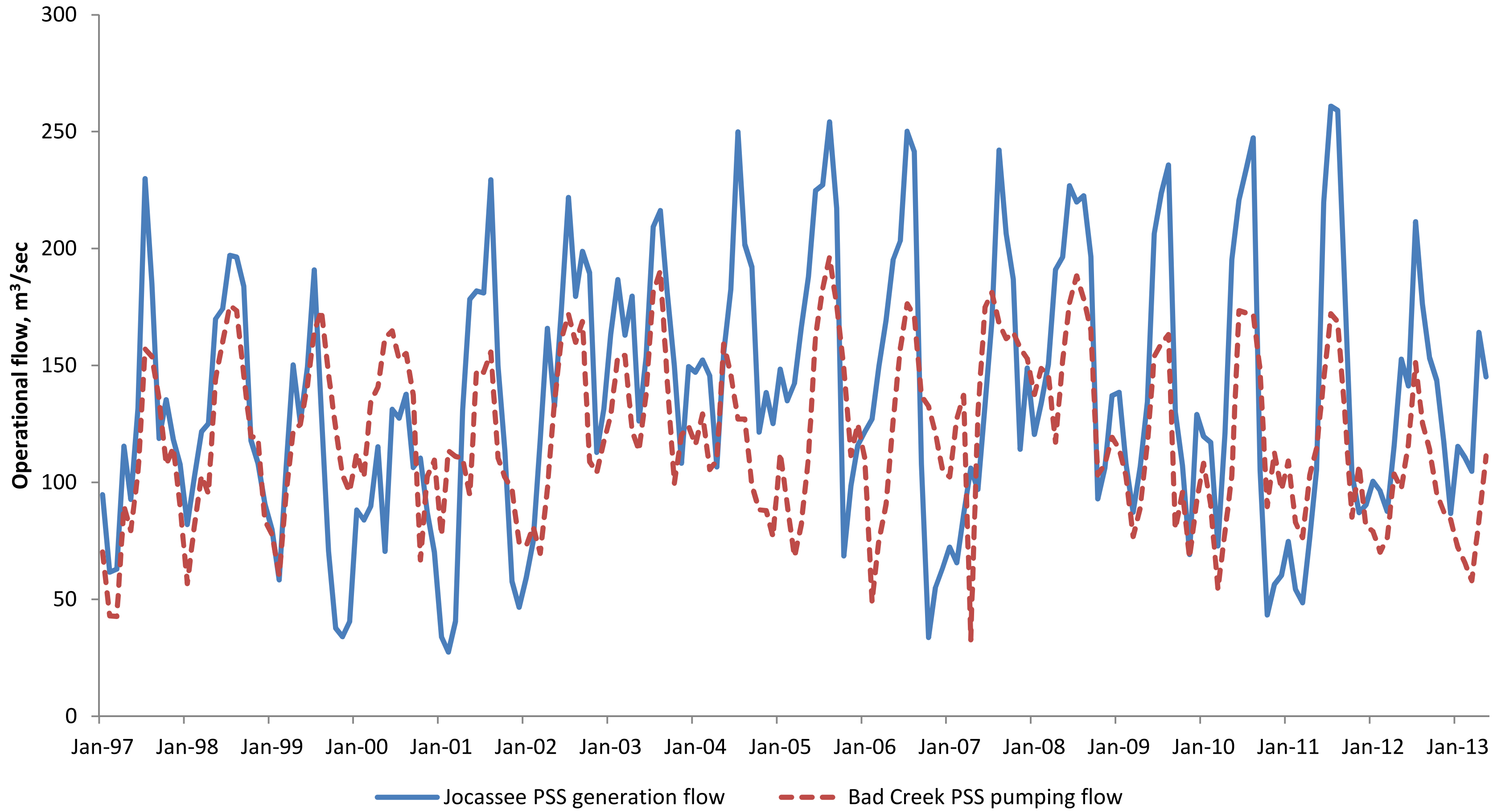


Figure 2. Monthly mean Jocassee Pumped Storage Station generation flow and Bad Creek Pumped Storage Station pumping flow, January 1997 through May 2013.

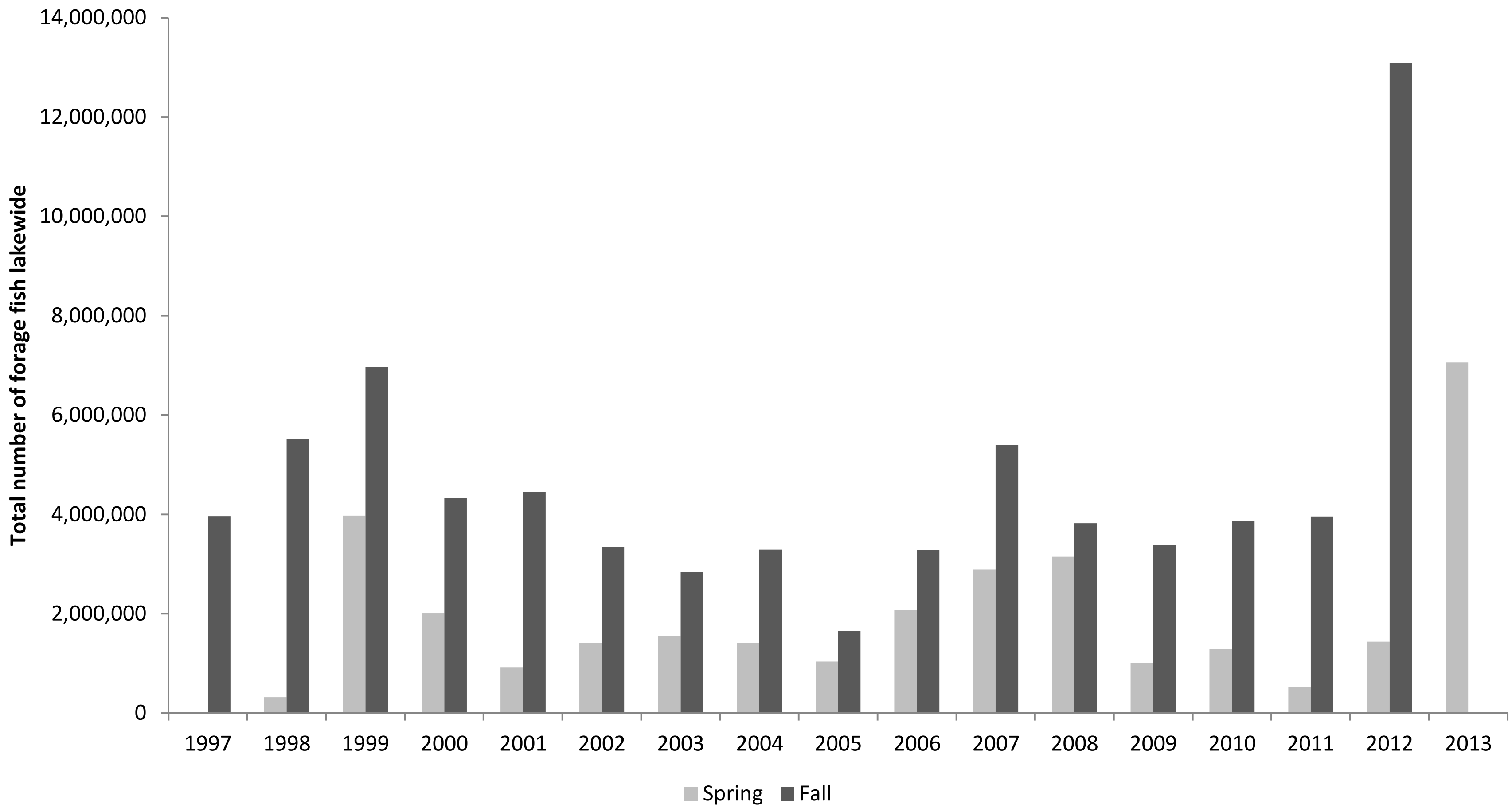


Figure 3. Total number of pelagic forage fish on Lake Jocassee in spring and fall, based on hydroacoustics sampling carried out fall 1997 through spring 2013.

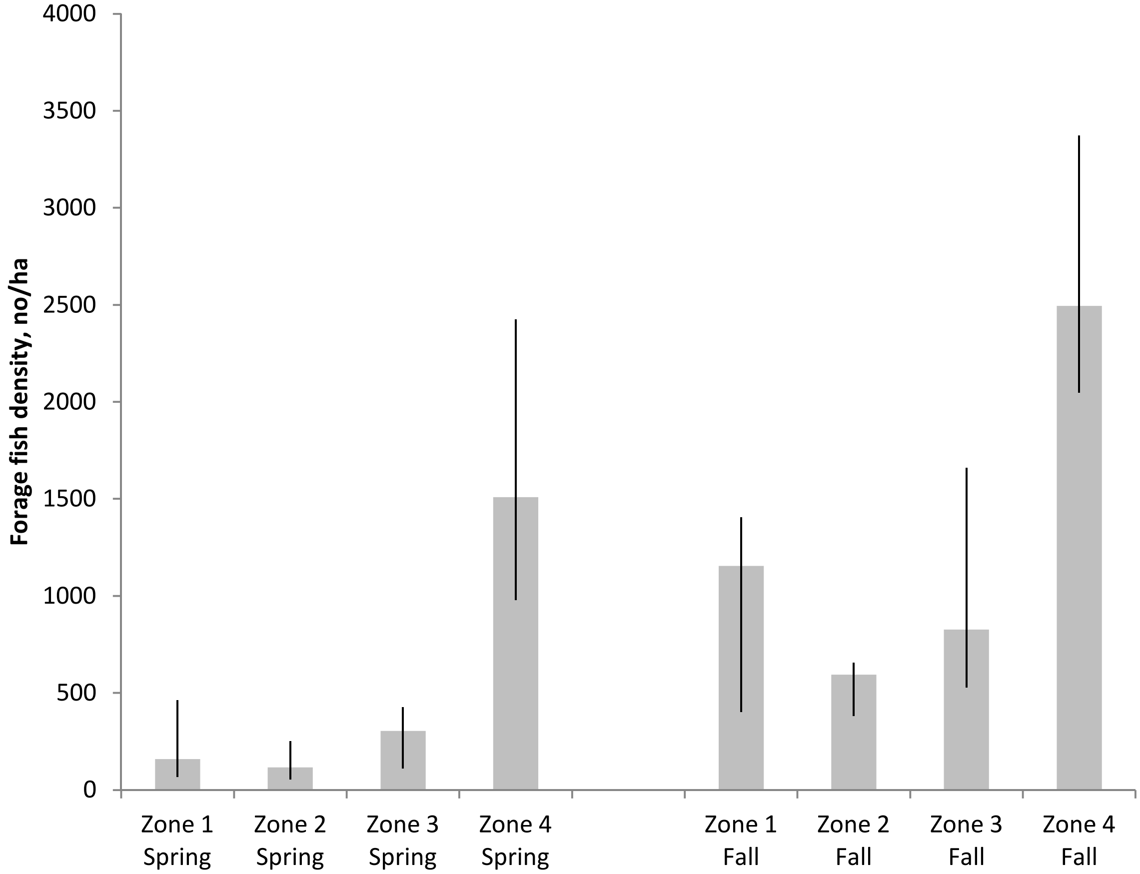


Figure 4. Median spring and fall forage fish densities in Zones 1, 2, 3, and 4 on Lake Jocassee, based on hydroacoustics data collected fall 1997 through spring 2013. Lines are bounded by 25% and 75% quantiles.

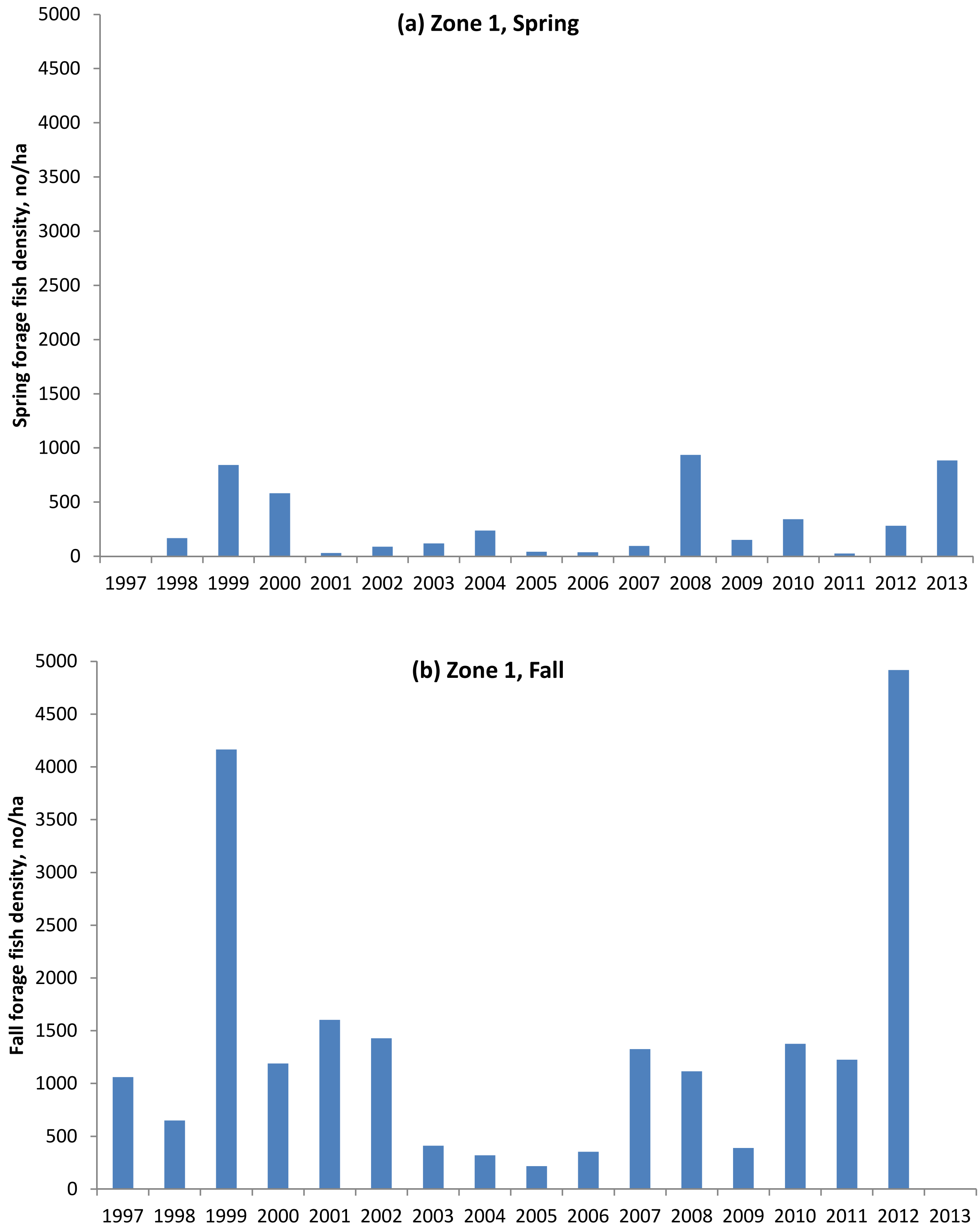


Figure 5. Forage fish densities in Zone 1 of Lake Jocassee in (a) spring and (b) fall, fall 1997 through spring 2013.

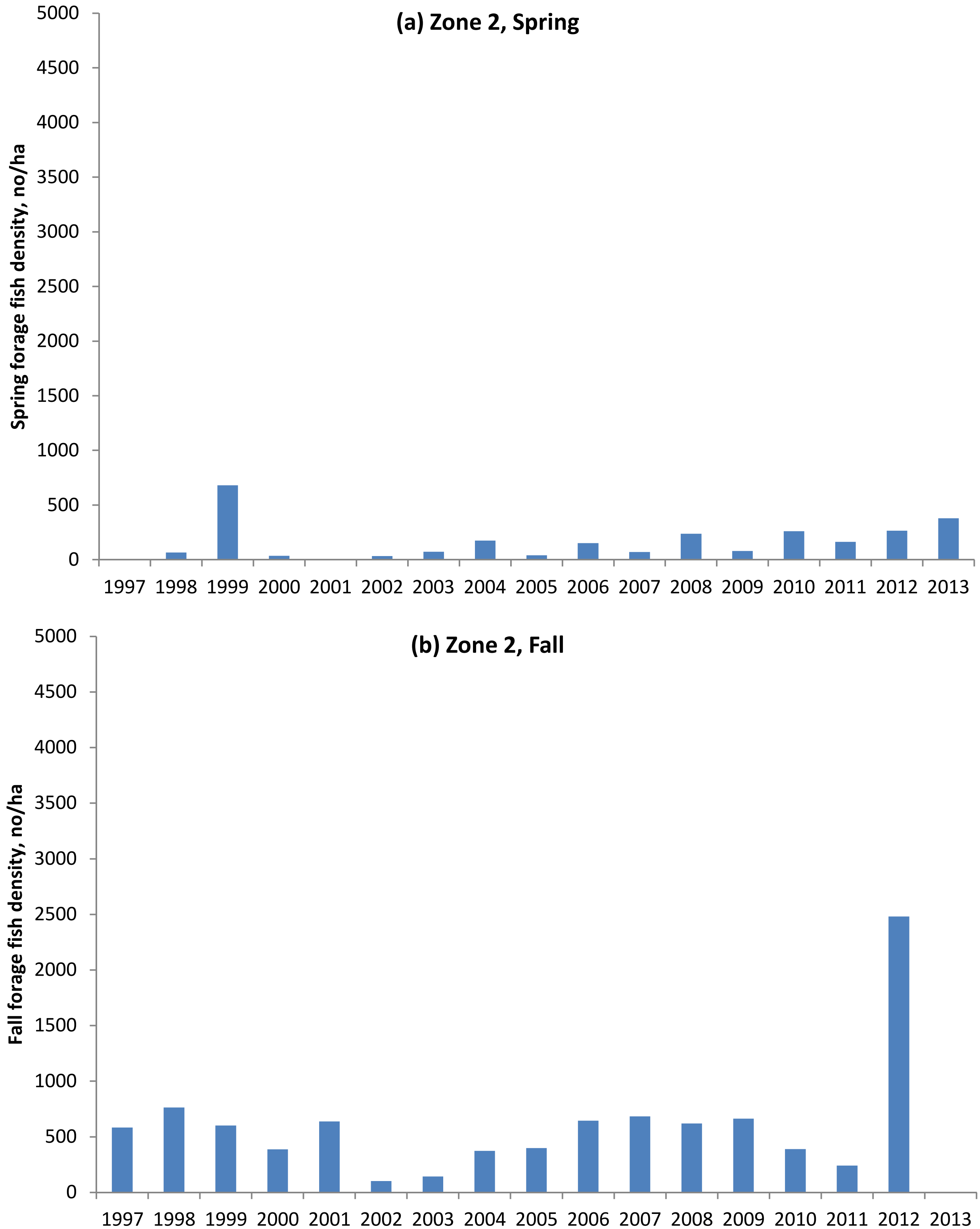


Figure 6. Forage fish densities in Zone 2 of Lake Jocassee in (a) spring and (b) fall, fall 1997 through spring 2013.

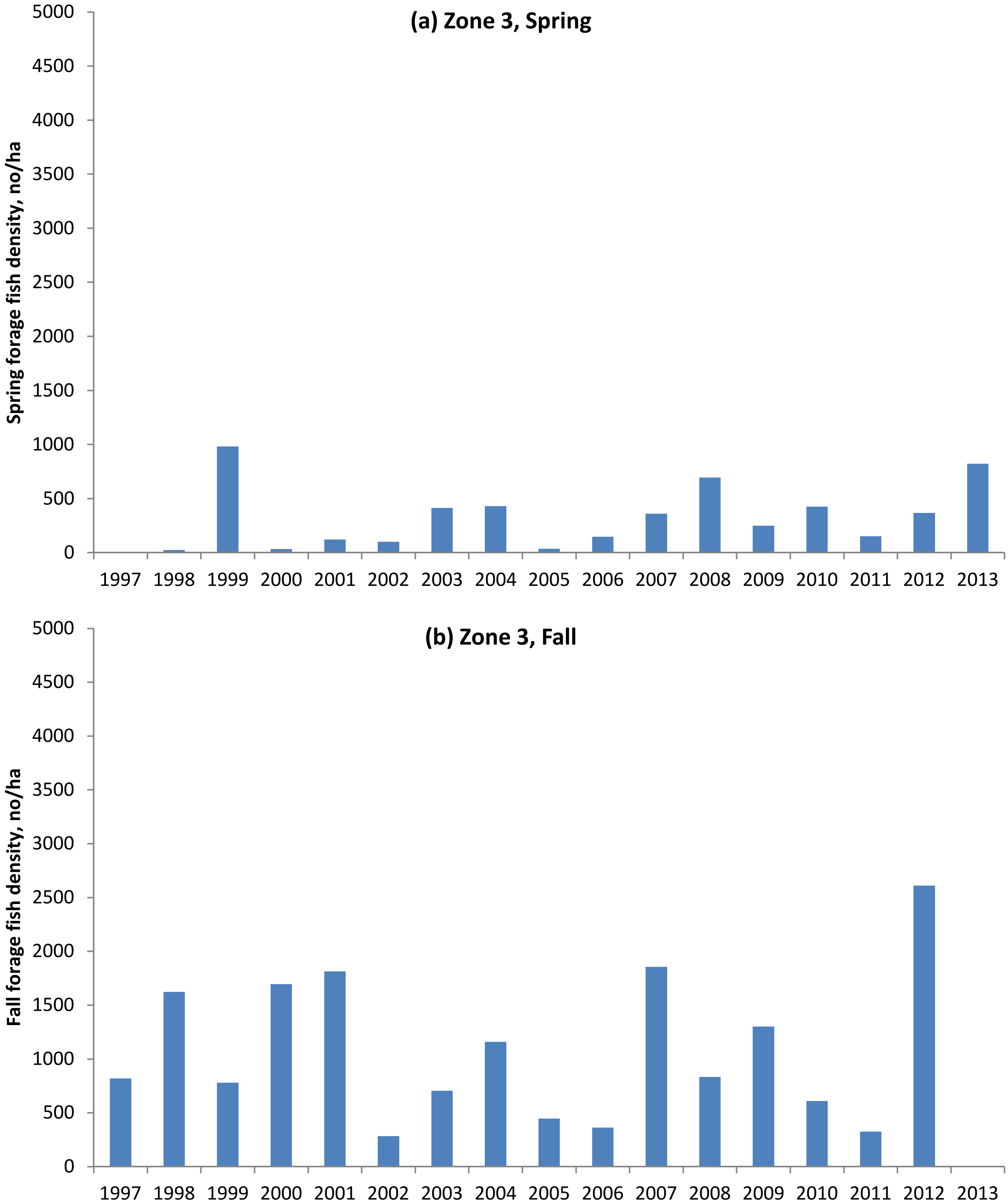


Figure 7. Forage fish densities in Zone 3 of Lake Jocassee in (a) spring and (b) fall, fall 1997 through spring 2013.

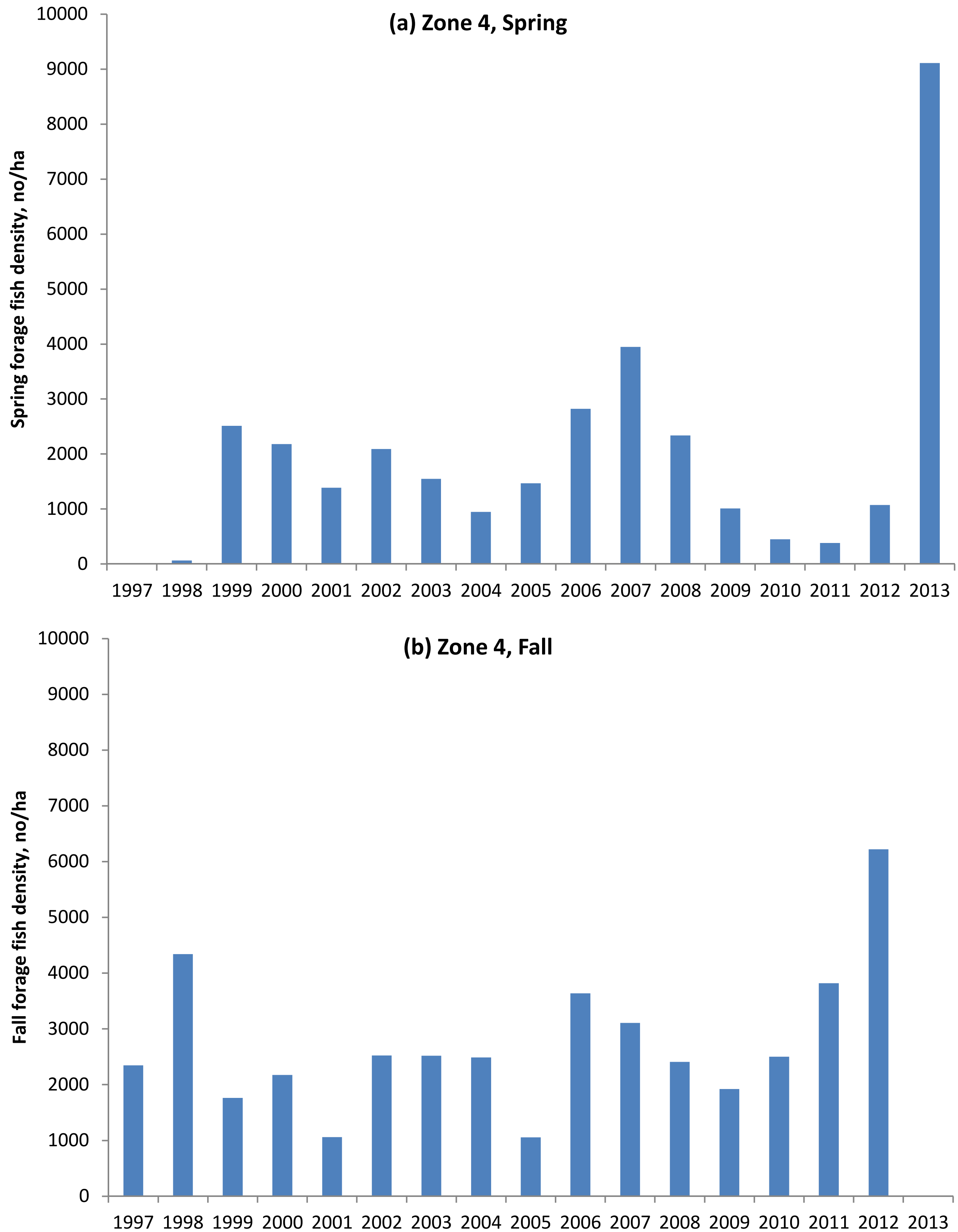


Figure 8. Forage fish densities in Zone 4 of Lake Jocassee in (a) spring and (b) fall, fall 1997 through spring 2013. Note scale when comparing to other zones.

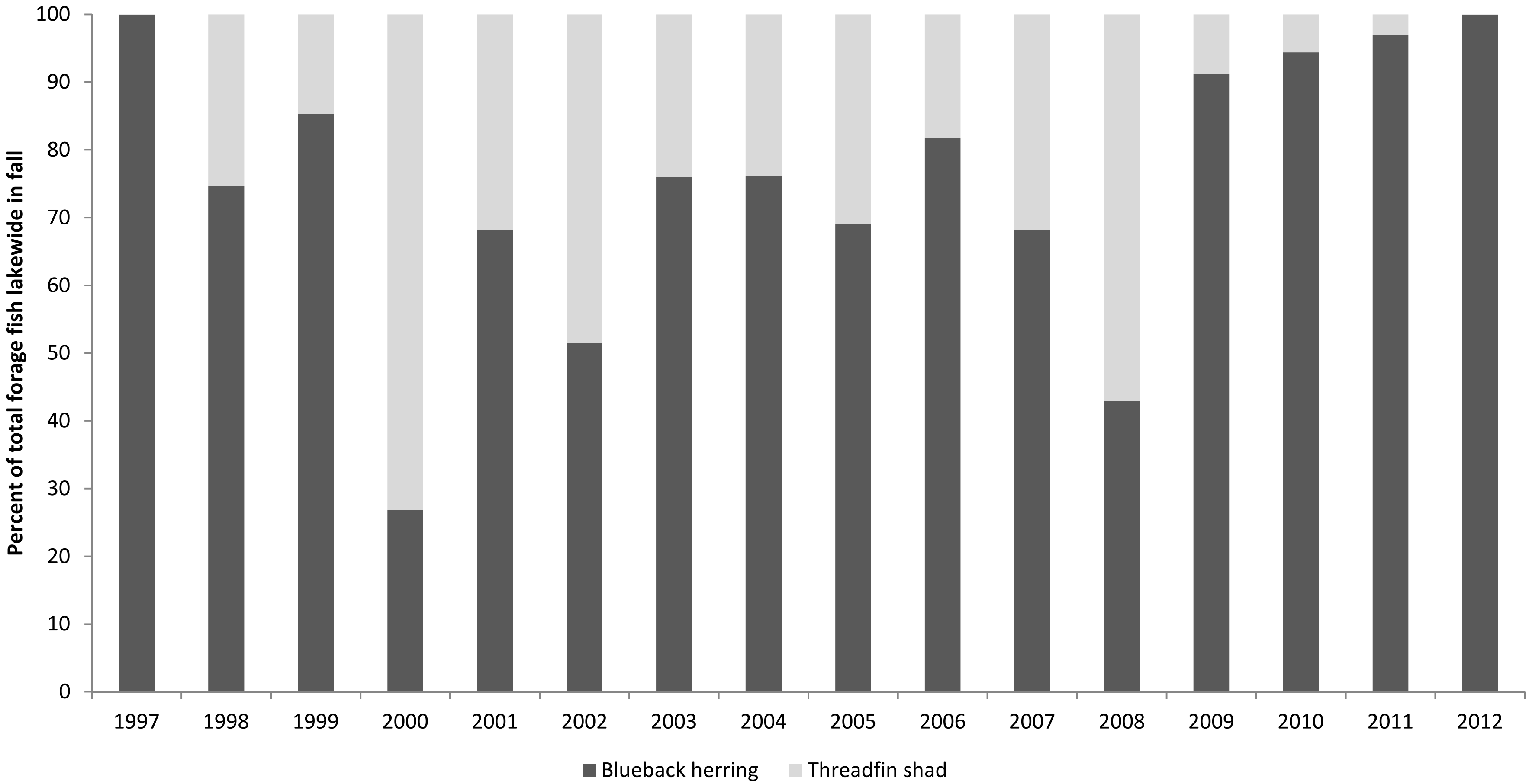


Figure 9. Percent which blueback herring and threadfin shad constituted of the pelagic forage fish community in Lake Jocassee, based on purse seine sampling in fall, 1997-2012.

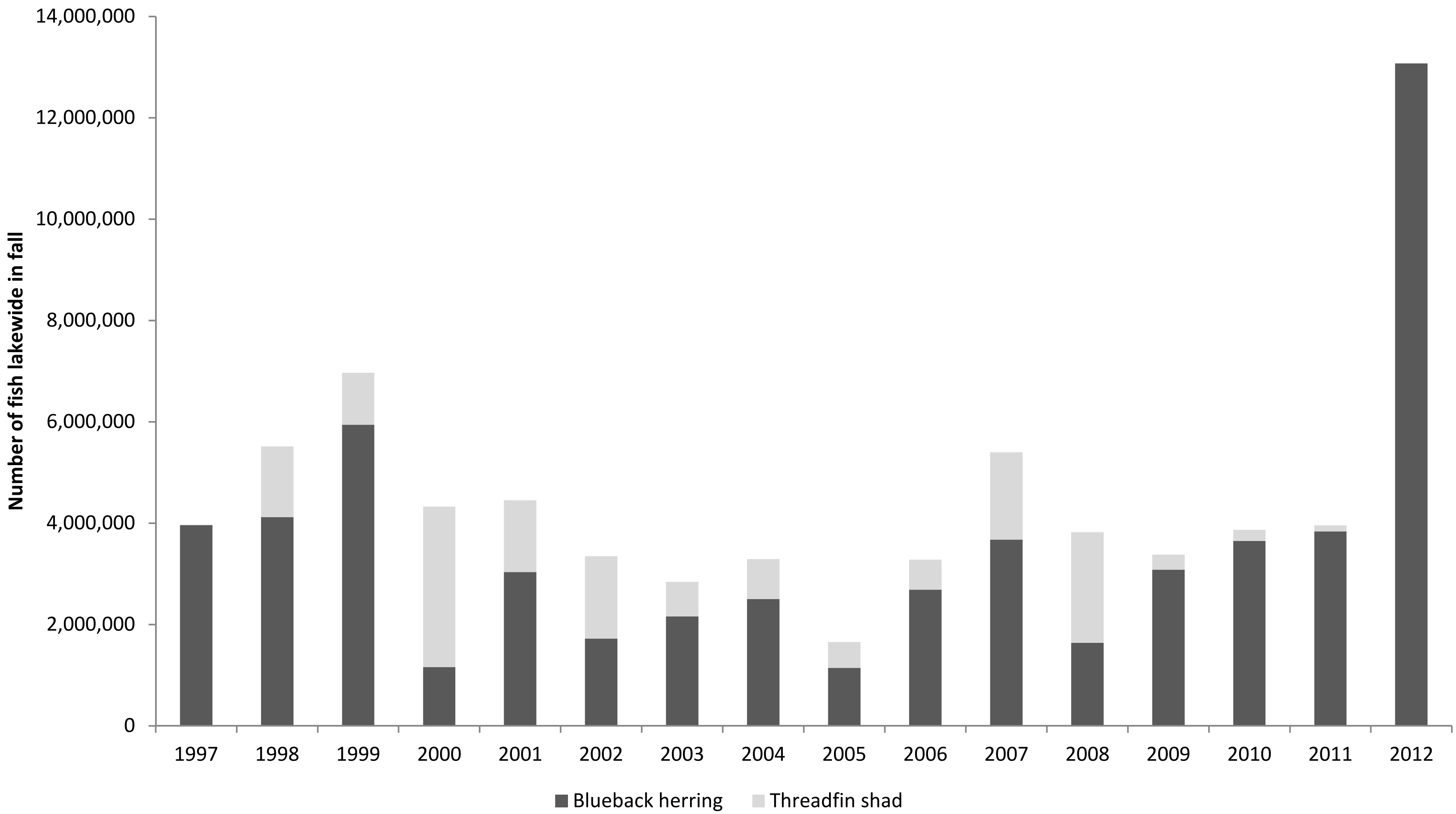


Figure 10. Total numbers of blueback herring and threadfin shad on Lake Jocassee, 1997-2012, based on percent composition from purse seine samples and forage fish lakewide numbers from hydroacoustics sampling.

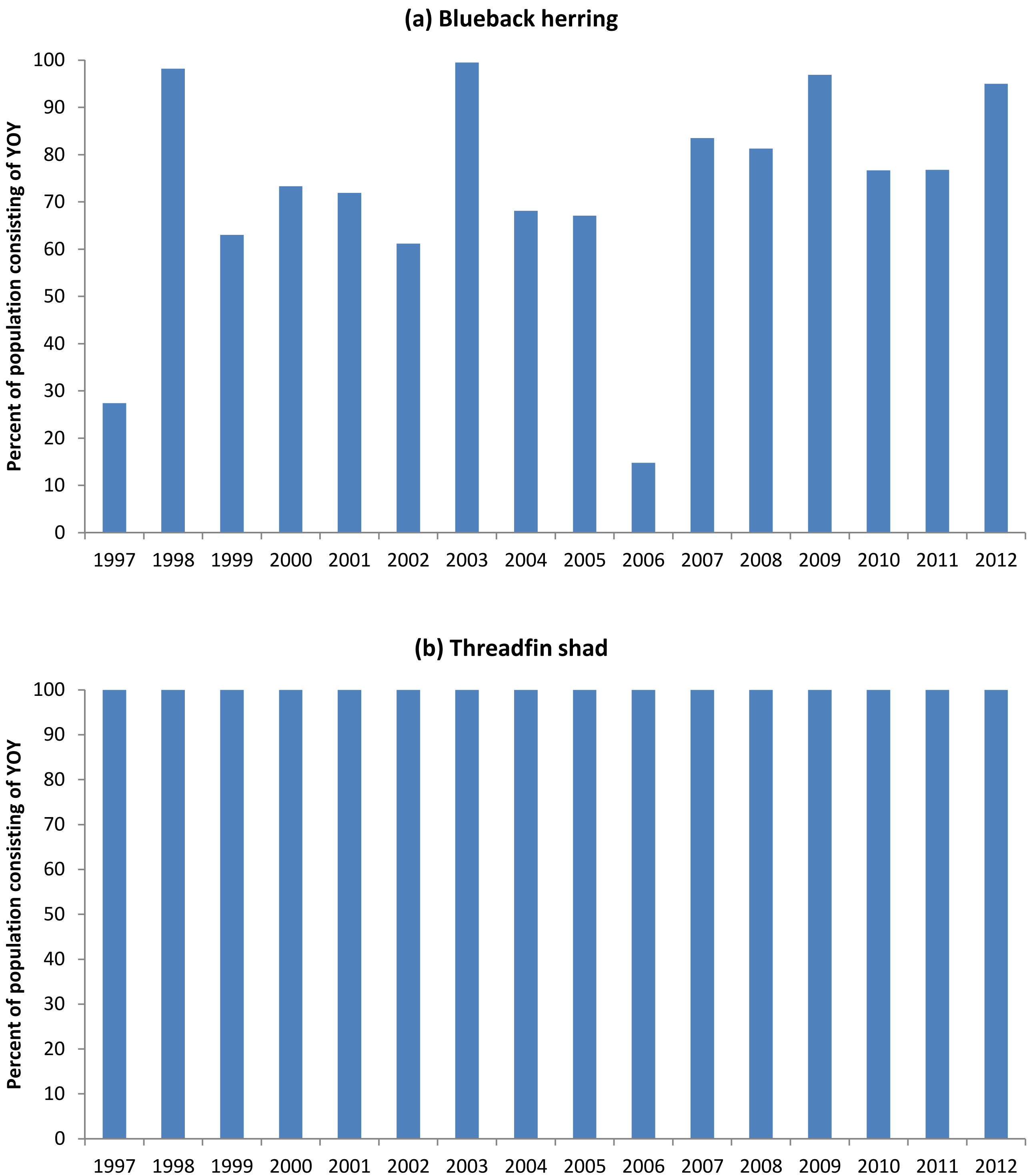


Figure 11. Percent of total (a) blueback herring and (b) threadfin shad population consisting of young-of-the-year fish, as determined from fall purse seine samples, 1997-2012.

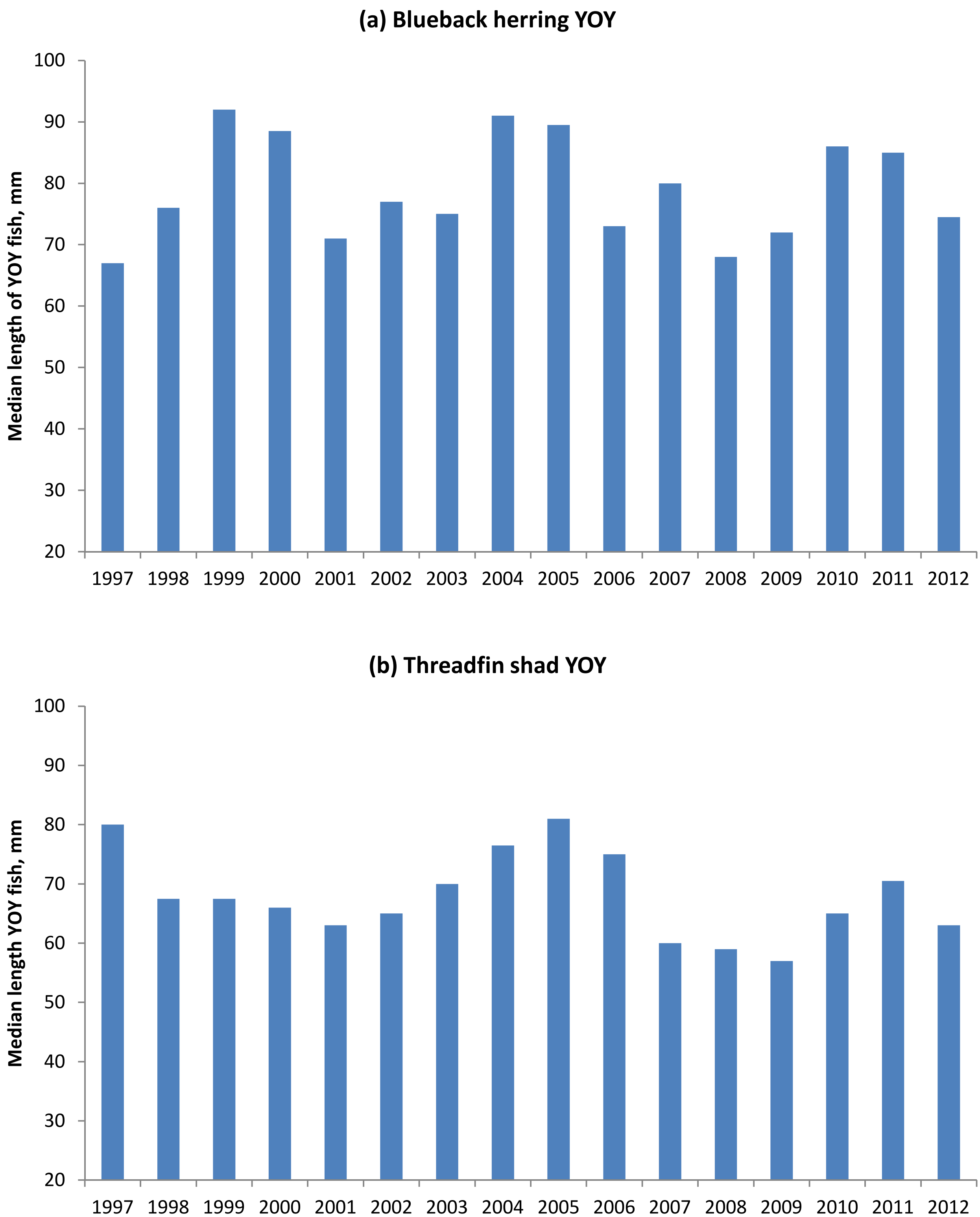


Figure 12. Median lengths of young-of-the-year (a) blueback herring and (b) threadfin shad in fall purse seine samples on Lake Jocassee, 1997-2012.

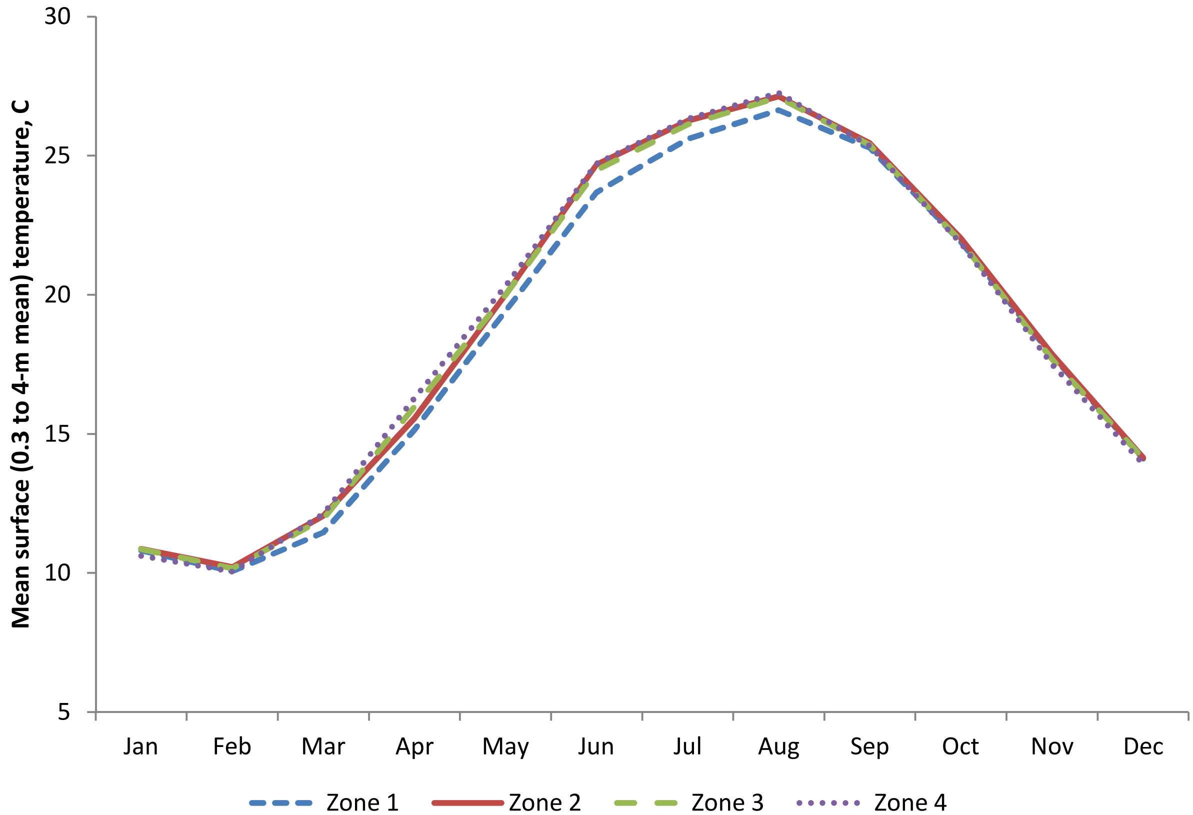


Figure 13. Mean seasonal variation in surface (0.3 to 4-m mean) temperature in forage fish sampling zones on Lake Jocassee, based on data collected 1997-2012.

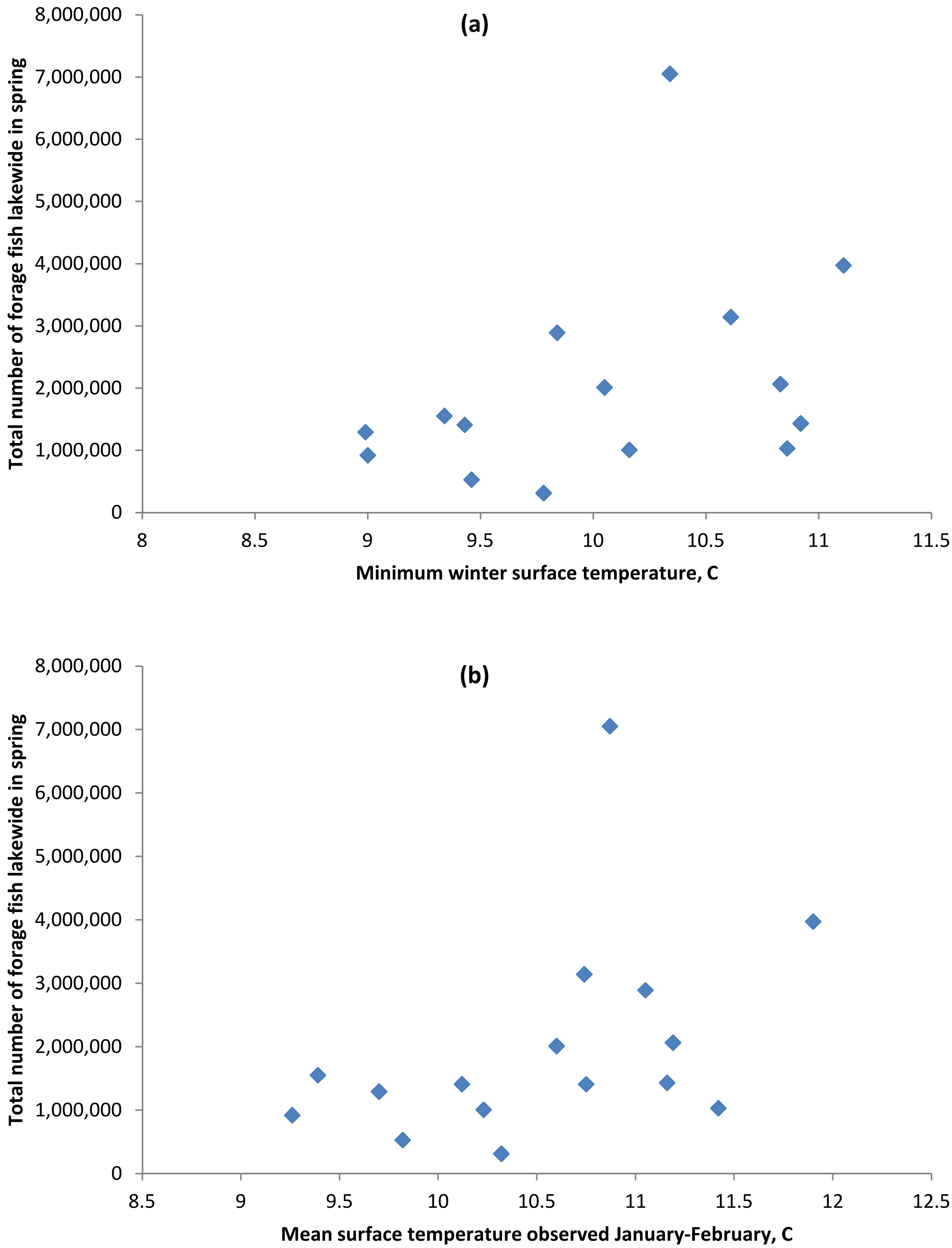


Figure 14. Total number of forage fish lakewide in spring on Lake Jocassee vs. (a) minimum winter surface temperature and (b) mean January-February surface temperature, for the years 1998 through 2013. Surface temperature refers to mean temperature in the top four meters of the water column.

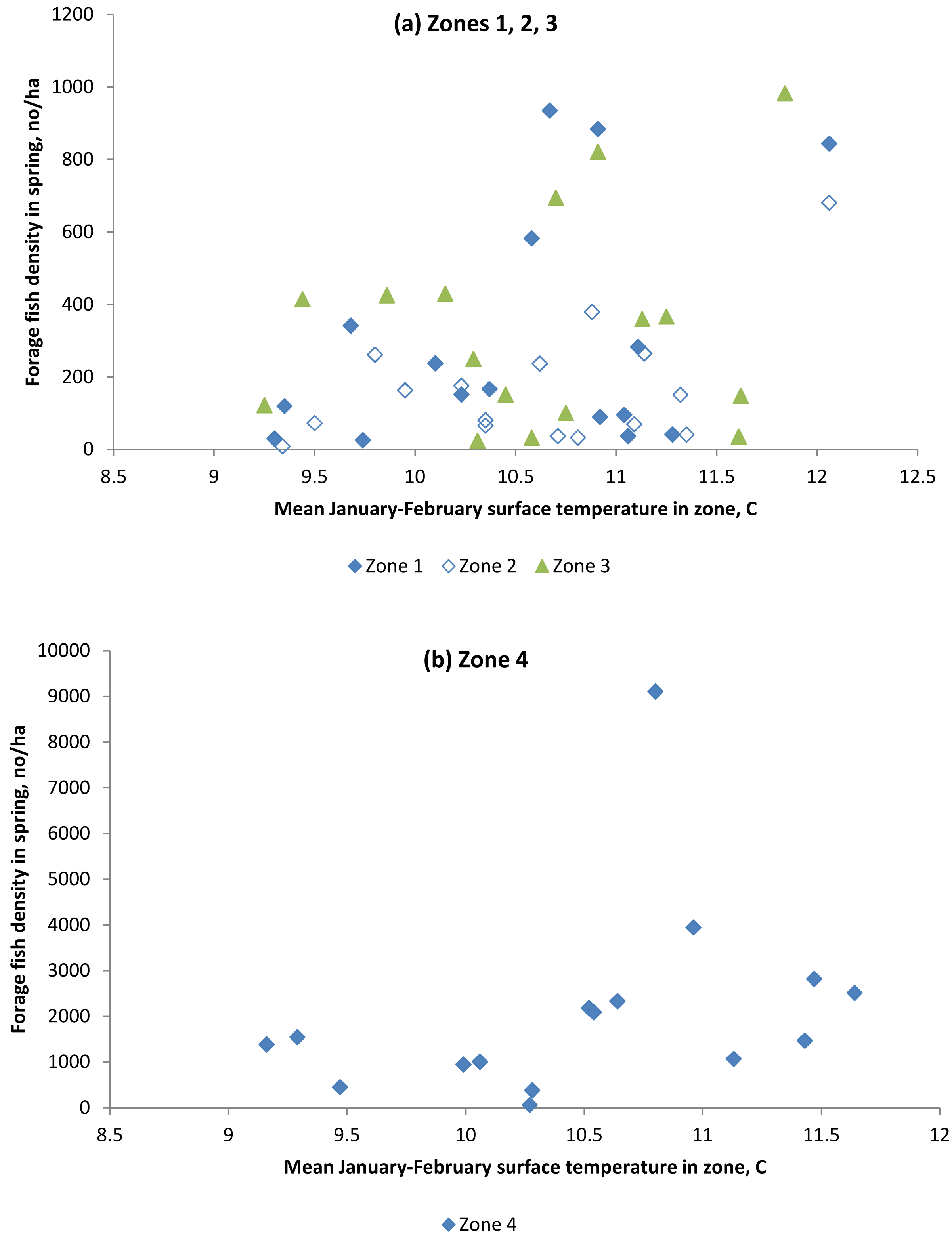


Figure 15. Spring forage fish densities in zones of Lake Jocassee vs. mean January-February surface (0.3 to 4-m mean) zonal temperatures, 1998-2013. Note scales for forage fish density.

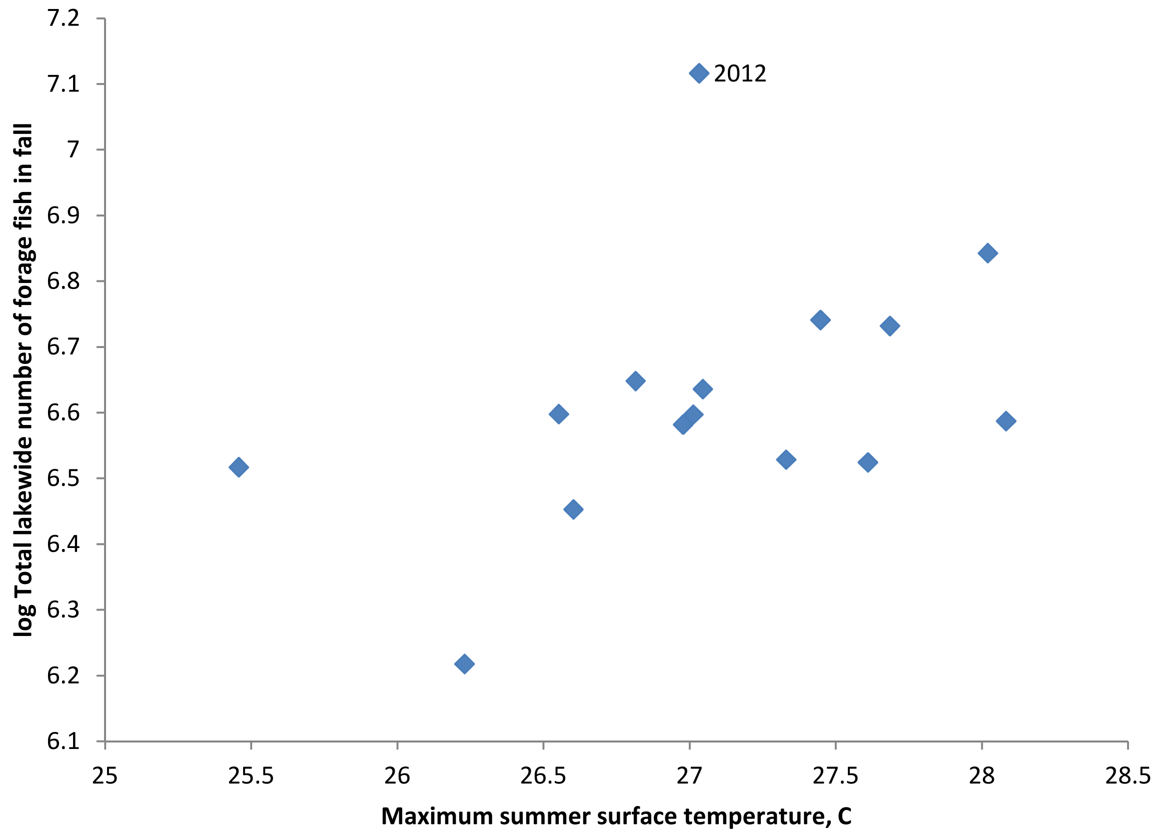


Figure 16. log Total number of forage fish lakewide in fall vs. maximum summer surface (0.3 to 4-m mean) lakewide temperature, 1997-2012.

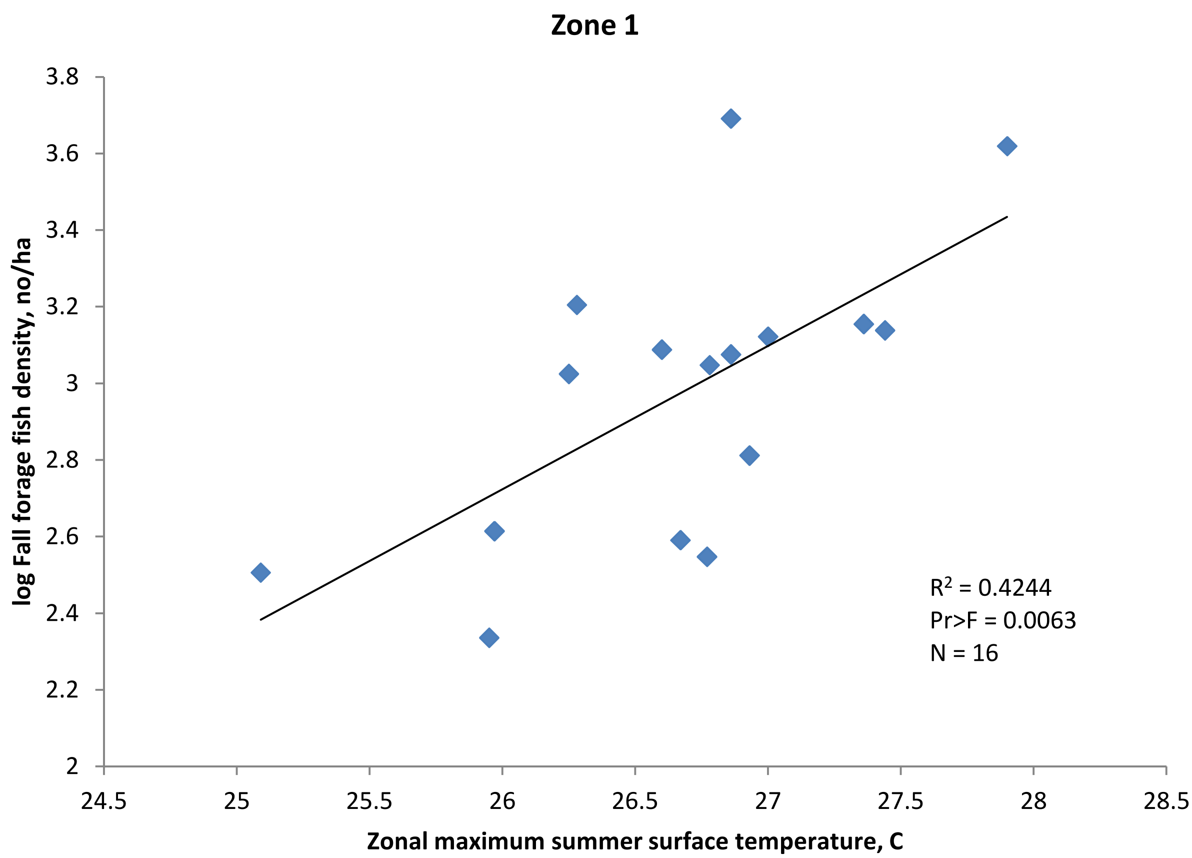


Figure 17. log Fall forage fish density in Zone 1 of Lake Jocassee vs. zonal maximum summer surface (0.3 to 4-m mean) temperature, 1997-2012.

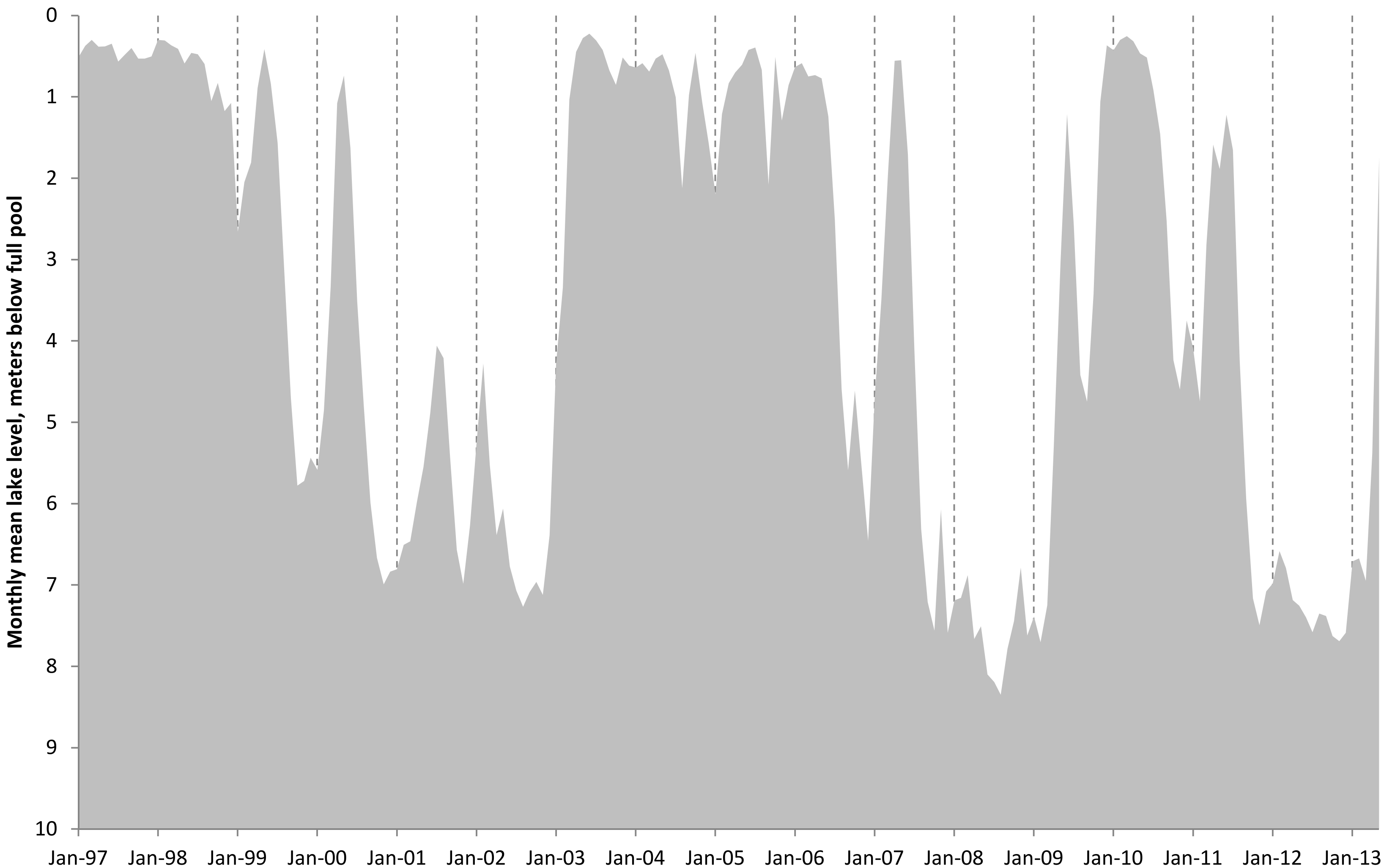


Figure 18. Monthly mean Lake Jocassee lake level, January 1997 through May 2013.

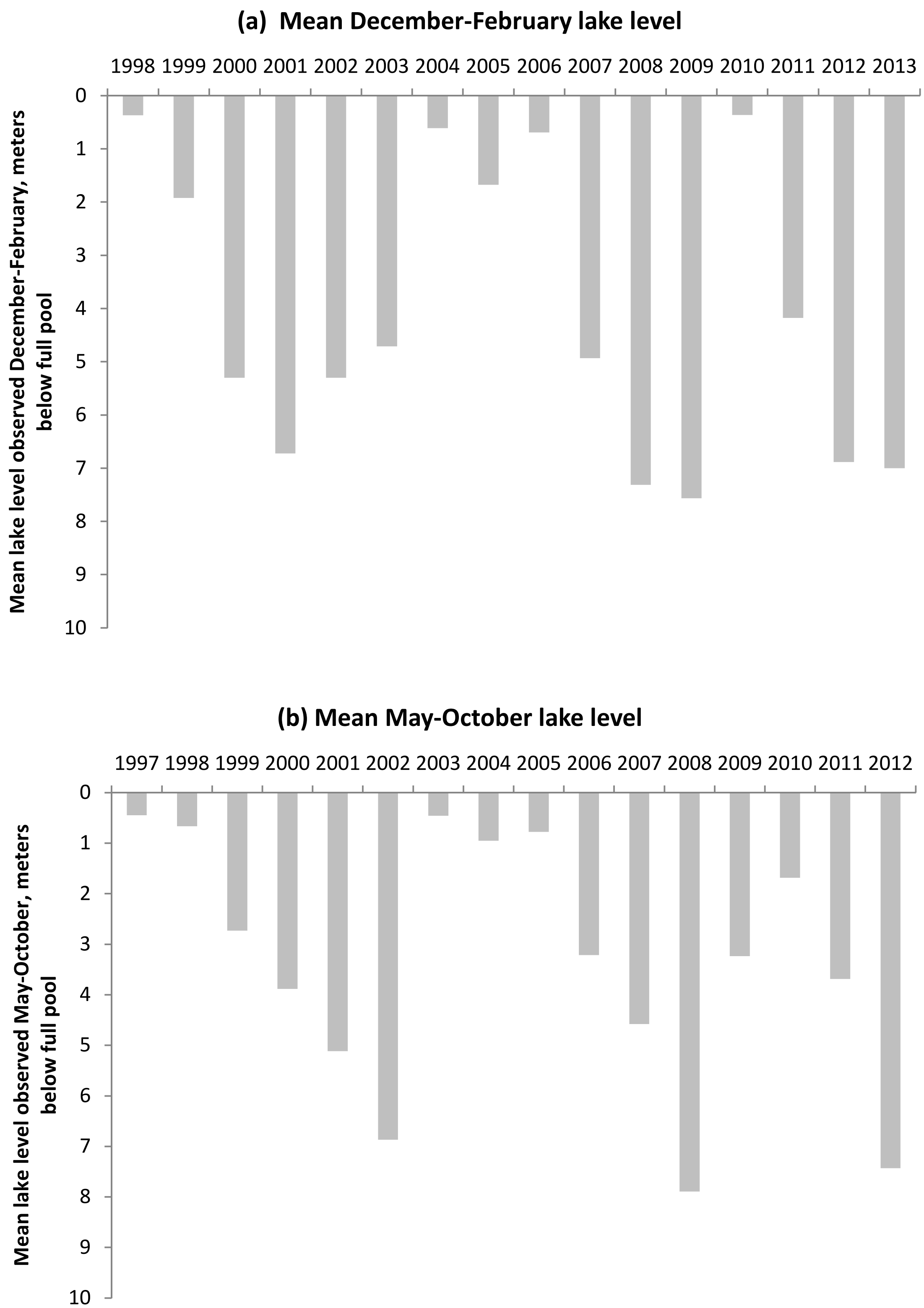


Figure 19. Mean Lake Jocassee lake level observed (a) December-February and (b) May-October, 1997-2013. Means are based on daily lake level data. Year associated with December-February data is year of January-February measurements.

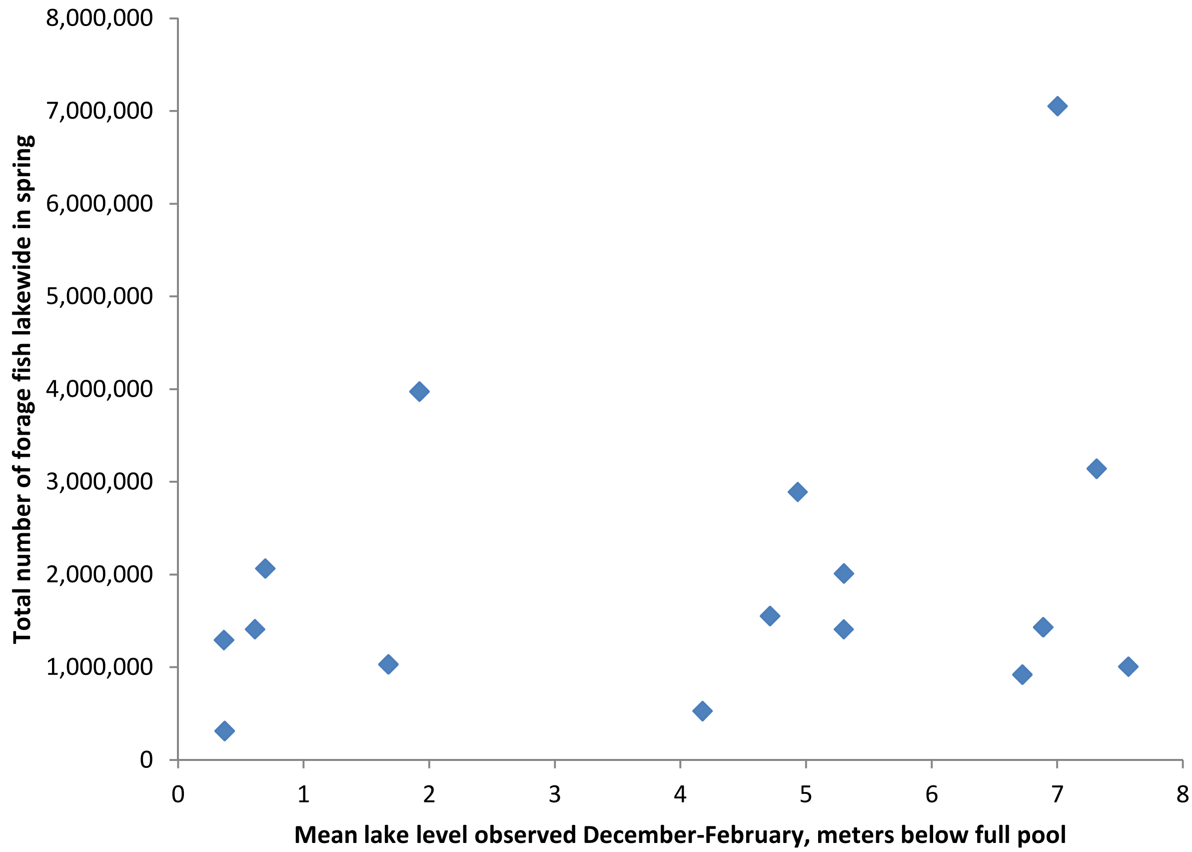


Figure 20. Total number of pelagic forage fish lakewide on Lake Jocassee in spring vs. mean December-February lake level, 1998-2013.

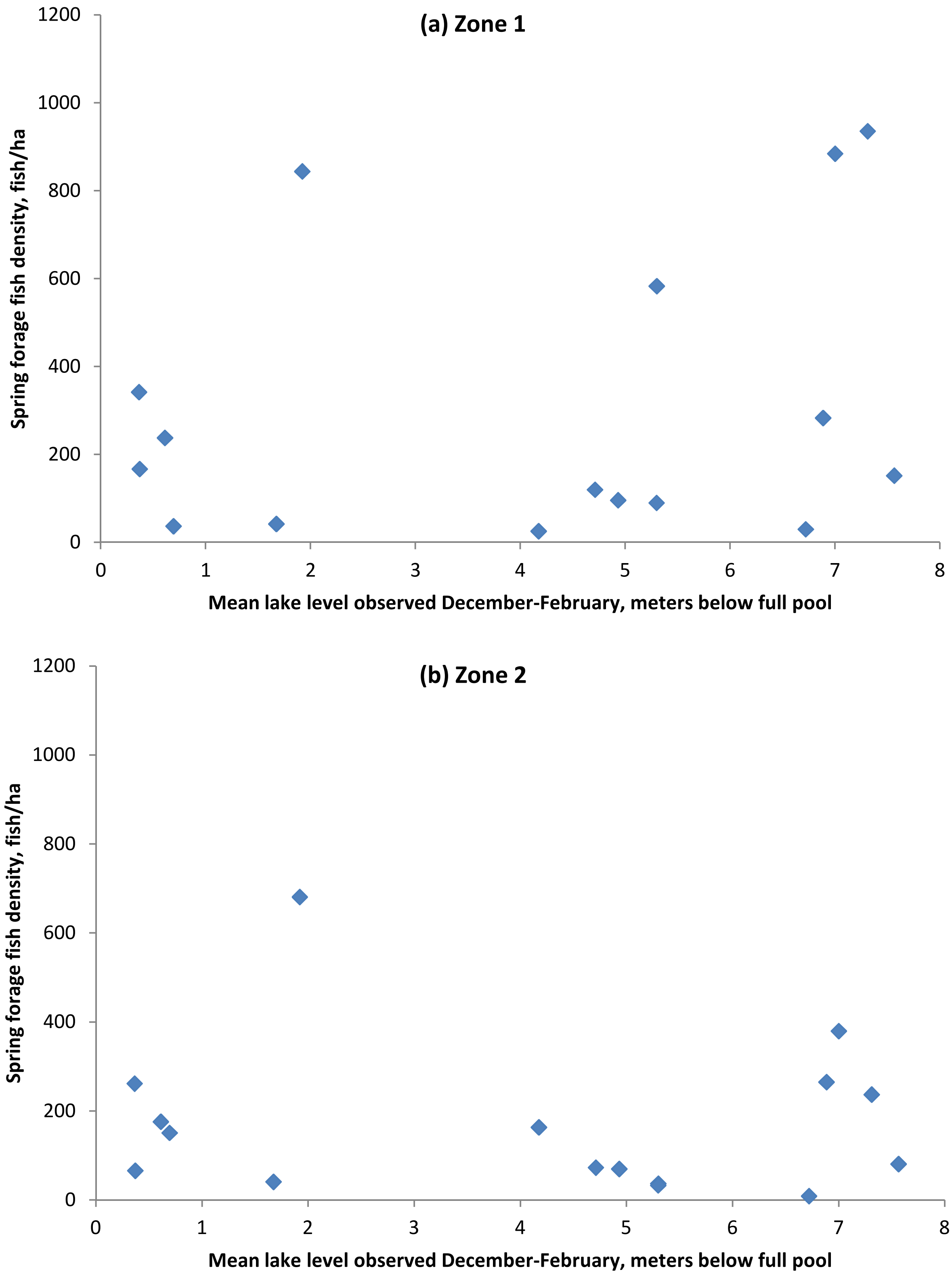
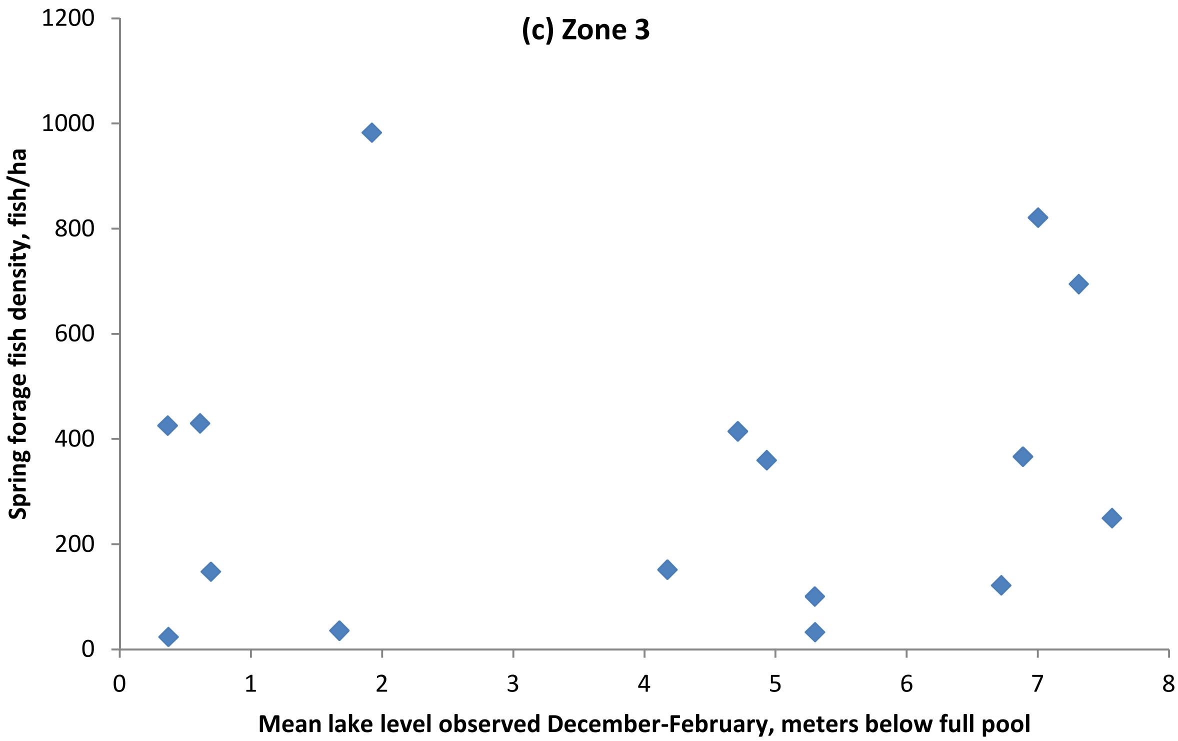


Figure 21 (page 1 of 2). Spring forage fish densities in forage fish sampling zones on Lake Jocassee vs. mean lake level observed December-February, 1998-2013. Note scale when comparing zones.



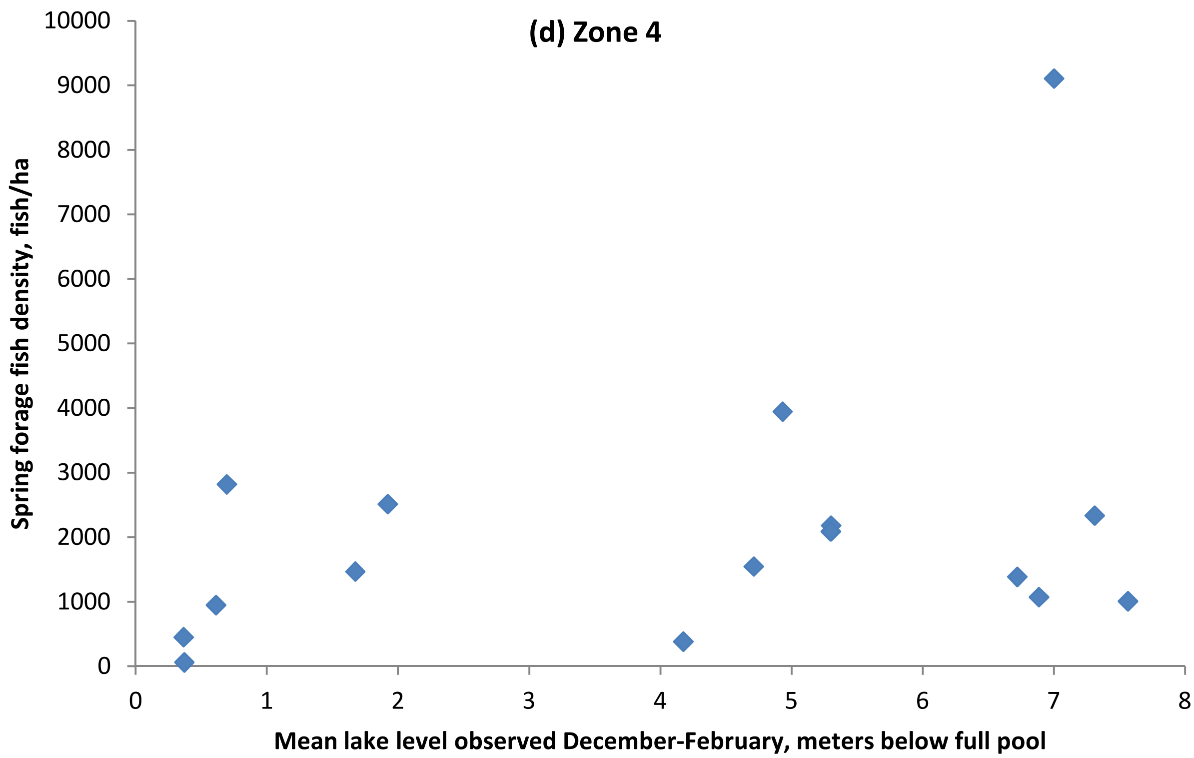


Figure 21 (page 2 of 2). Spring forage fish densities in forage fish sampling zones on Lake Jocassee vs. mean lake level observed December-February, 1998-2013. Note scale when comparing zones.

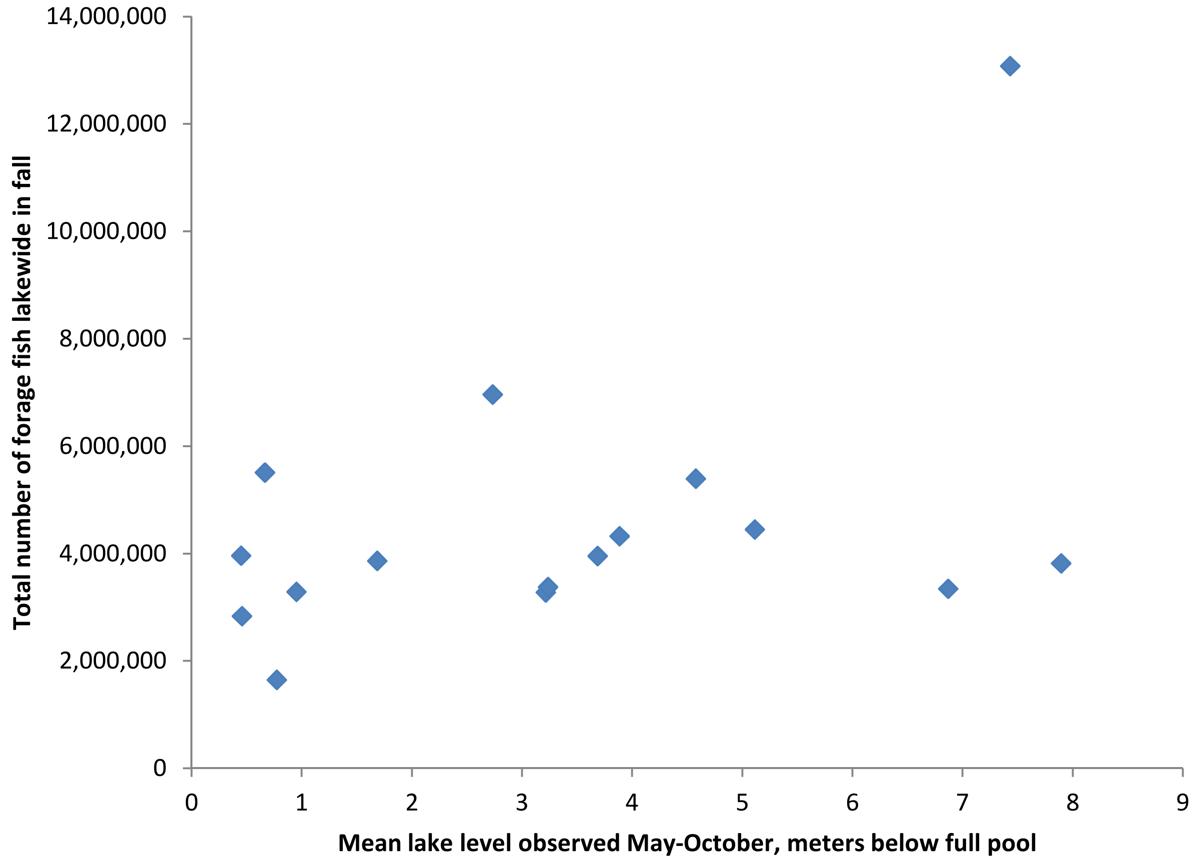


Figure 22. Total number of forage fish lakewide in fall on Lake Jocassee vs. mean Lake Jocassee lake level observed May-October, 1997-2012.

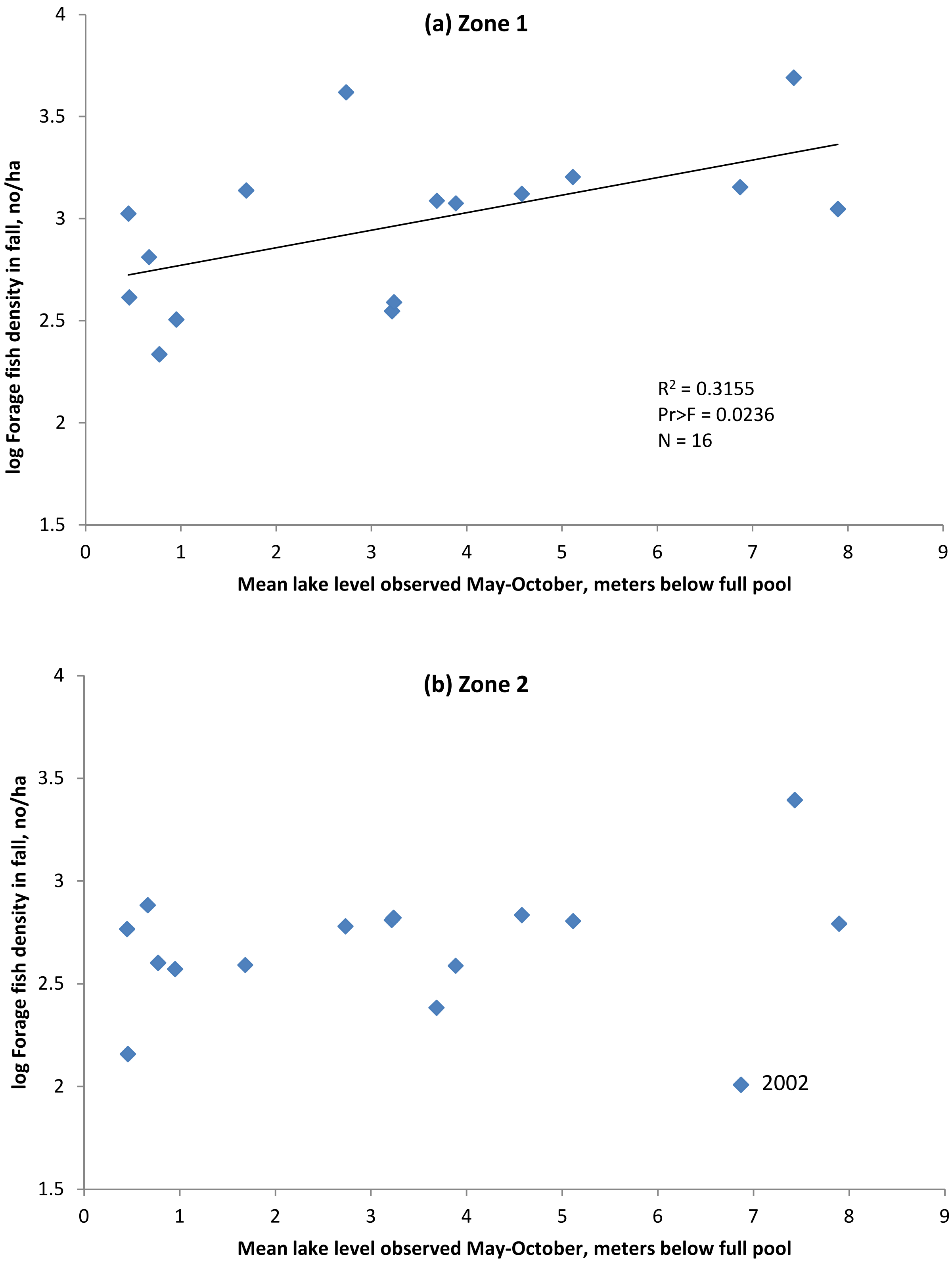
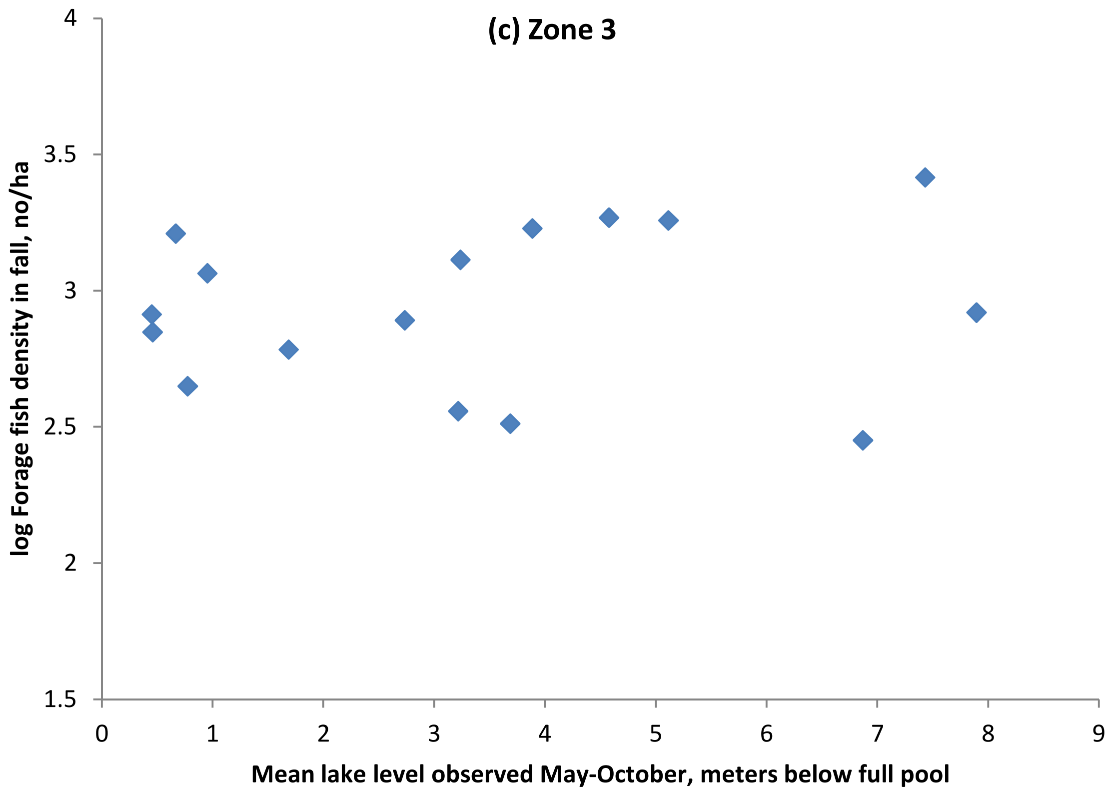


Figure 23 (page 1 of 2). log Fall forage fish density in forage fish sampling zones on Lake Jocassee vs. mean lake level observed May-October, 1997-2012.



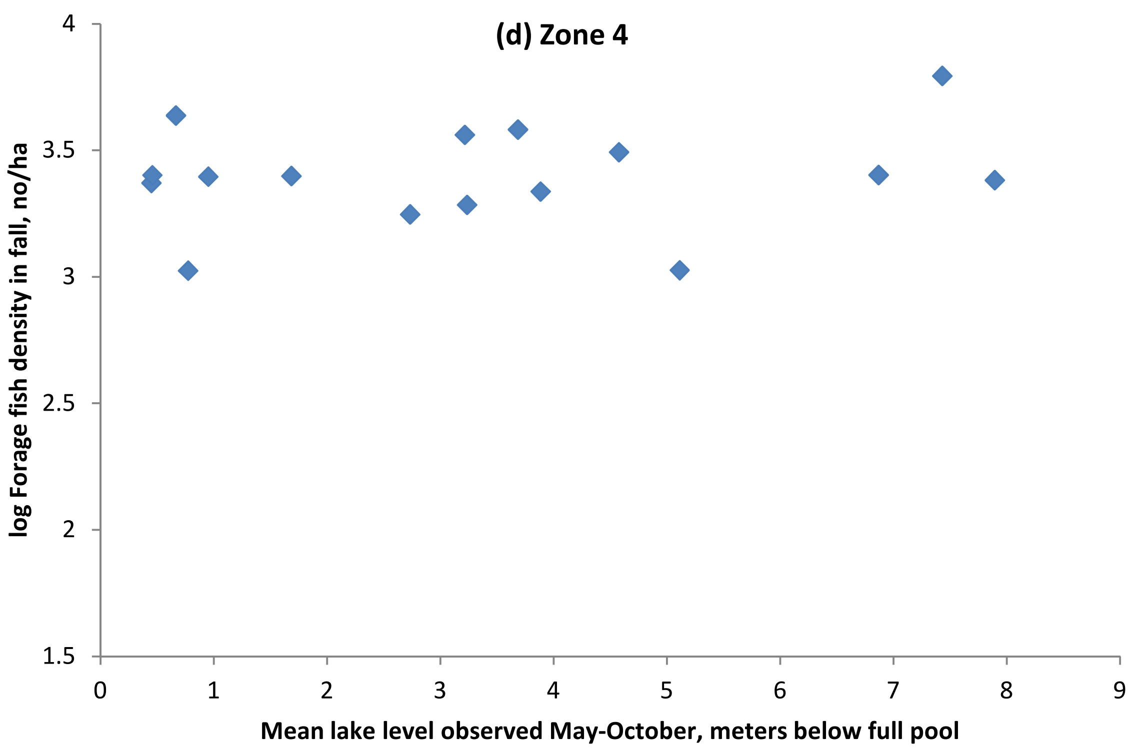


Figure 23 (page 2 of 2). log Fall forage fish density in forage fish sampling zones on Lake Jocassee vs. mean lake level observed May-October, 1997-2012.

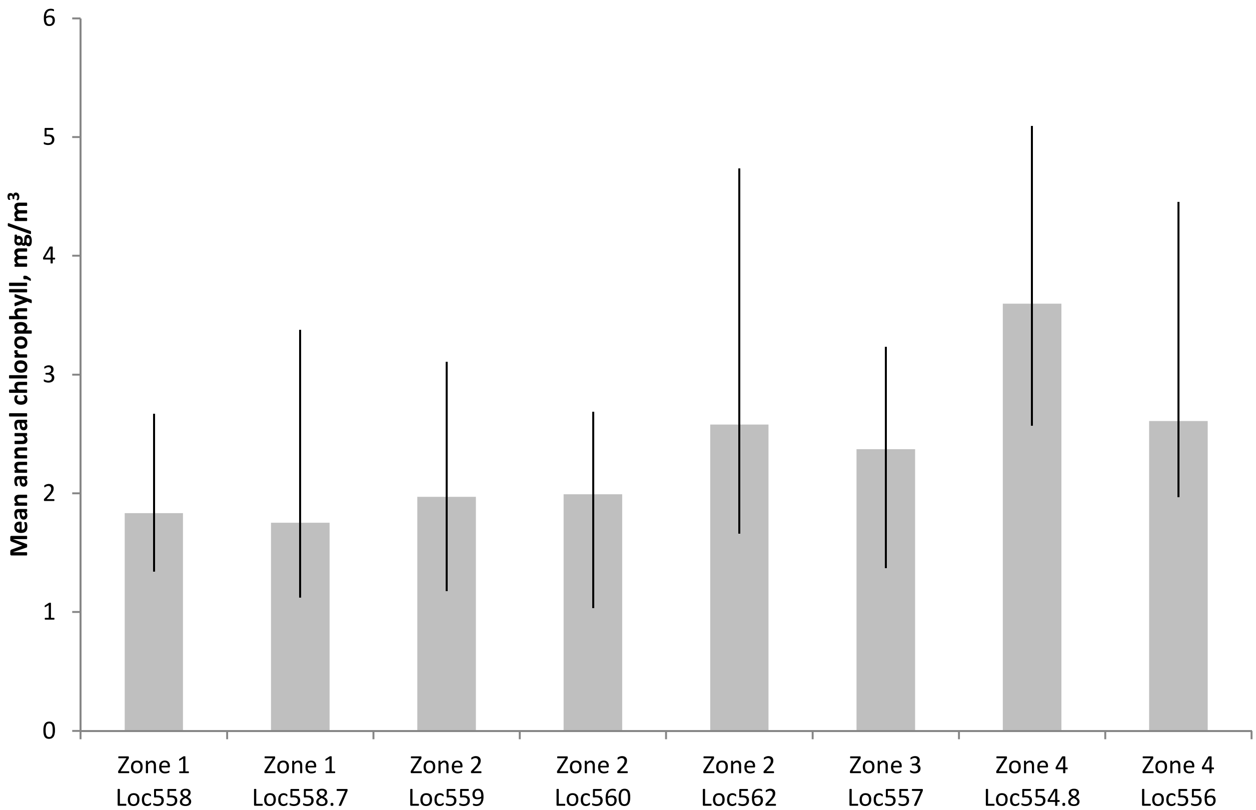


Figure 24. Mean annual chlorophyll concentration in the top ten meters of the water column at locations in forage fish sampling zones on Lake Jocassee, based on monthly data collected in 2012. Lines are bounded by minimum and maximum monthly mean concentrations for 2012.

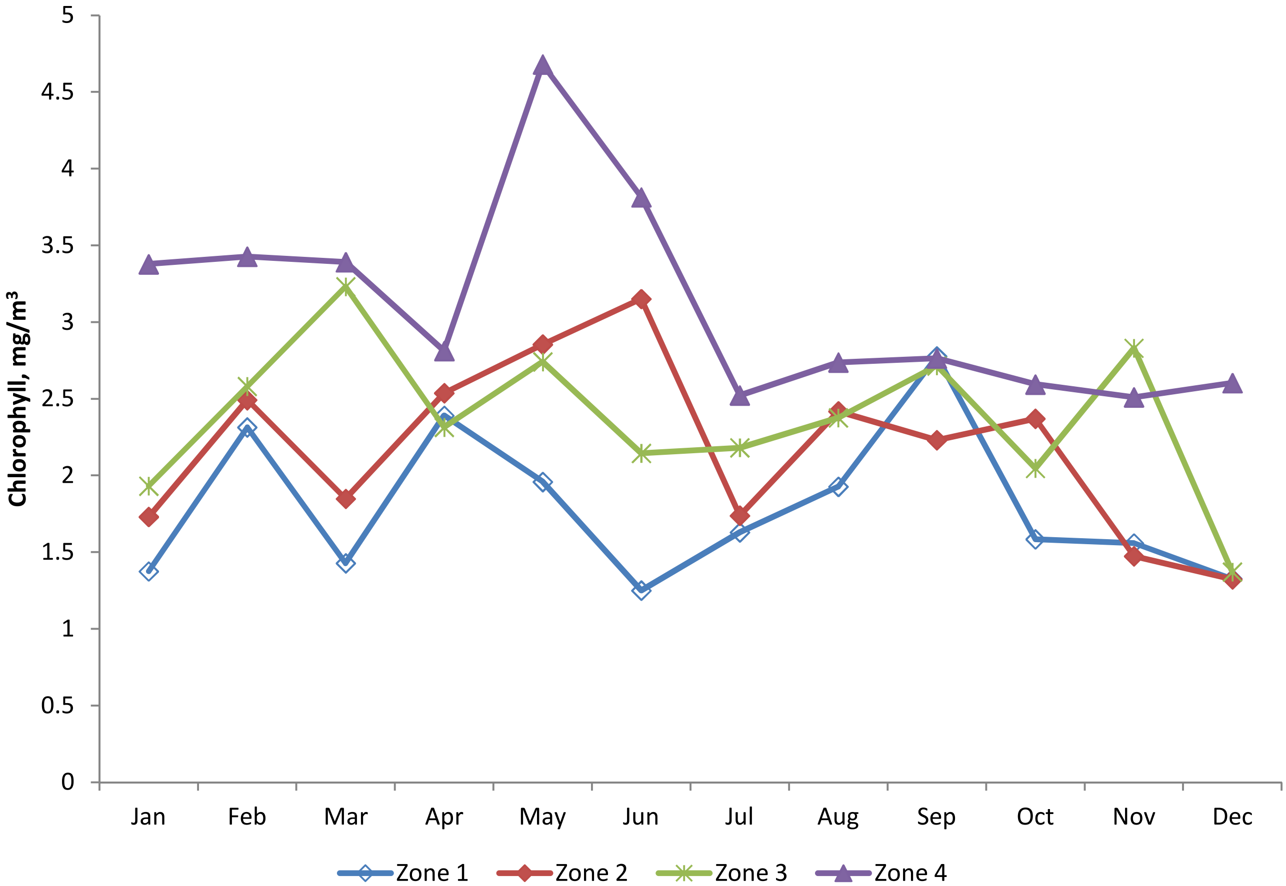


Figure 25. Seasonal variation in chlorophyll concentration in the top ten meters of the water column in forage fish sampling zones of Lake Jocassee in 2012. Zonal means are based on data collected at Locations 558 and 558.7 (Zone 1); 559, 560, and 562 (Zone 2); 557 (Zone 3); and 554.8 and 556 (Zone 4).

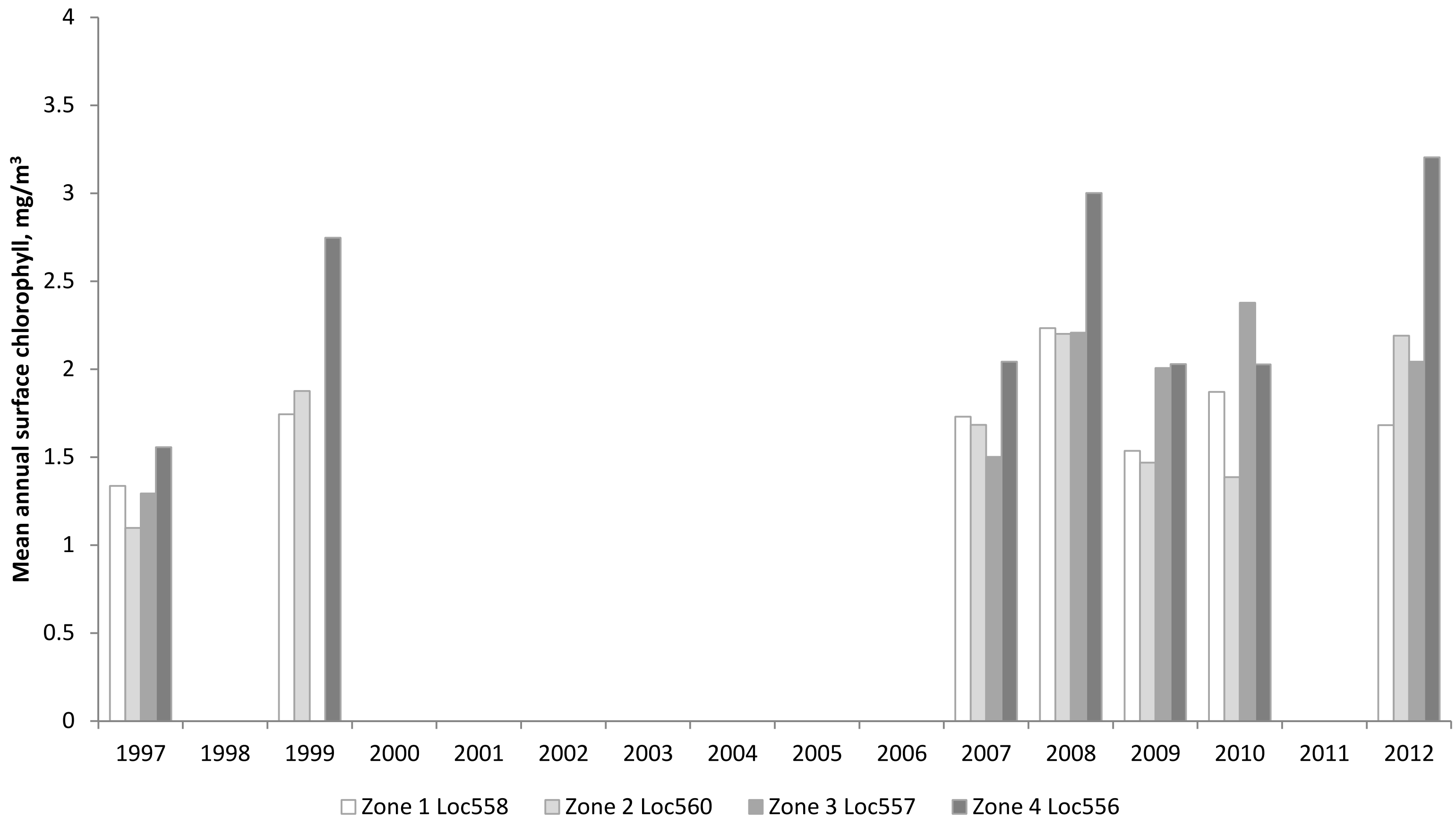


Figure 26. Long-term variation in mean annual surface (0.3 m) chlorophyll concentrations at locations in forage fish sampling zones of Lake Jocassee, based on data collected quarterly in 1997, 1999, 2007-2010, and 2012. No data were collected in Zone 3 in 1999.

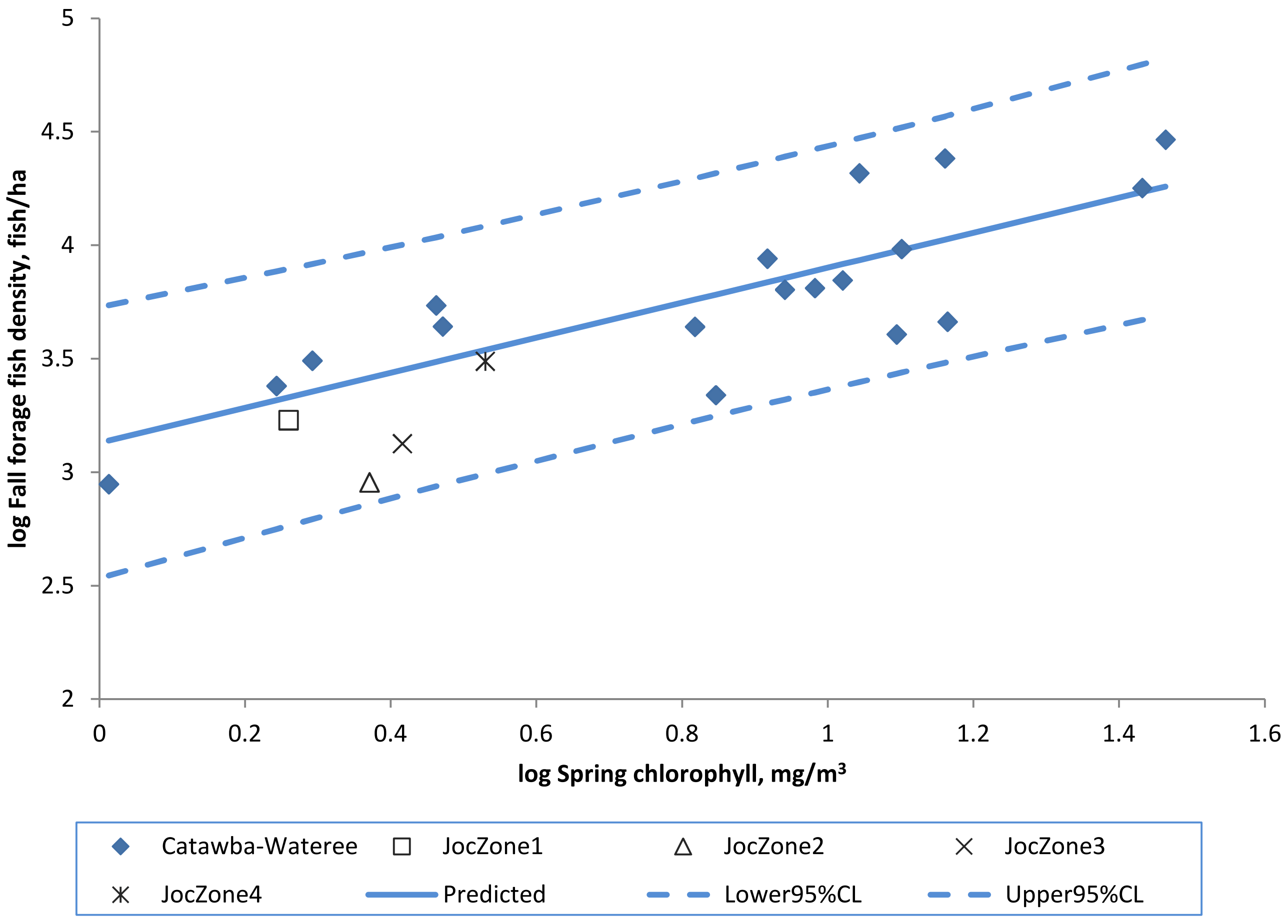


Figure 27. Mean fall forage fish densities in forage fish sampling zones on Lake Jocassee vs. zonal surface (0.3 m) chlorophyll concentrations measured in May, superimposed on plot of regression relating fall forage fish densities to mean spring chlorophyll concentrations (mean of chlorophyll concentrations measured in April and May in top five meters of water column). Means for Lake Jocassee data were calculated based on data collected 1997, 2007-2010, and 2012. Regression was developed based on data from 18 sites on nine reservoirs of the Catawba-Wateree Hydroelectric Project in North and South Carolina (Rodriguez 2005). Regression equation: $\log_{10}$ fall forage fish density (fish/ha) = 3.1303 + 0.7705 $\log_{10}$ spring chlorophyll concentration (mg/m^3) (R2=0.6339; Pr>F<0.0001; N=18).

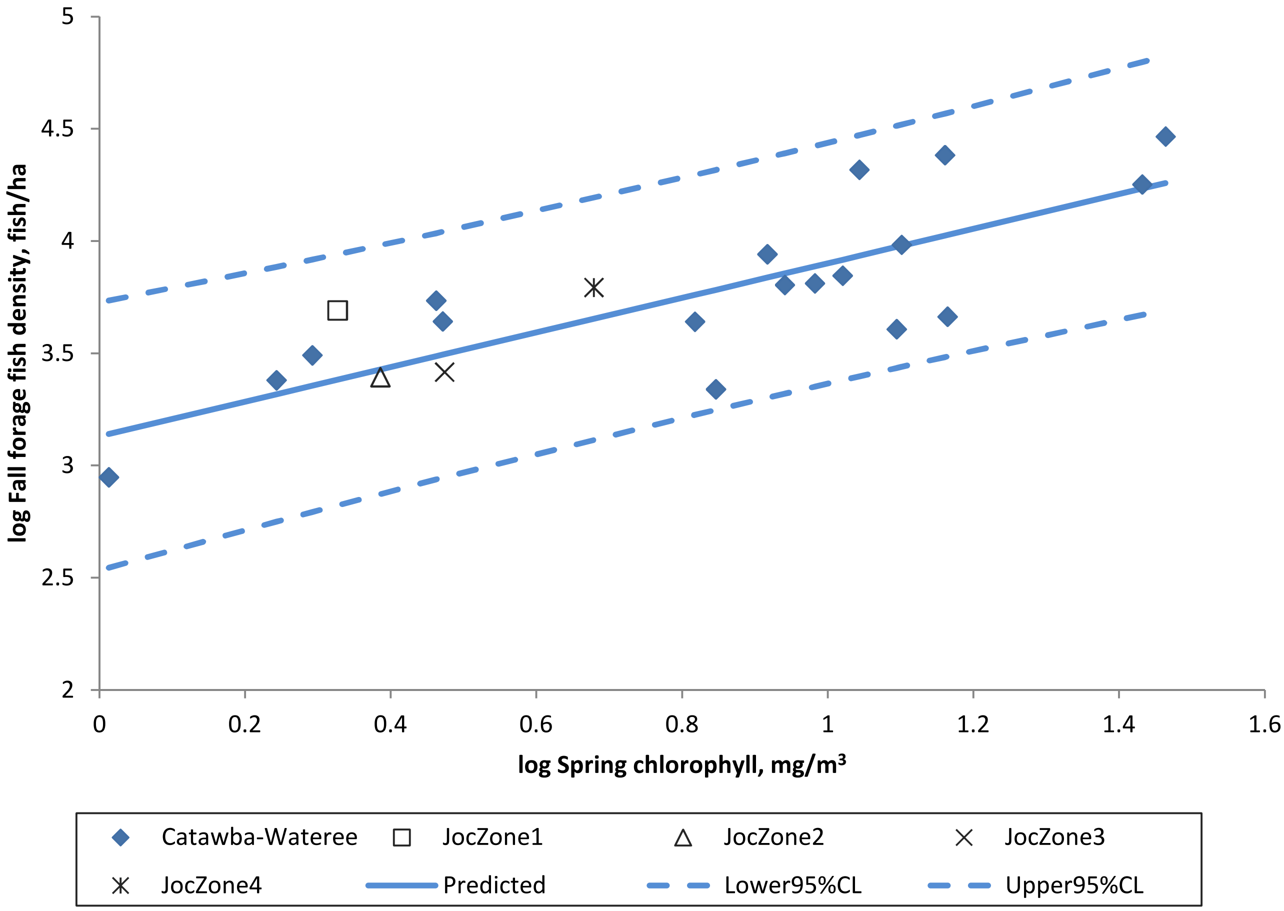


Figure 28. Fall forage fish densities in forage fish sampling zones on Lake Jocassee vs. spring zonal chlorophyll concentrations (mean of chlorophyll concentrations measured in April and May at depths of 0.3 and 5 m), as measured in 2012, superimposed on plot of regression relating fall forage fish densities to mean spring chlorophyll concentrations (mean of chlorophyll concentrations measured in April and May in top five meters of water column). Regression was developed based on data from 18 sites on nine reservoirs of the Catawba-Wateree Hydroelectric Project in North and South Carolina (Rodriguez 2005). Regression equation: $\log_{10}$ fall forage fish density (fish/ha) = 3.1303 + 0.7705 $\log_{10}$ spring chlorophyll concentration (mg/m^3) (R2=0.6339; Pr>F<0.0001; N=18).

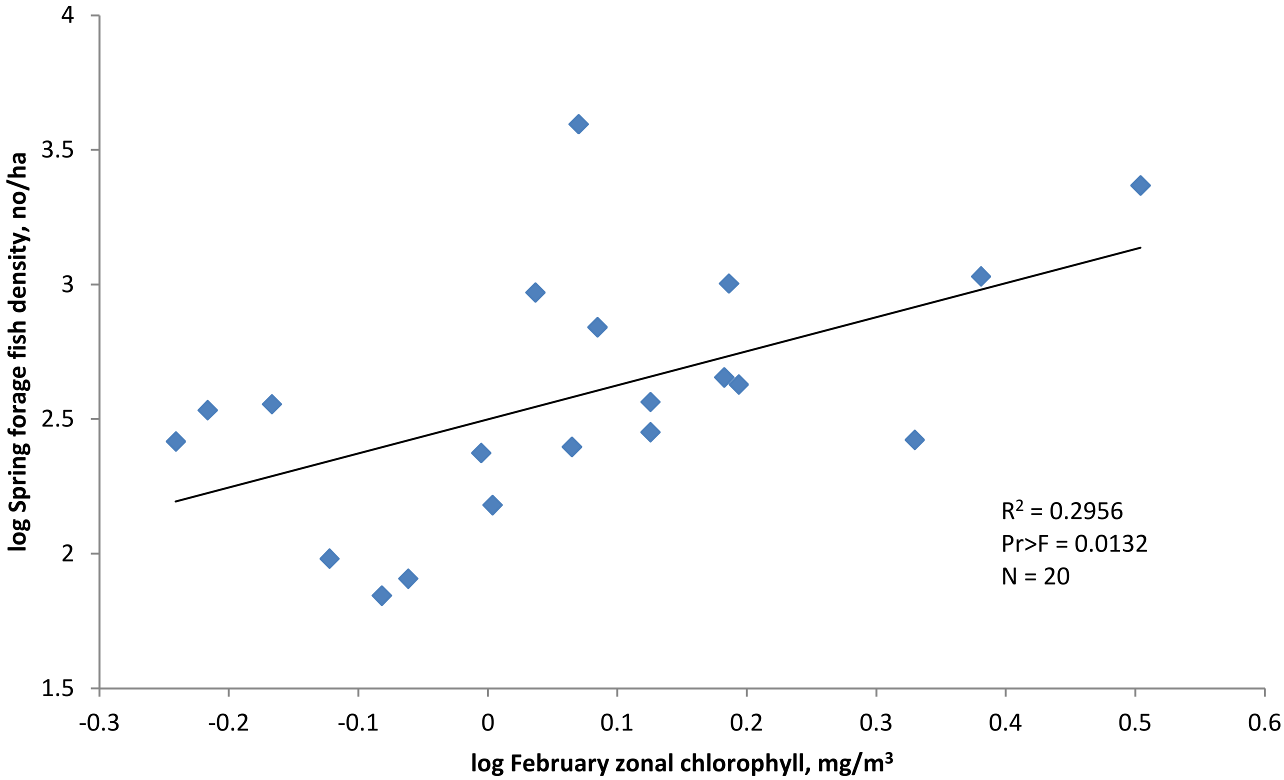


Figure 29. Spring forage fish densities in forage fish sampling zones of Lake Jocassee vs. surface (0.3 m) chlorophyll concentrations observed in February, 2007-2010 and 2012.

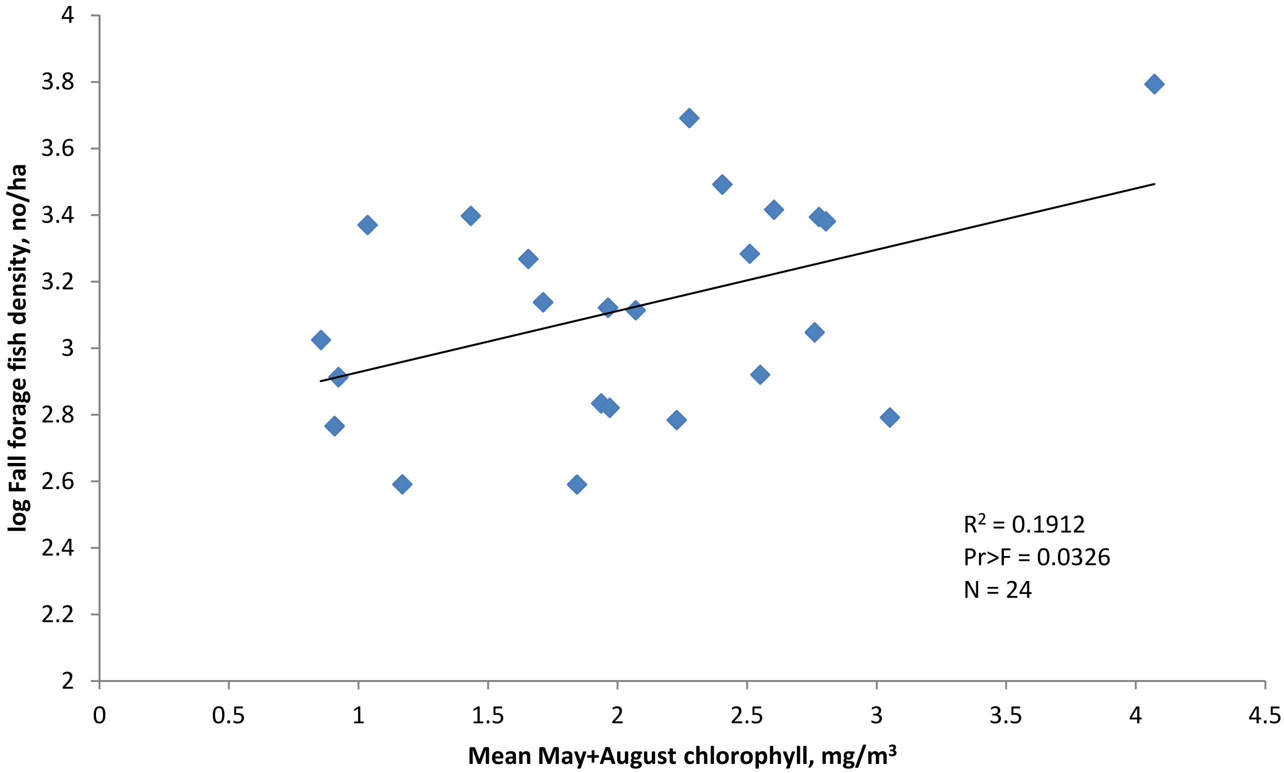


Figure 30. Fall forage fish densities in forage fish sampling zones of Lake Jocassee vs. mean of May and August zonal surface (0.3 m) chlorophyll concentrations, 1997, 2007-2010, and 2012.

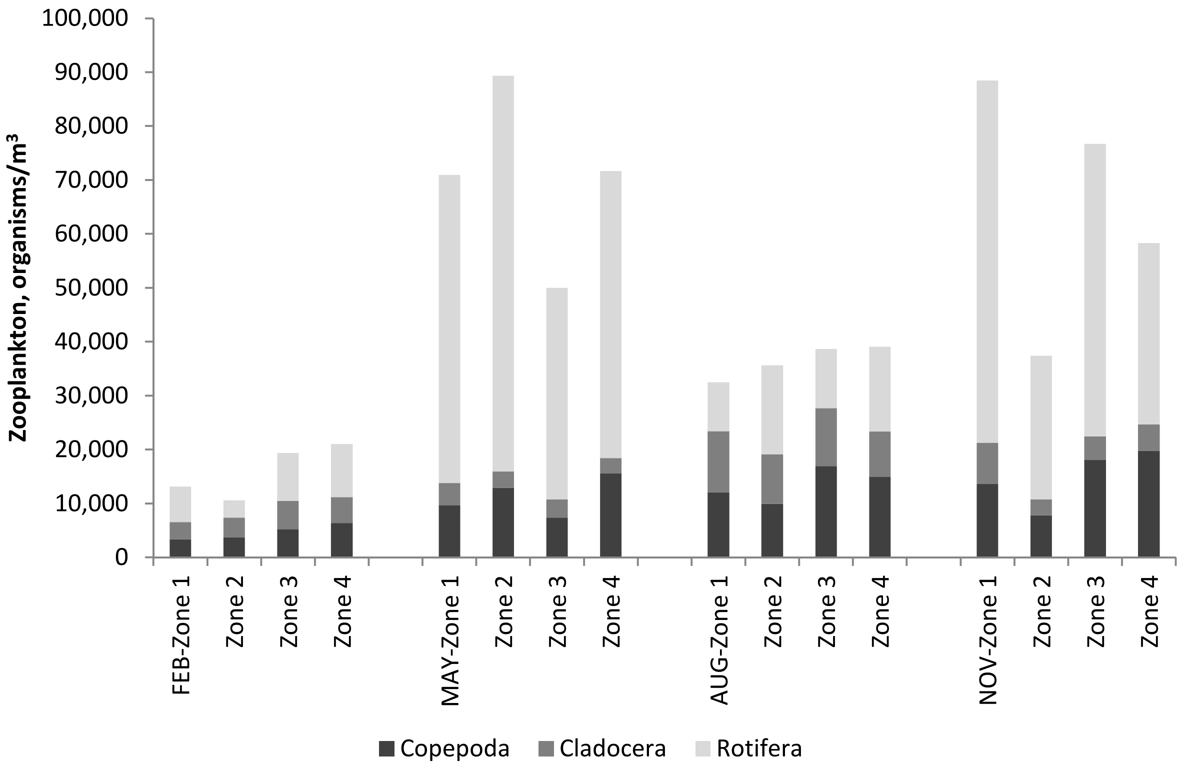


Figure 31. Seasonal variation in zooplankton abundance and community composition on Lake Jocassee, based on 20m-to-surface net tows carried out in February, May, August, and November 2012.

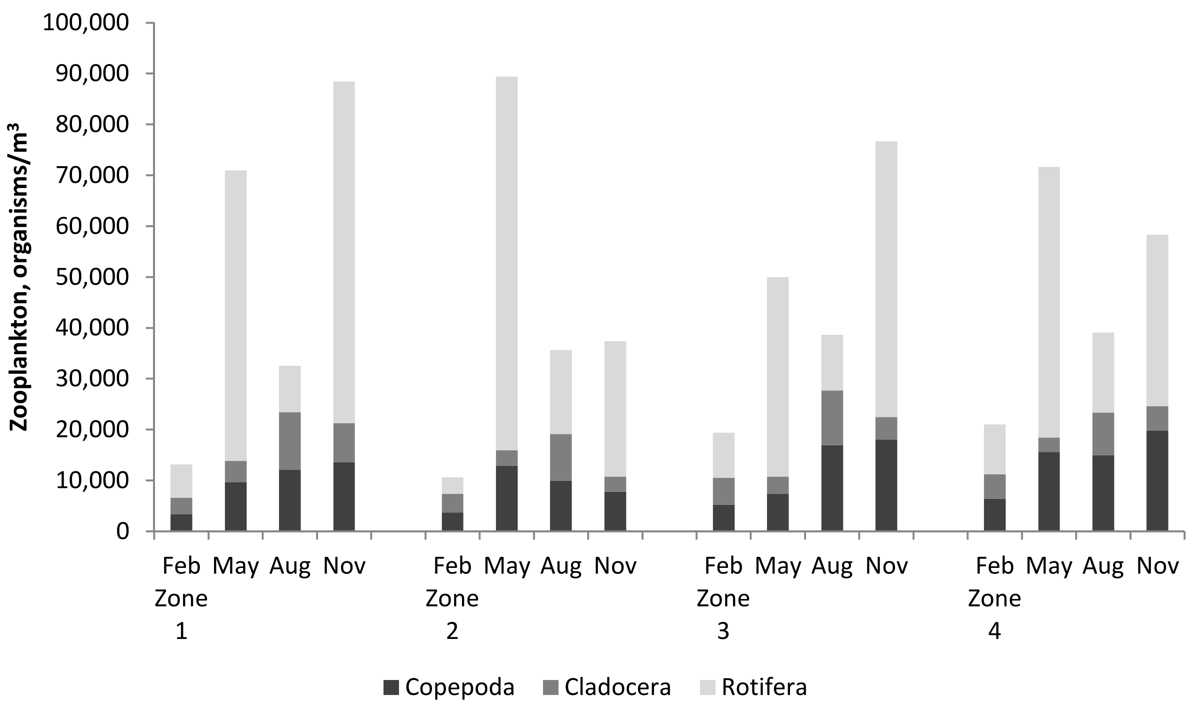


Figure 32. Spatial variation in zooplankton abundance and community composition on Lake Jocassee, based on 20m-to-surface net tows carried out in Zones 1, 2, 3, and 4 in 2012.

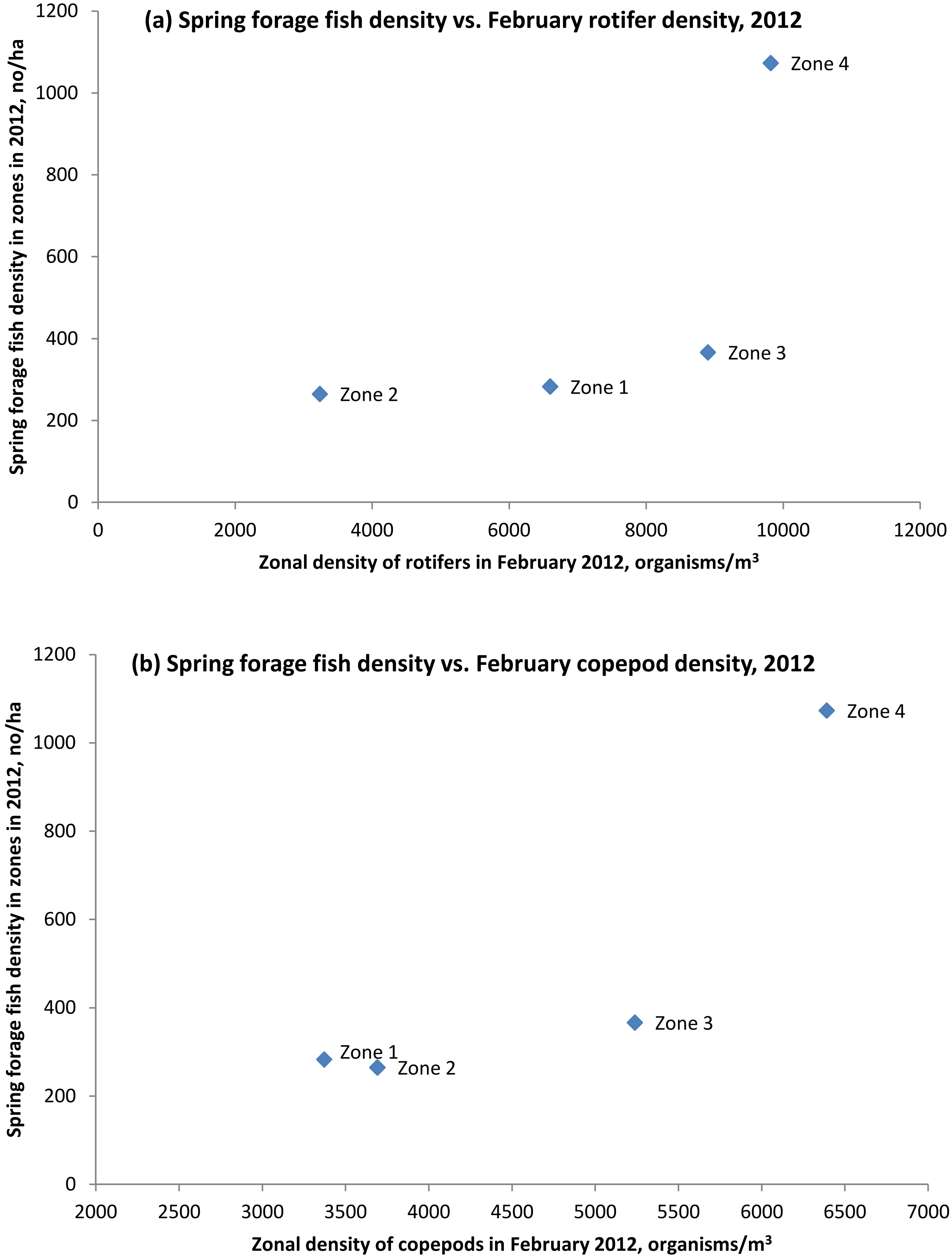


Figure 33. Spring forage fish density in zones on Lake Jocassee in 2012, vs. zonal density of (a) rotifers and (b) copepods measured in February 2012.

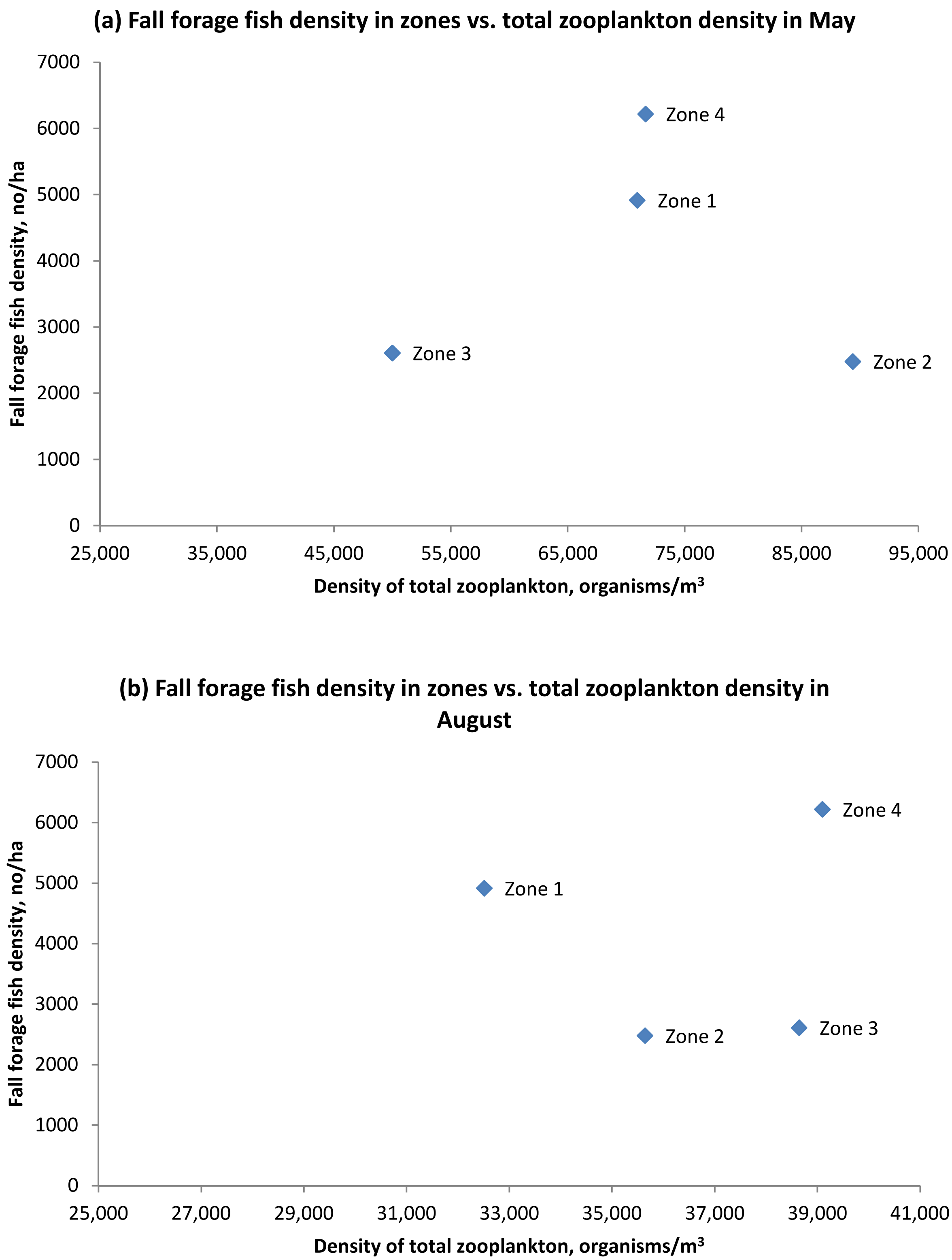
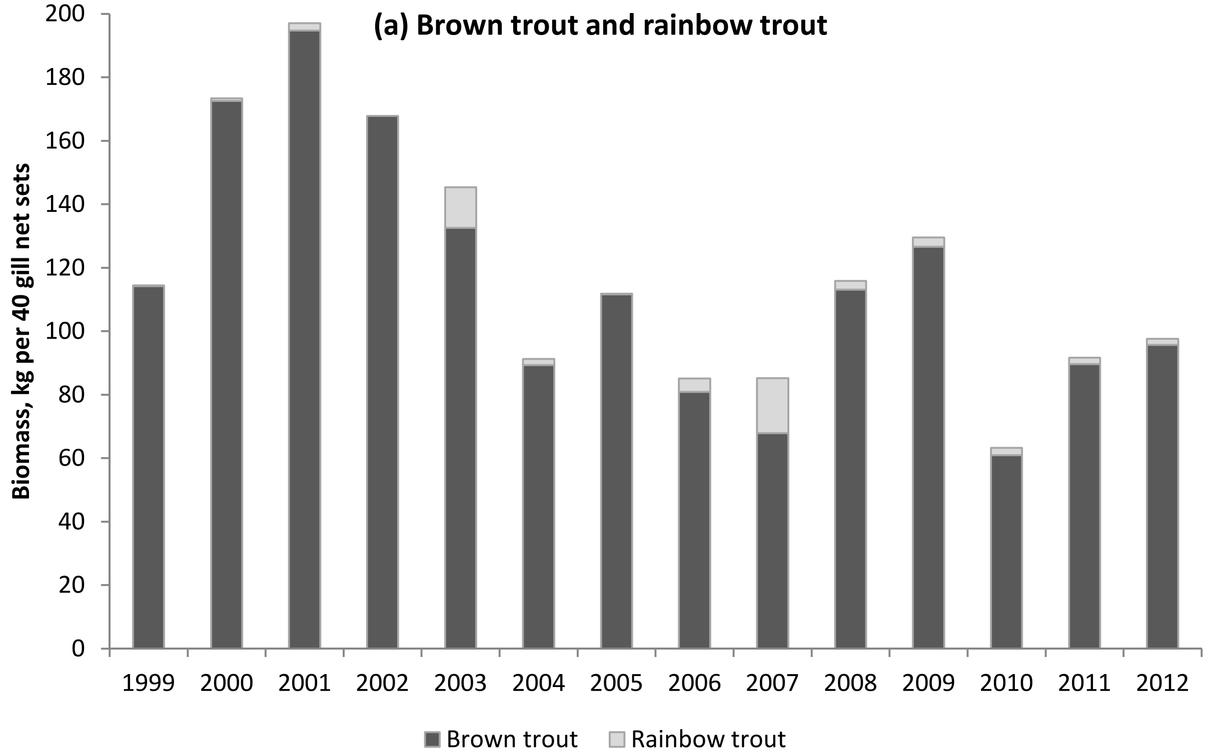


Figure 34. Fall forage fish densities in zones of Lake Jocassee vs. total zooplankton densities in (a) May and (b) August, based on data collected in 20 m-to-surface net tows in 2012.



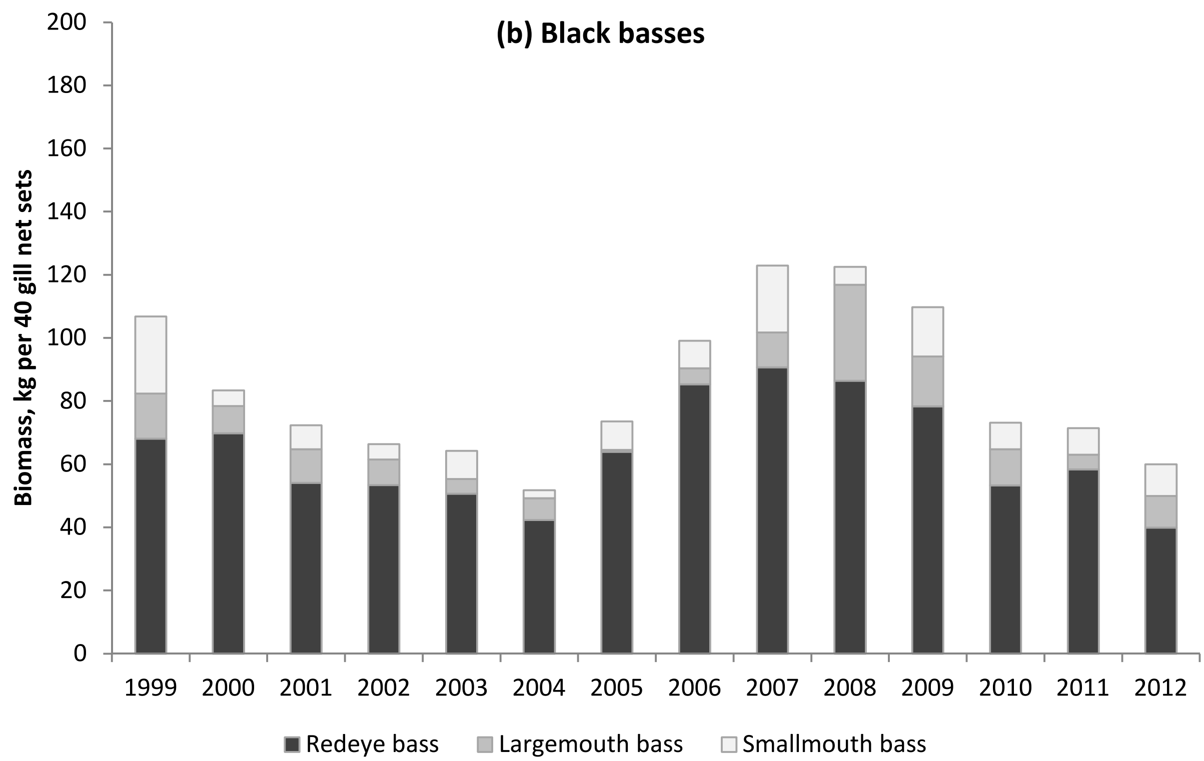


Figure 35. Biomass of (a) brown and rainbow trout and (b) black basses in gill net sampling on Lake Jocassee, 1999-2012. Data courtesy of Rankin (2013).

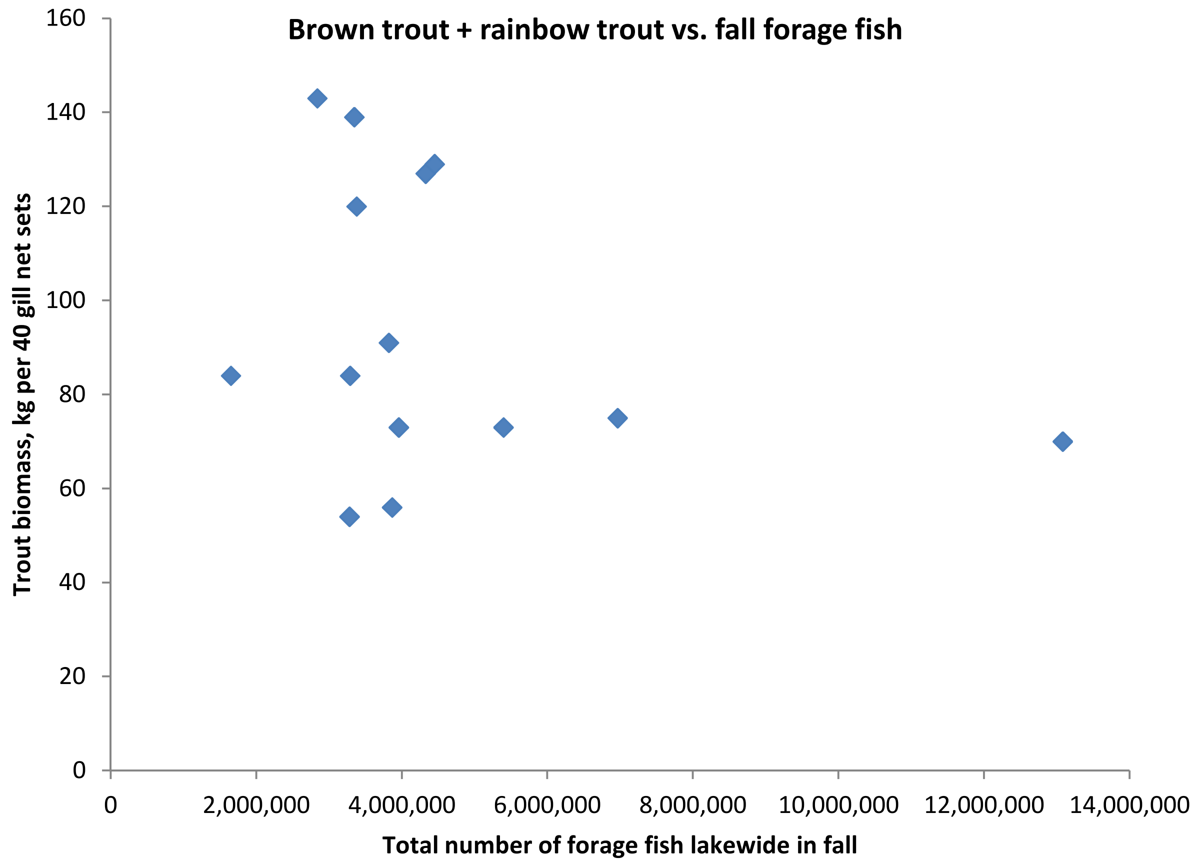
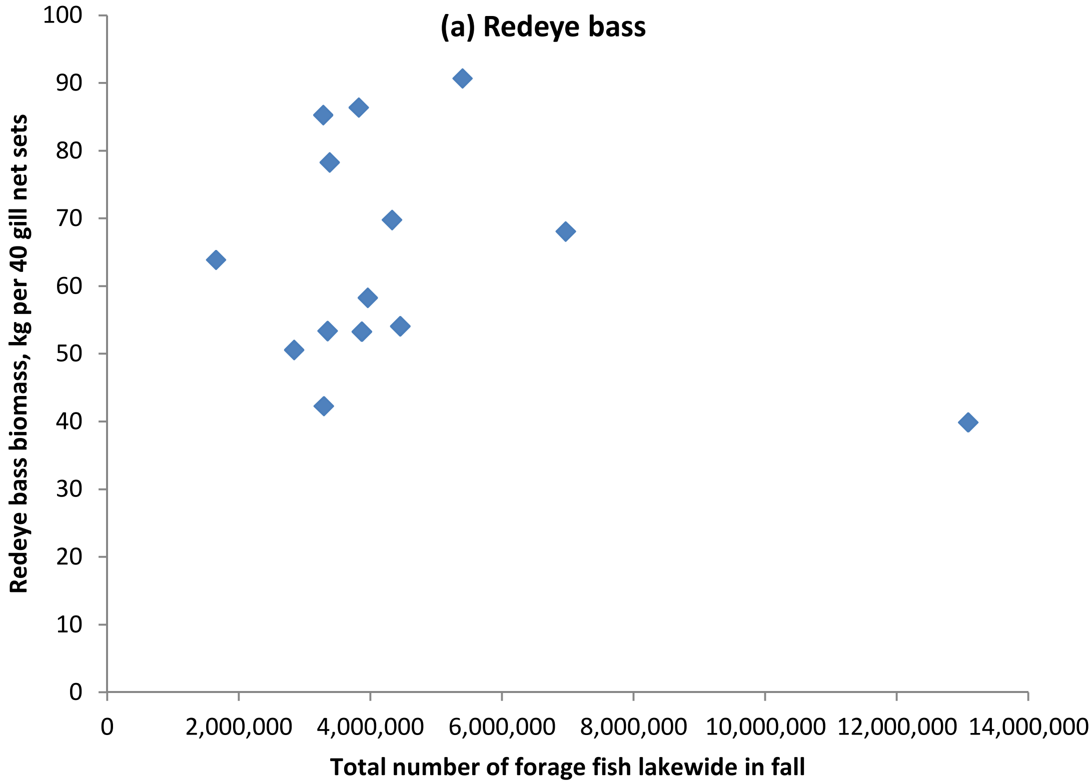


Figure 36. Biomass of brown trout plus rainbow trout in gill net sampling vs. total number of forage fish lakewide in fall, 1999-2012.



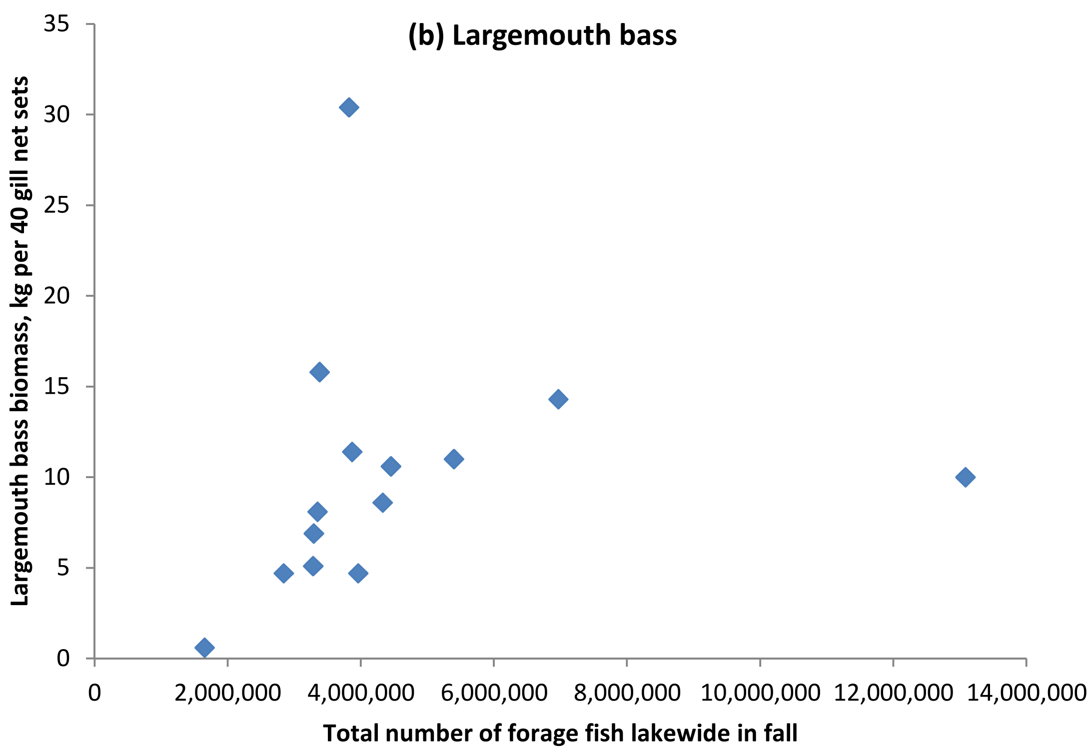


Figure 37. Biomass of (a) redeye bass and (b) largemouth bass in gill net sampling vs. total number of forage fish lakewide in fall, 1999-2012.

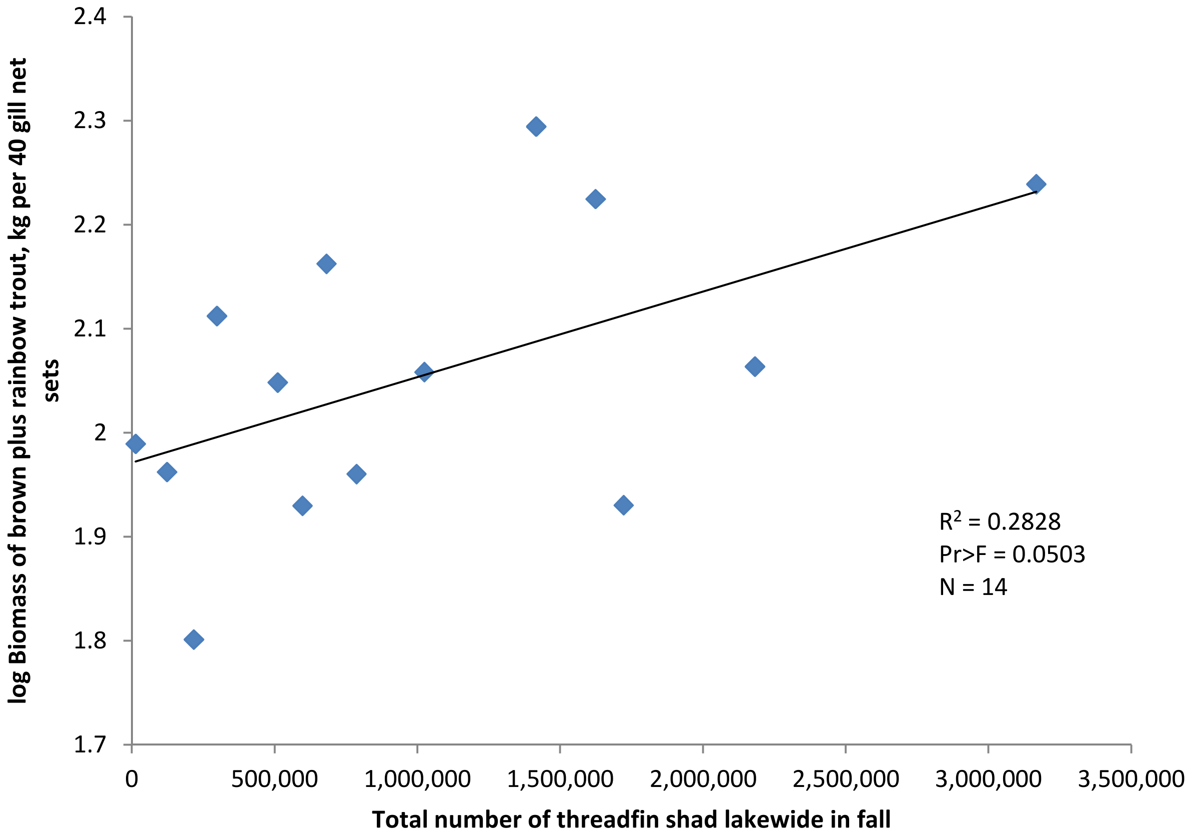


Figure 38. log Biomass of brown trout plus rainbow trout in gill net sampling vs. total number of threadfin shad lakewide in fall, 1999-2012.

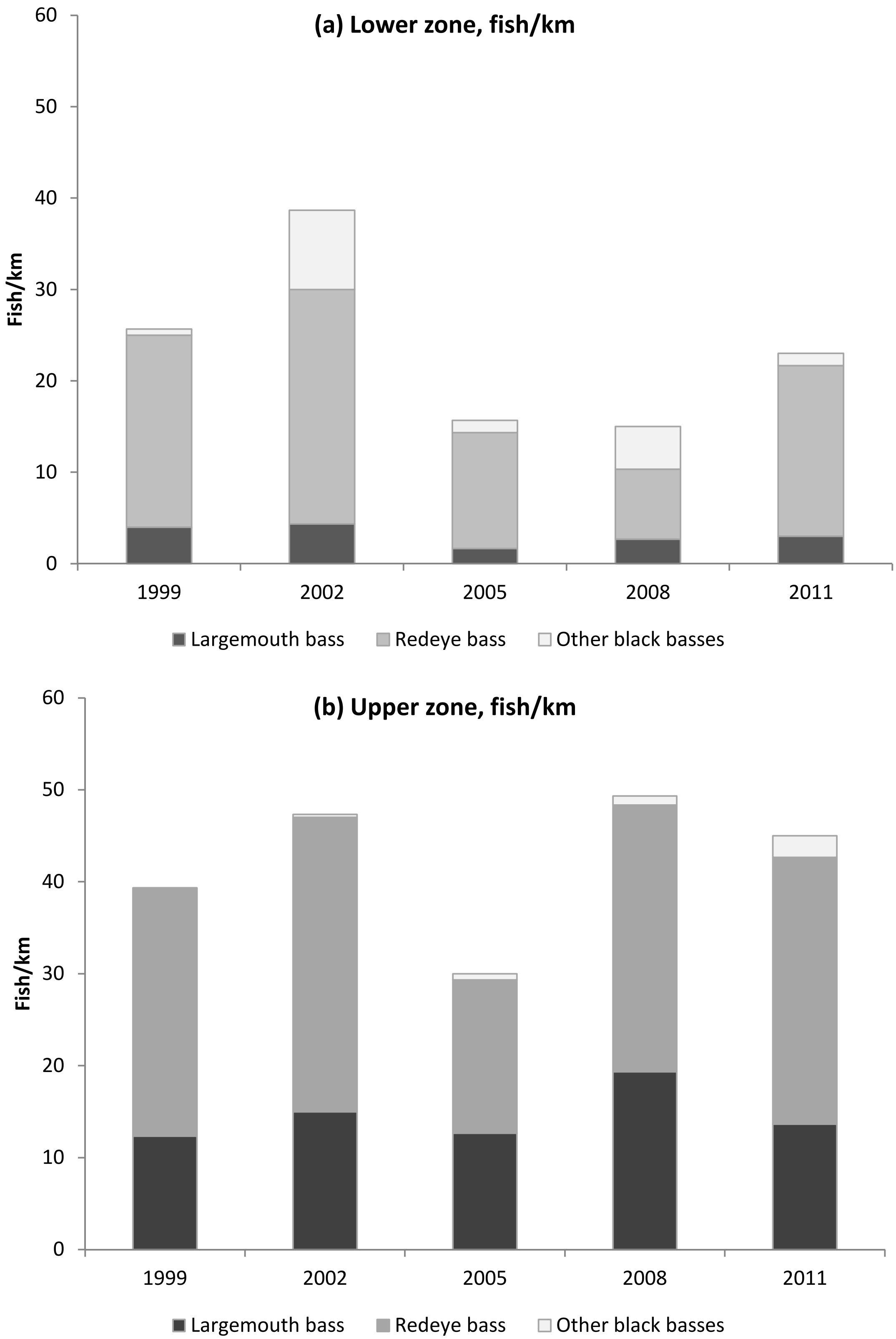


Figure 39. Littoral density (fish/km) of black basses based on electrofishing carried out in 1999, 2002, 2005, 2008, and 2011 on Lake Jocassee, in the (a) Lower and (b) Upper electrofishing zones.

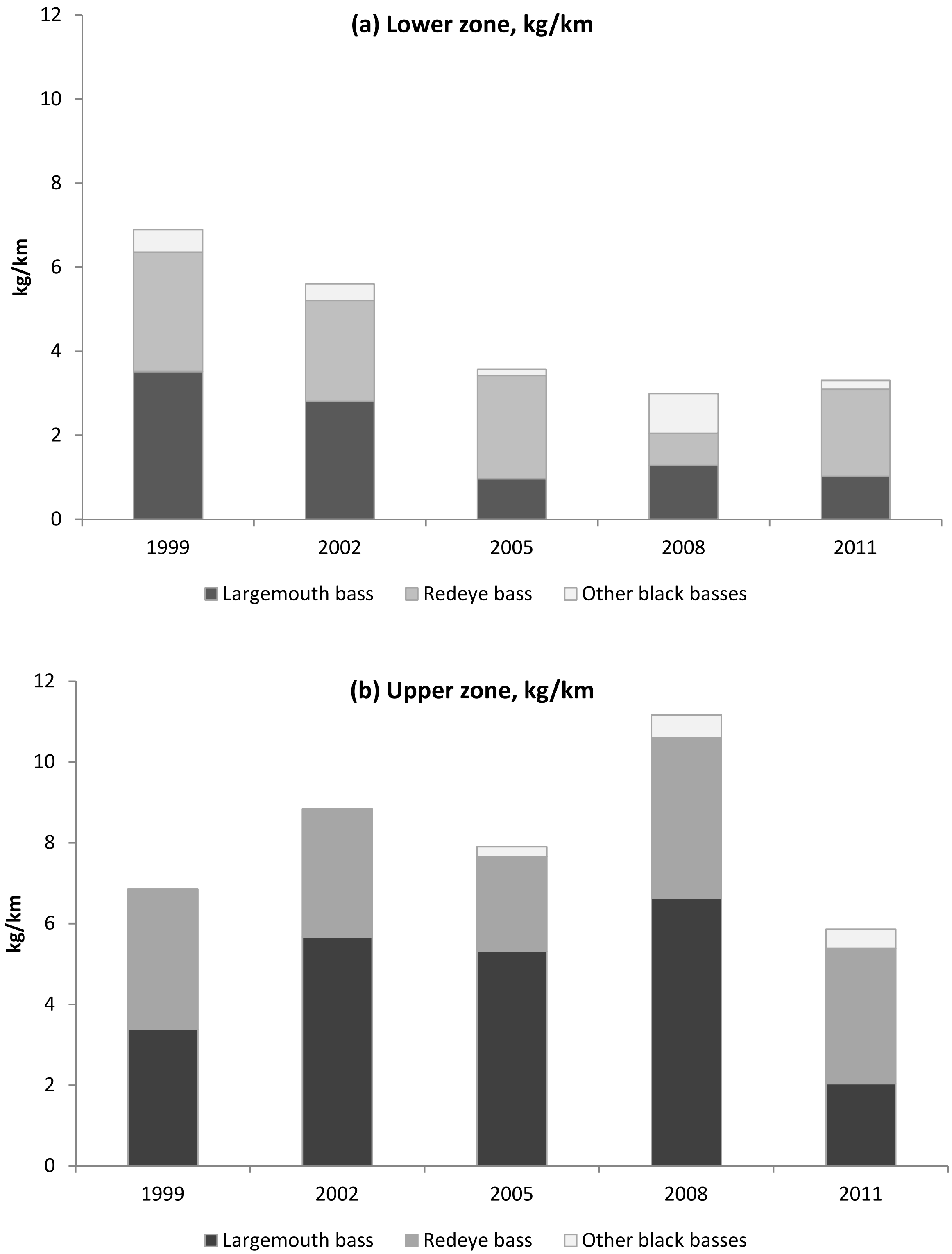


Figure 40. Littoral biomass (kg/km) of black basses based on electrofishing carried out in 1999, 2002, 2005, 2008, and 2011 on Lake Jocassee, in the (a) Lower and (b) Upper electrofishing zones.

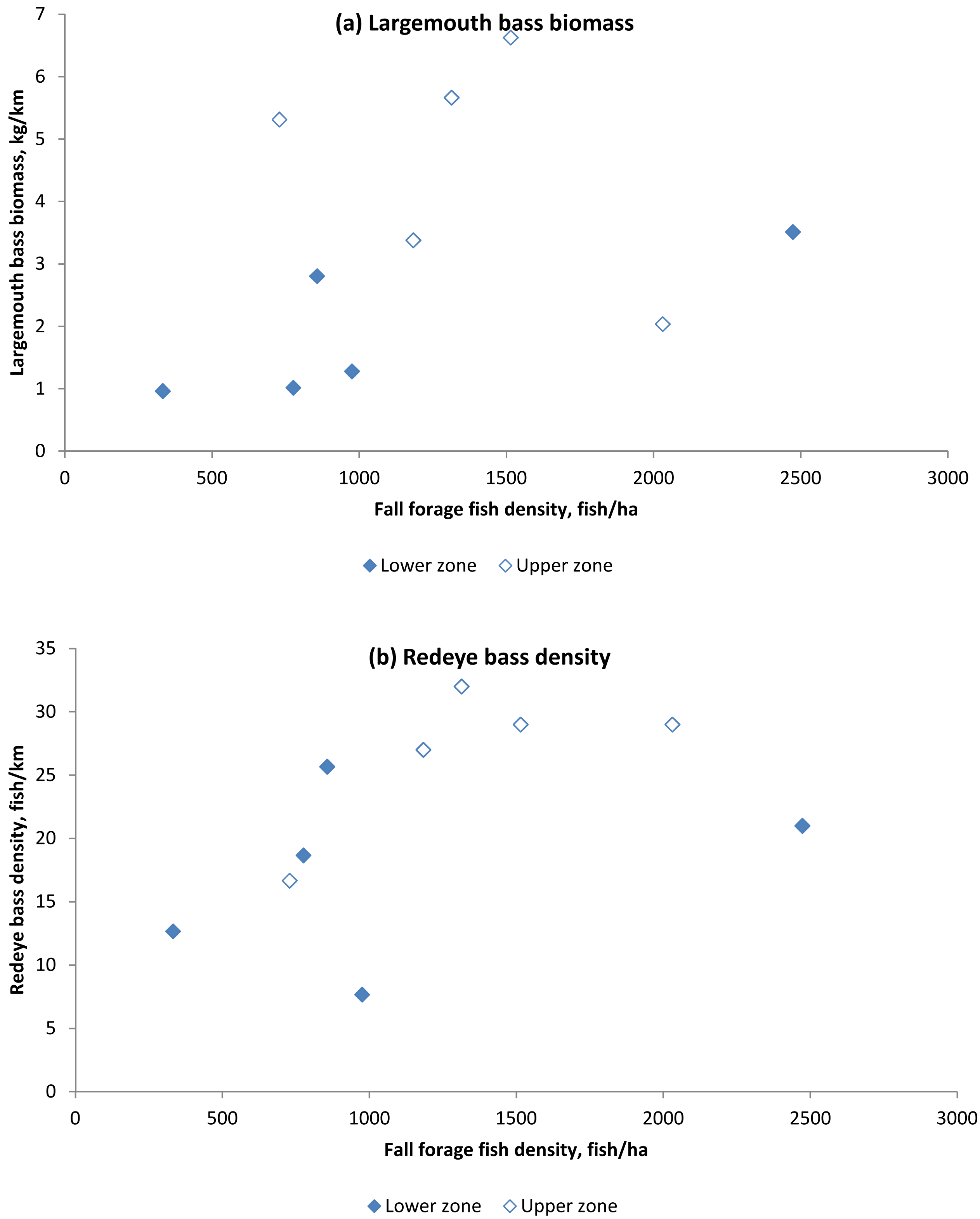


Figure 41. (a) Largemouth bass biomass and (b) redeye bass density from electrofishing carried out in 1999, 2002, 2005, 2008, and 2011 on Lake Jocassee vs. fall forage fish density from hydroacoustics sampling, for the Lower and Upper electrofishing zones.

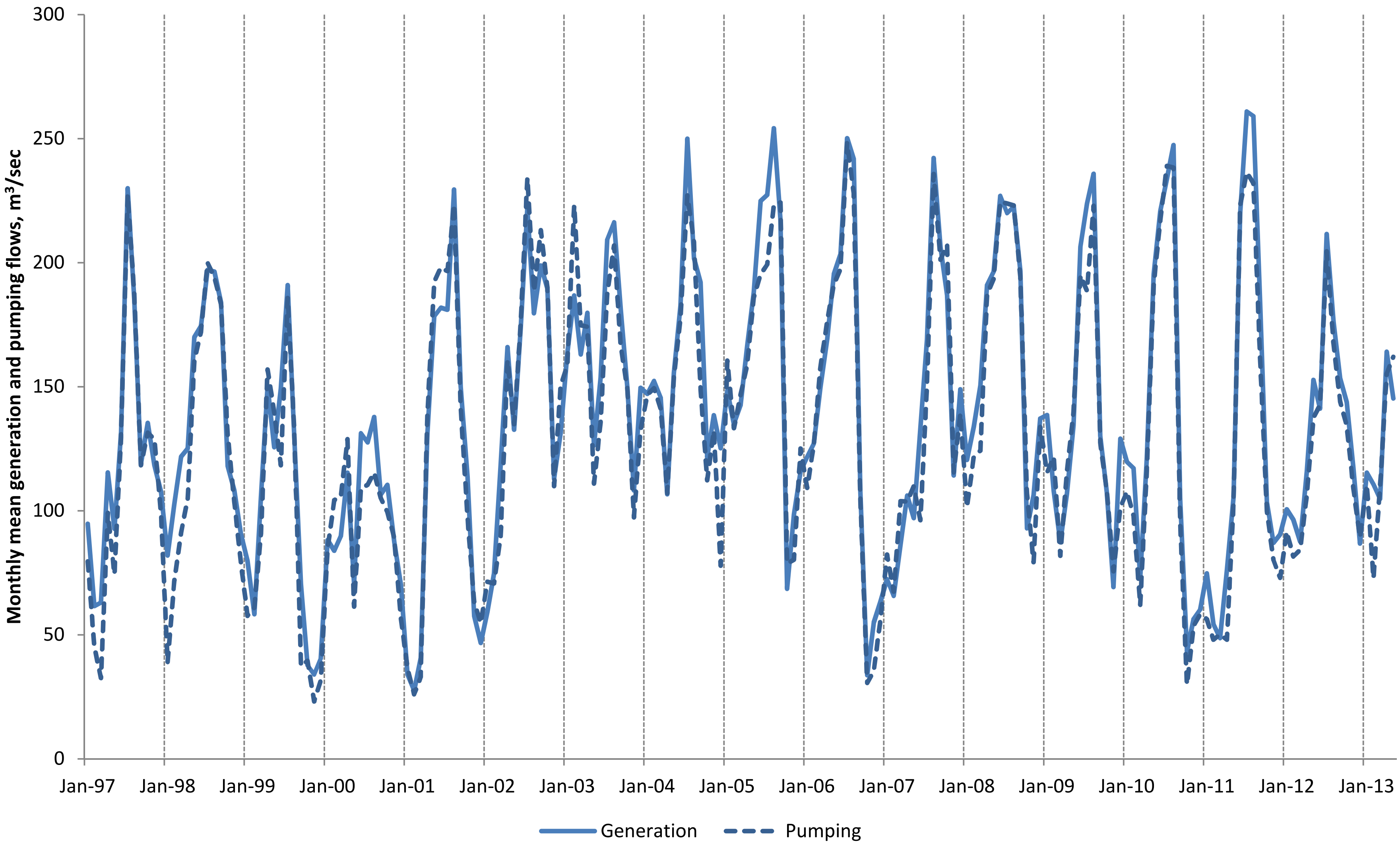


Figure 42. Monthly mean generation and pumping flows at Jocassee Pumped Storage Station, January 1997 through May 2013.

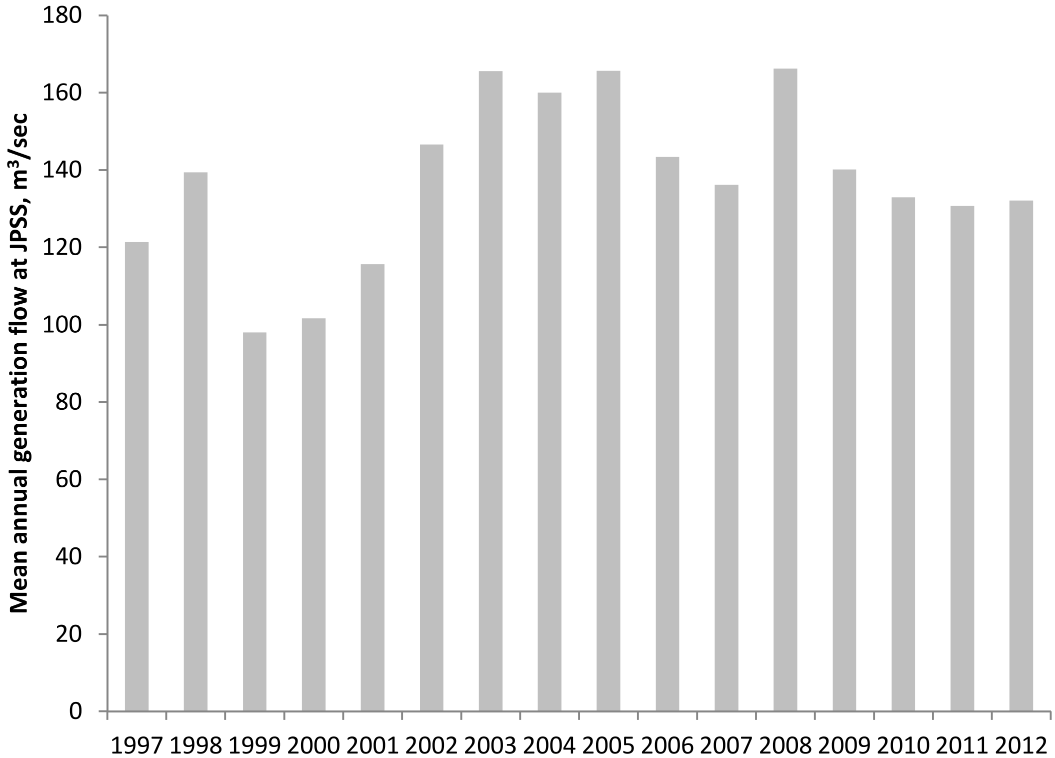


Figure 43. Mean annual generation flow at Jocassee Pumped Storage Station, 1997-2012.

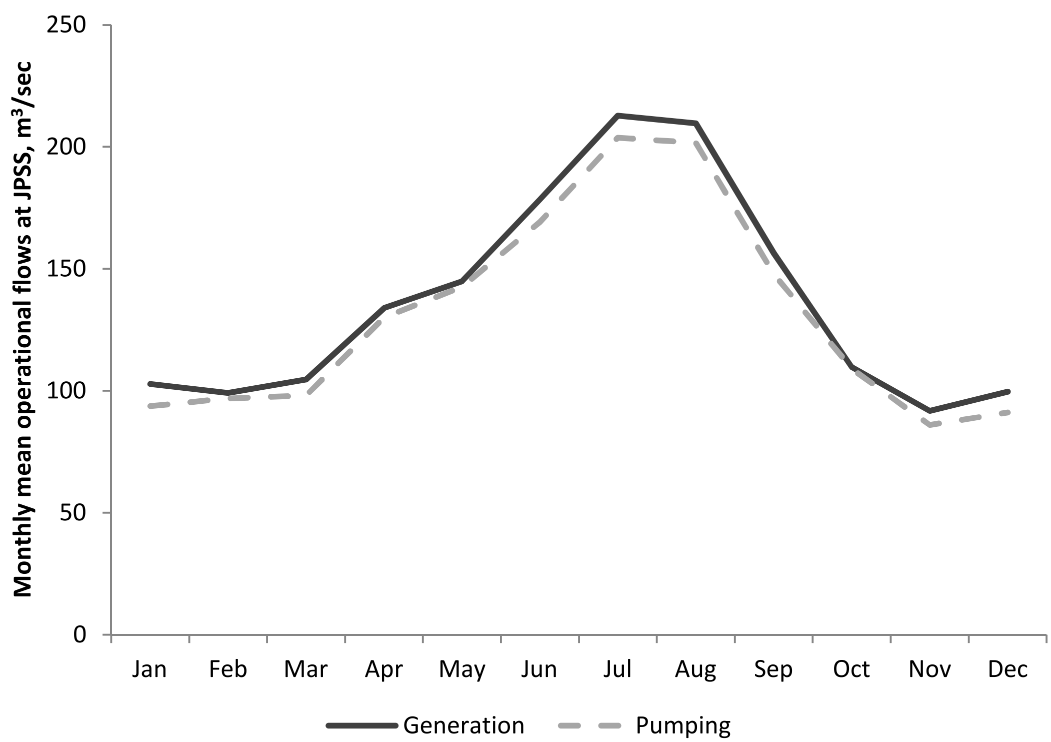


Figure 44. Mean seasonal variation in JPSS generation and pumping flows, based on data from 1997 through 2012.

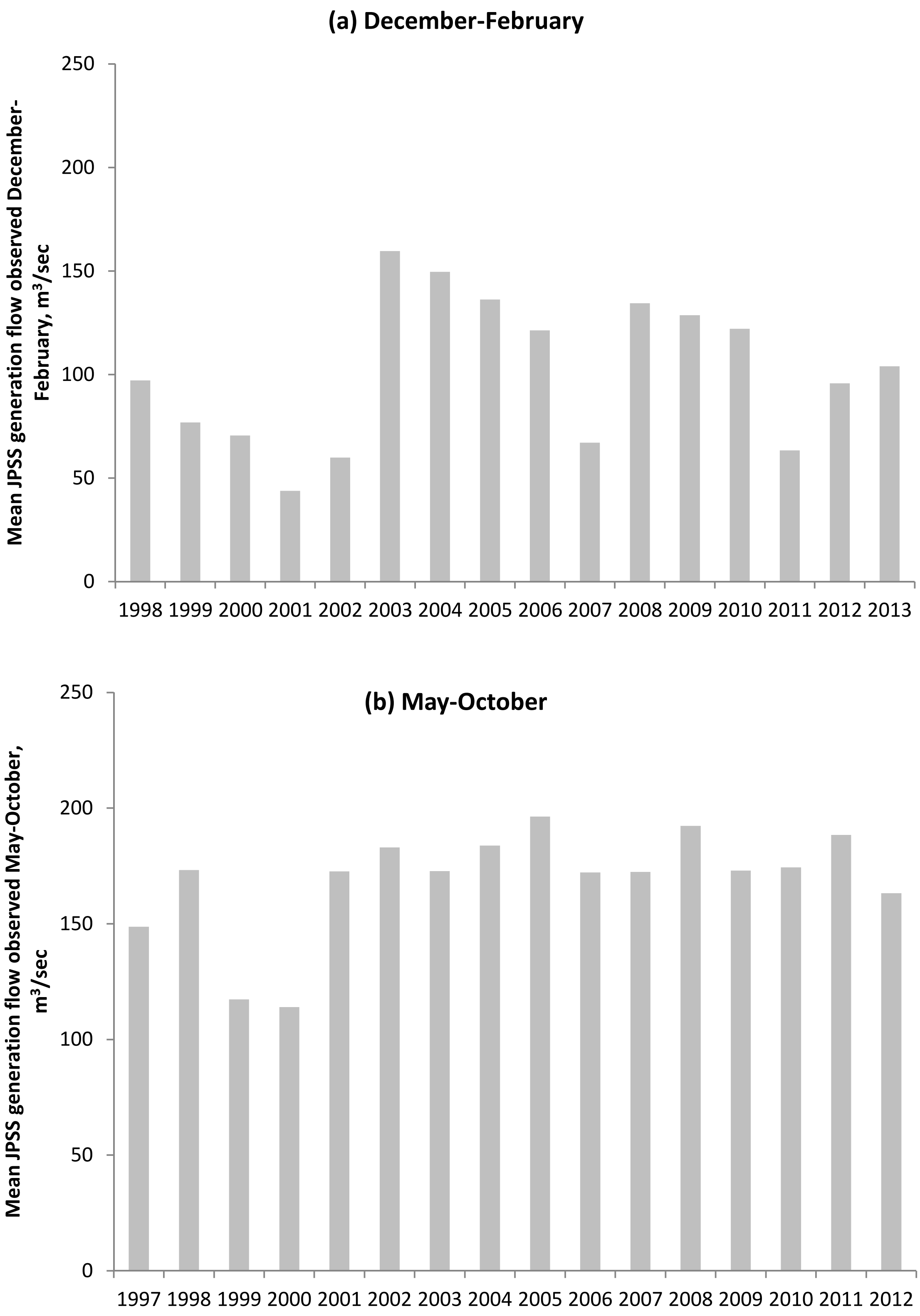


Figure 45. Mean JPSS generation flows observed (a) December-February and (b) May-October, based on daily mean data May 1997 through February 2013.

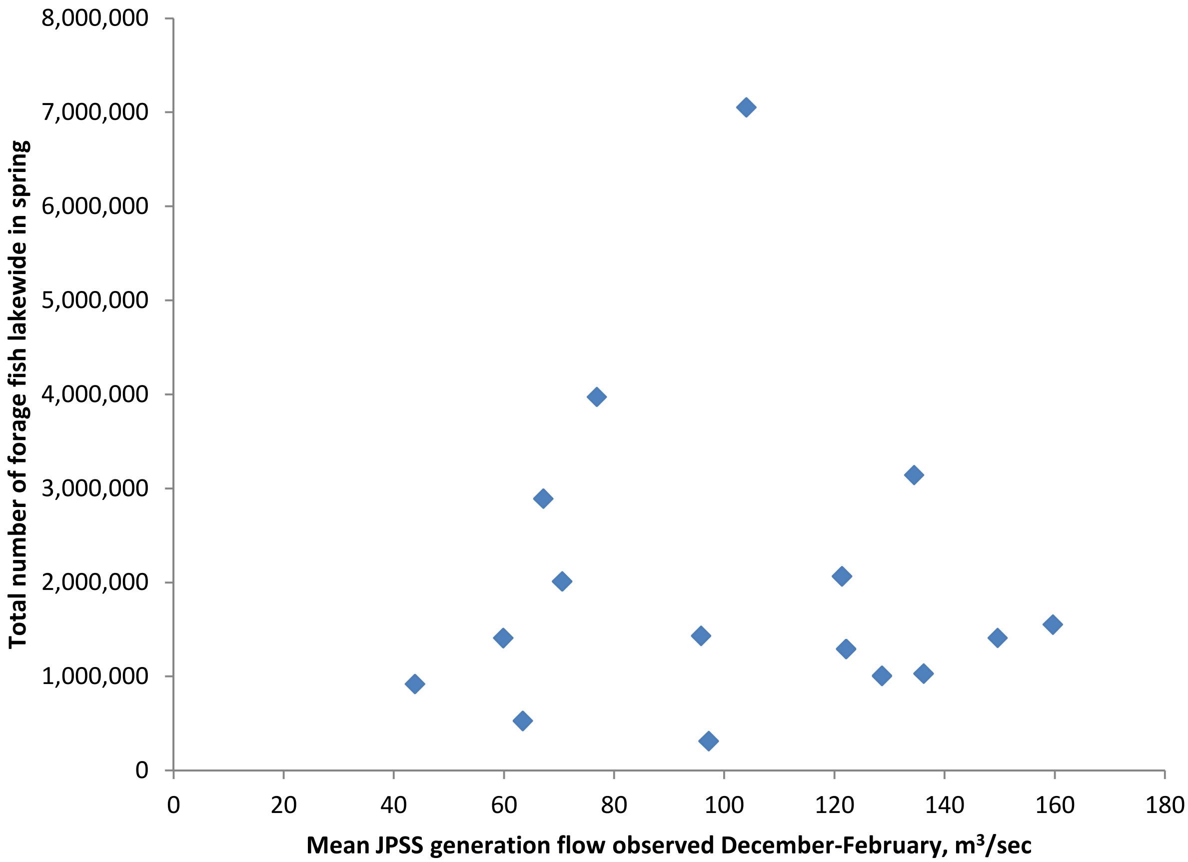


Figure 46. Total number of forage fish lakewide in spring on Lake Jocassee vs. mean Jocassee Pumped Storage Station generation flow observed December-February, 1998-2013.

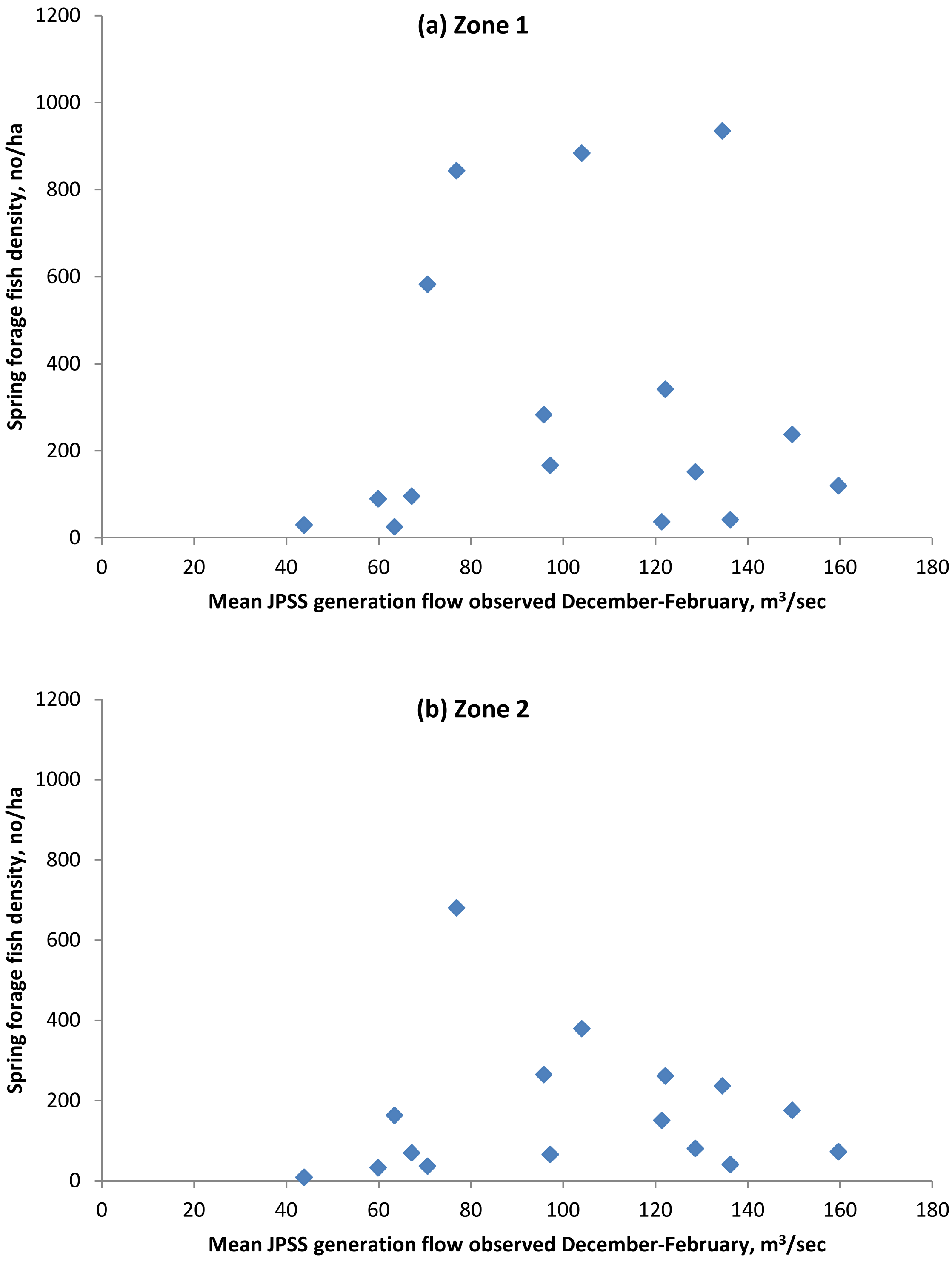
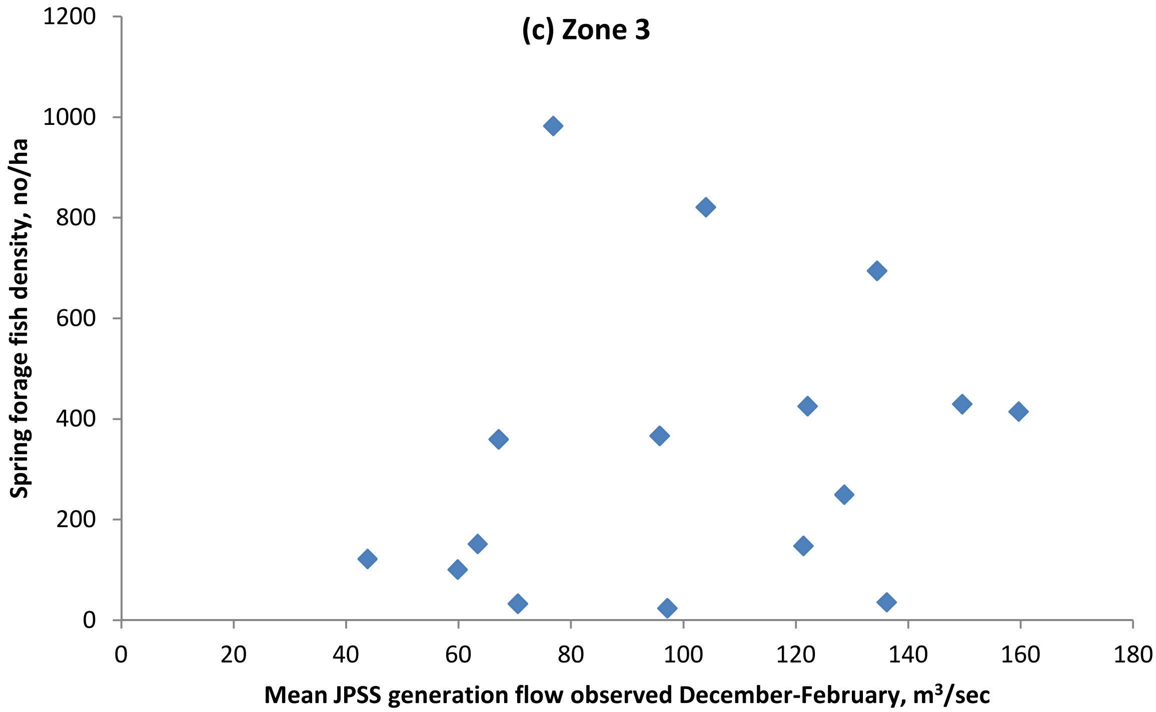


Figure 47 (page 1 of 2). Spring forage fish density in zones of Lake Jocassee vs. mean Jocassee Pumped Storage Station generation flow observed December-February, 1998-2013. Note scale when comparing locations.



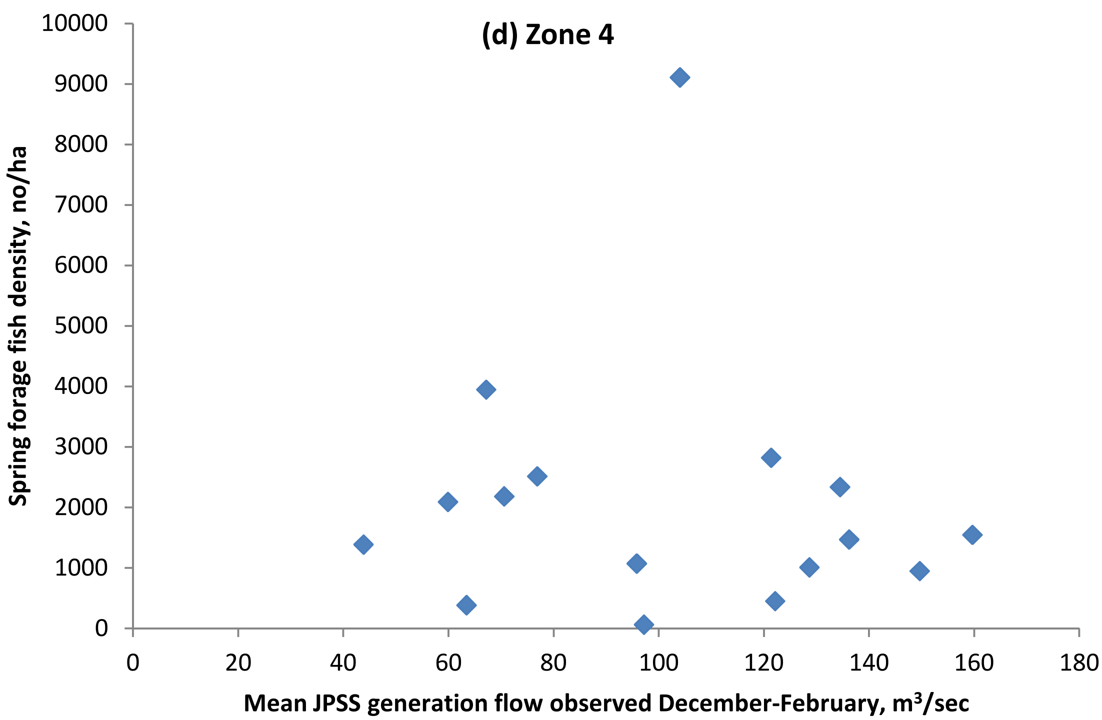


Figure 47 (page 2 of 2). Spring forage fish density in zones of Lake Jocassee vs. mean Jocassee Pumped Storage Station generation flow observed December-February, 1998-2013. Note scale when comparing locations.

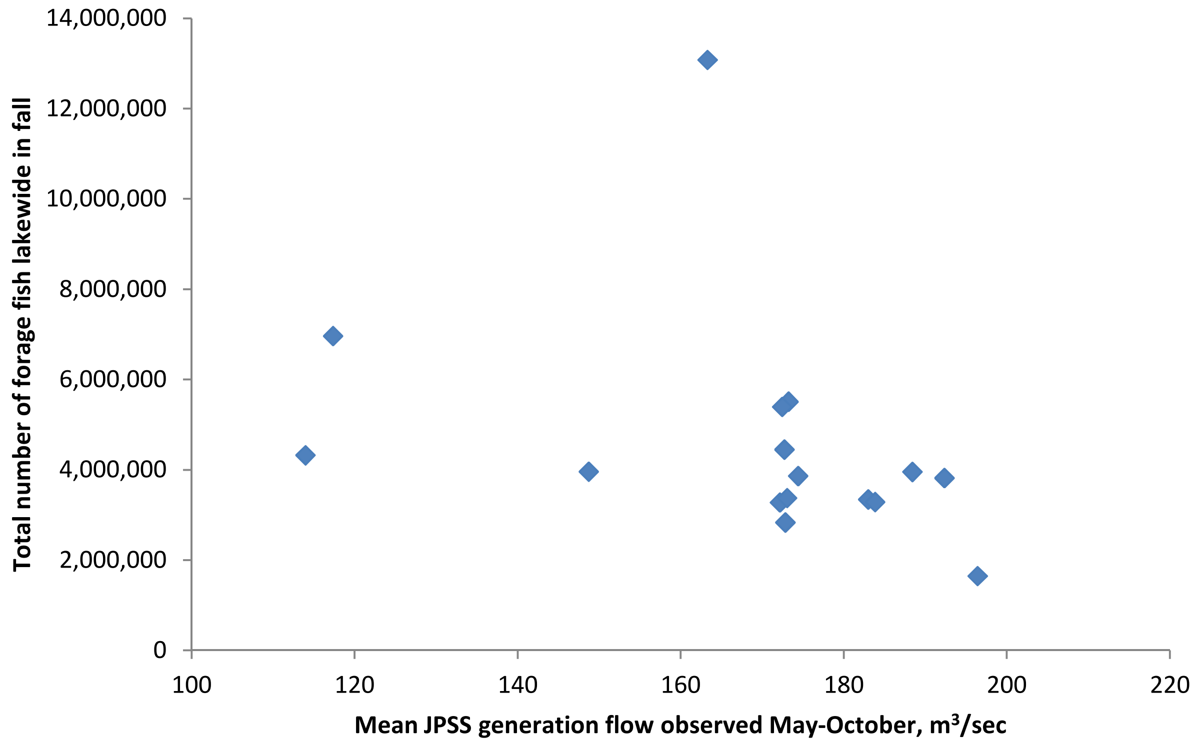
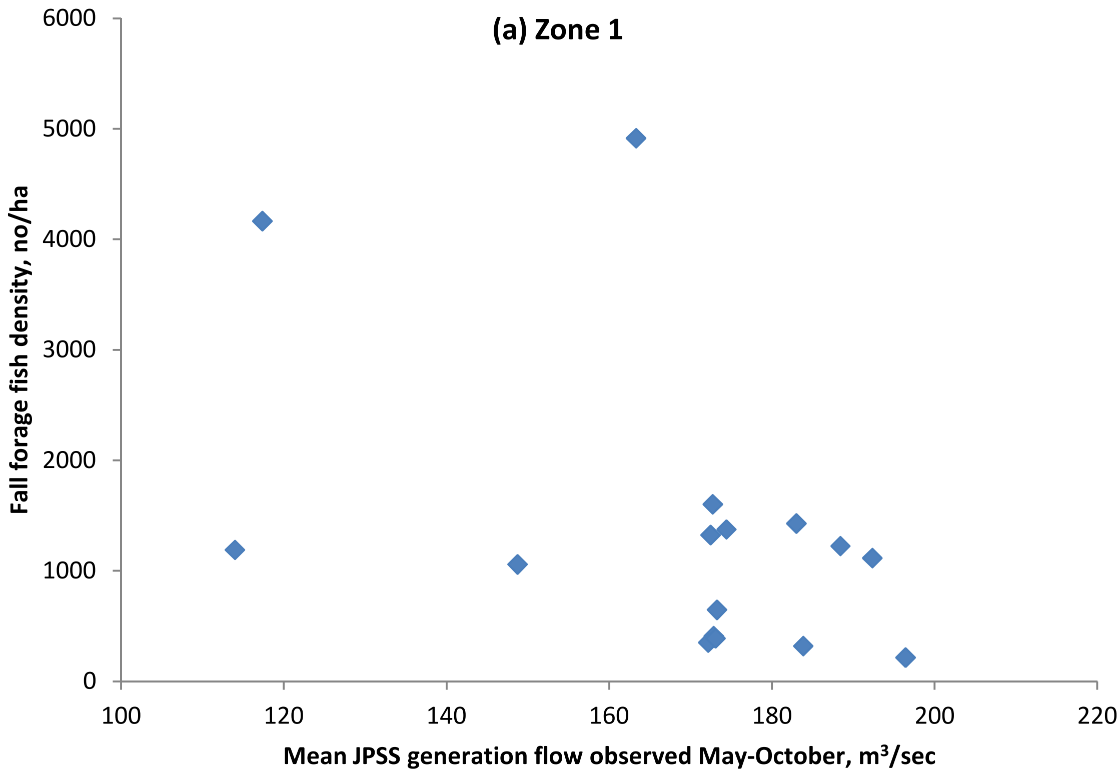


Figure 48. Total number of forage fish lakewide in fall on Lake Jocassee vs. mean JPSS generation flow observed May-October, 1997-2012.



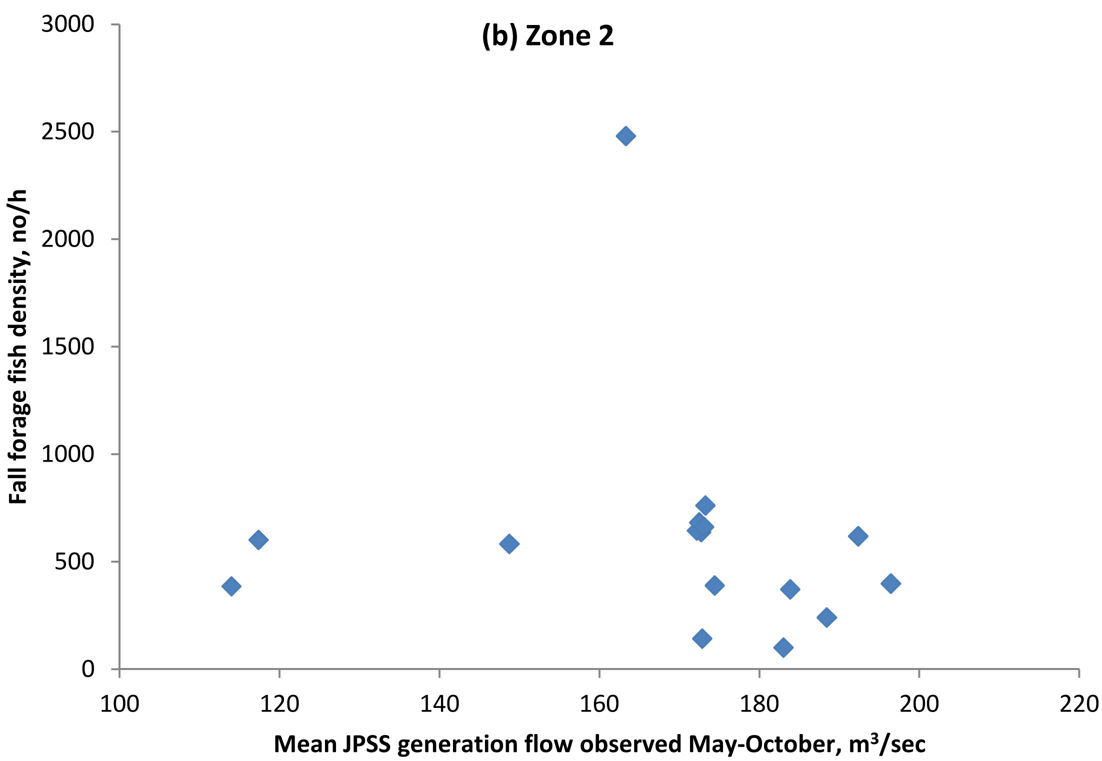
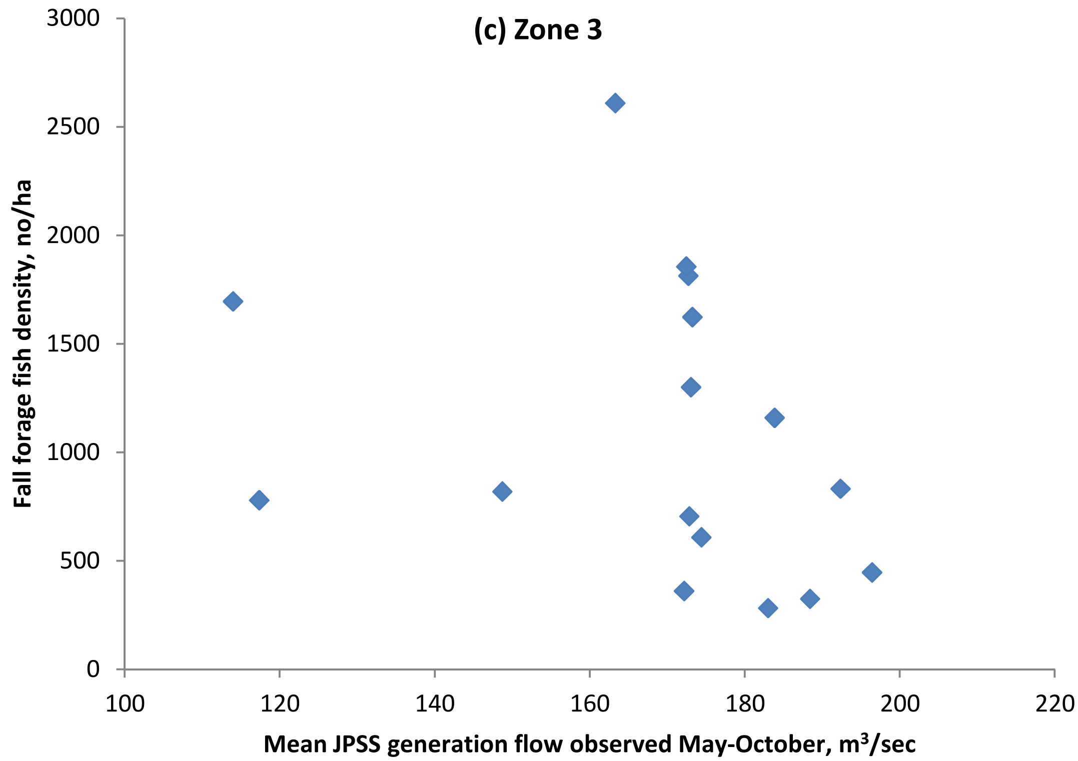


Figure 49 (page 1 of 2). Fall forage fish density in Zones 1, 2, 3, and 4 of Lake Jocassee vs. mean JPSS generation flow observed May-October, 1997-2012. Note scale when comparing locations.



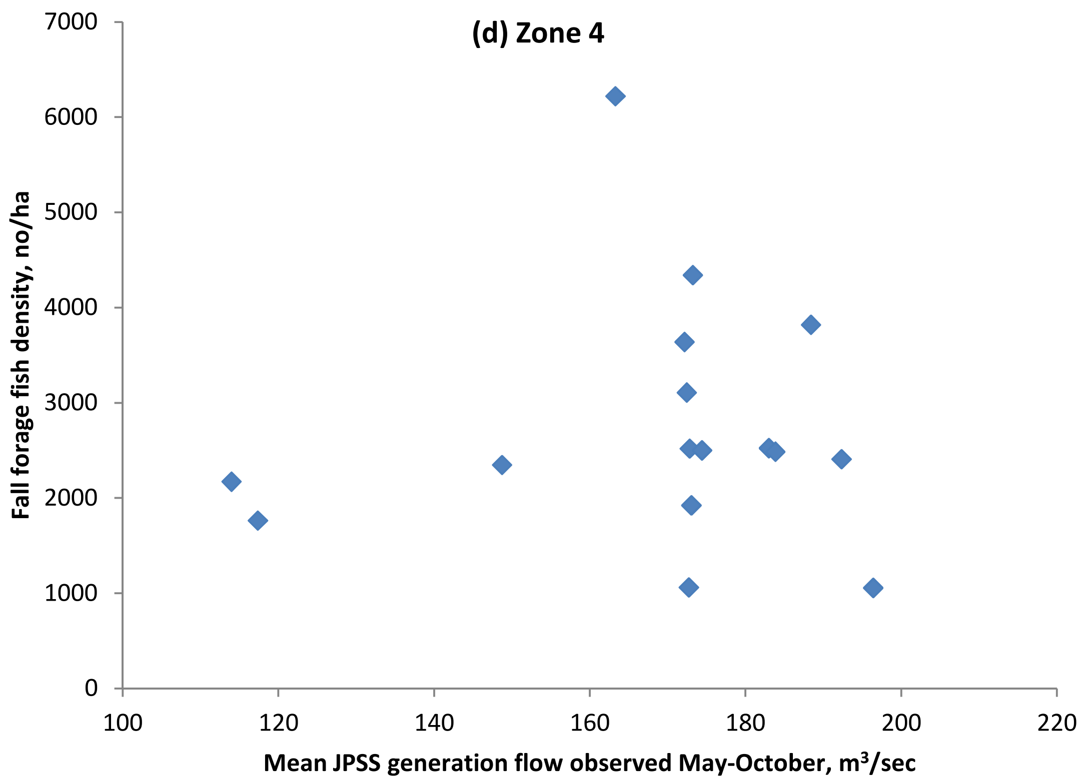


Figure 49 (page 2 of 2). Fall forage fish density in Zones 1, 2, 3, and 4 of Lake Jocassee vs. mean JPSS generation flow observed May-October, 1997-2012. Note scale when comparing locations.

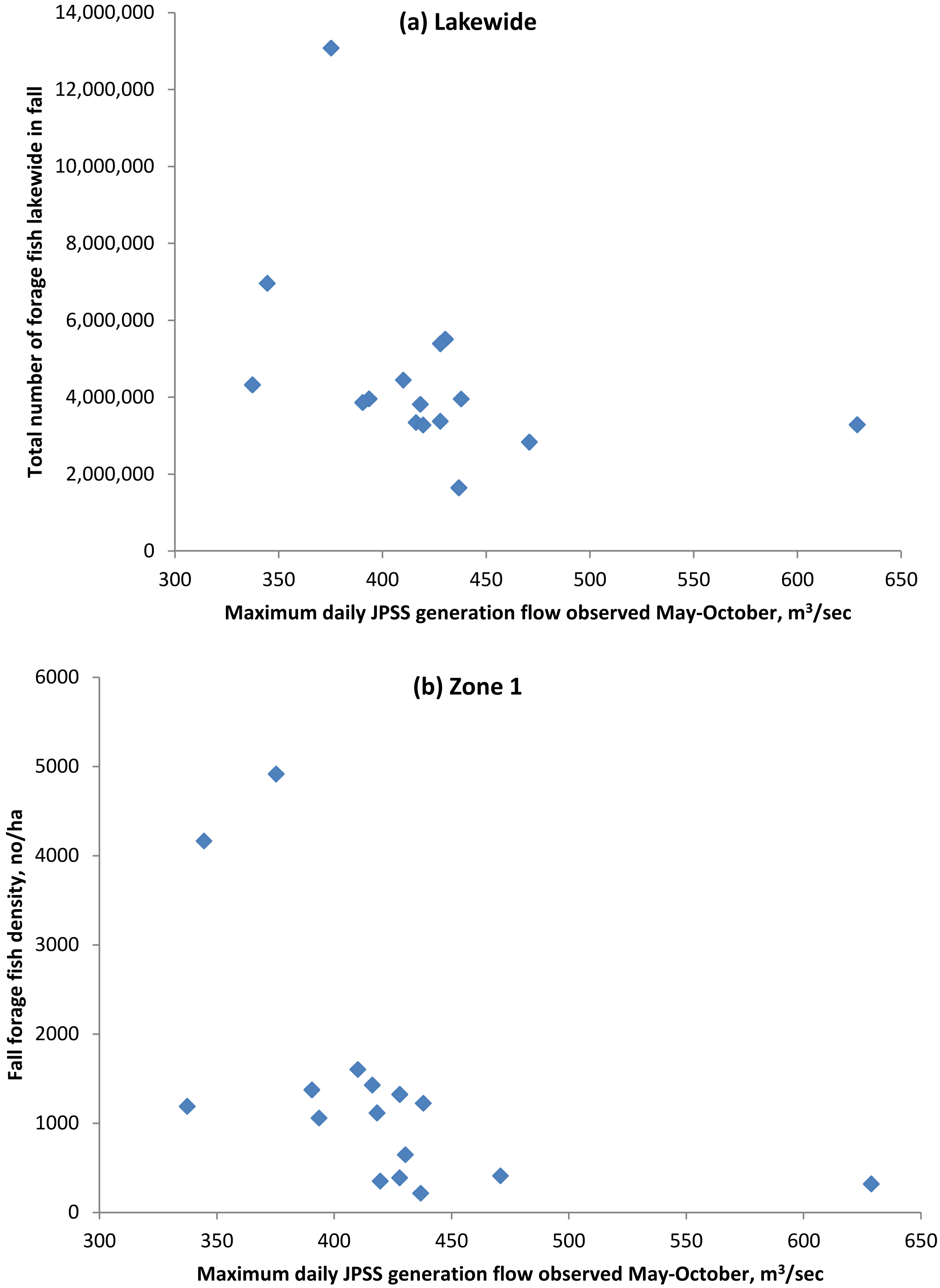


Figure 50. (a) Total number of forage fish lakewide in fall and (b) fall forage fish density in Zone 1 vs. maximum daily JPSS generation flow observed May-October, 1997-2012.

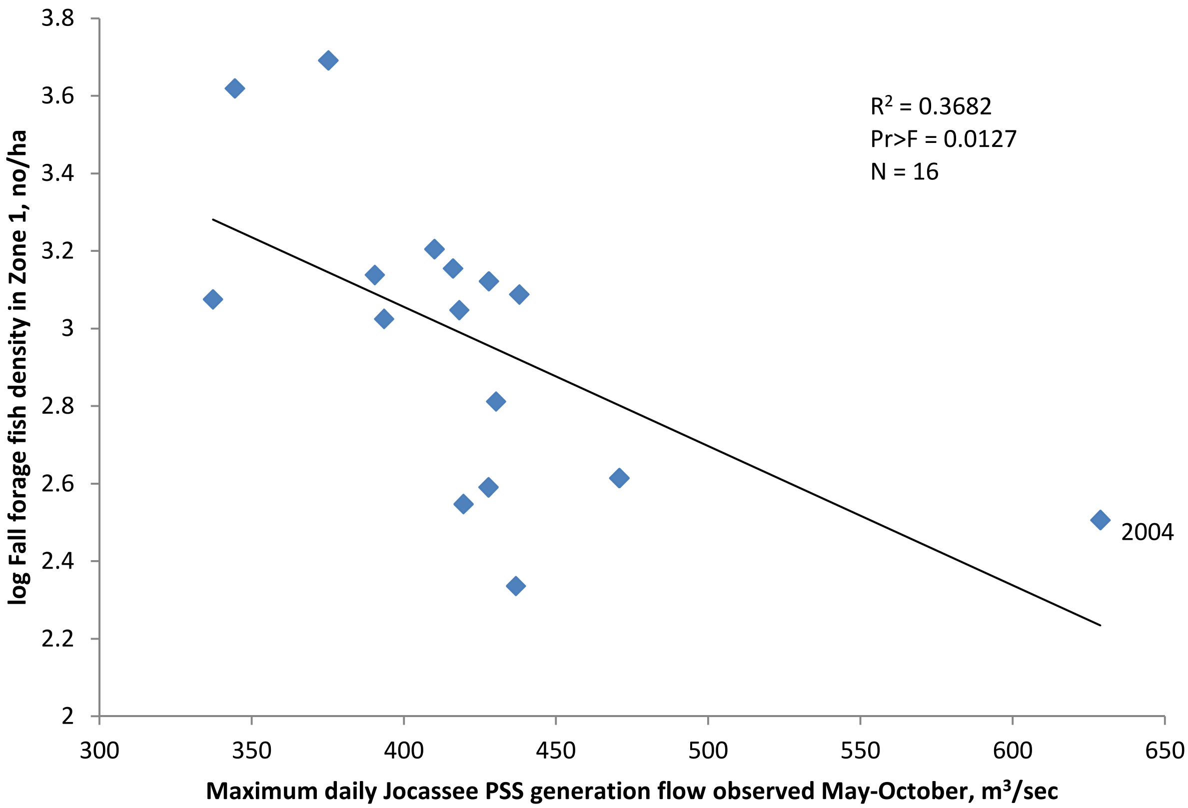


Figure 51. log Fall forage fish density in Zone 1 vs. maximum daily JPSS generation flow observed May-October, 1997-2012.

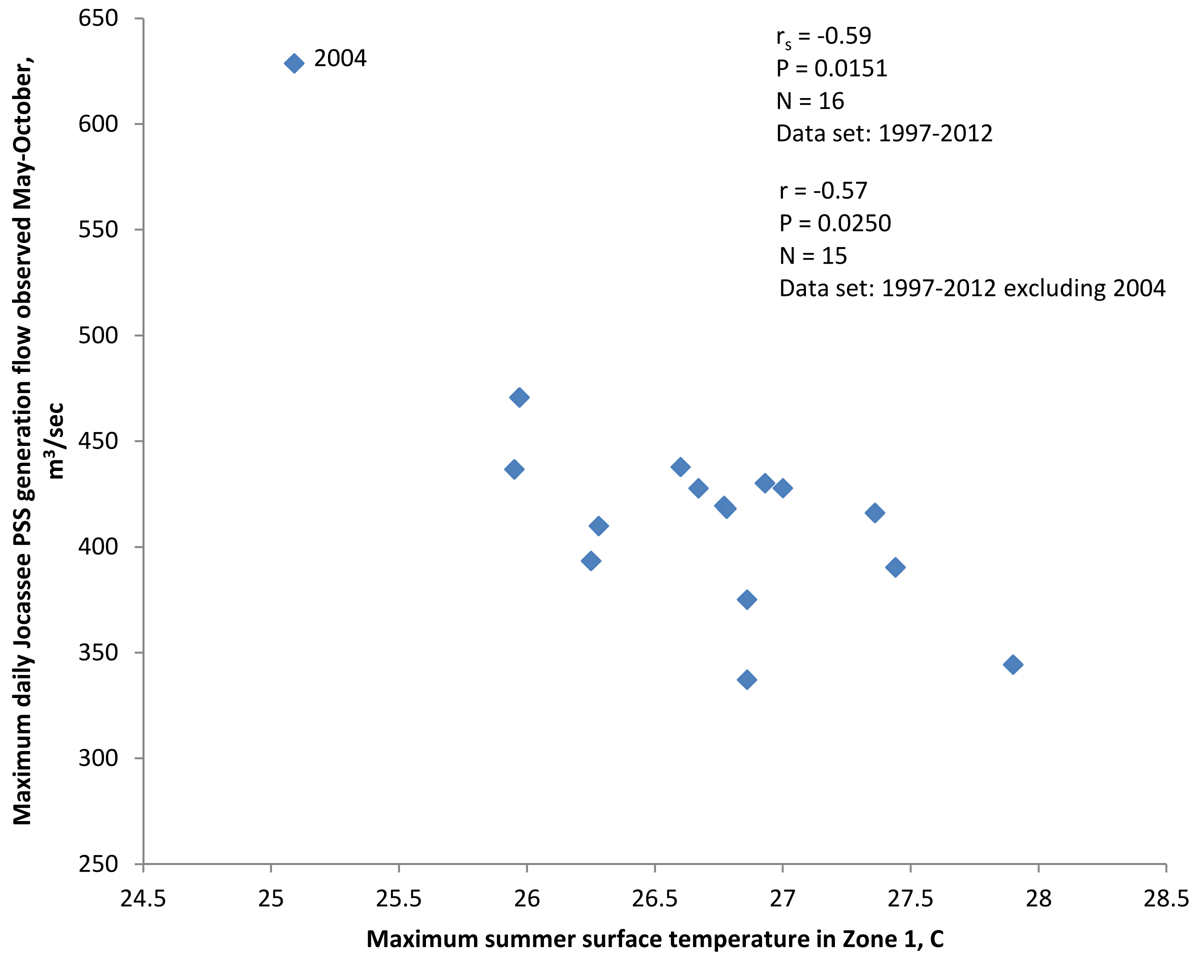


Figure 52. Maximum daily JPSS generation flow observed May-October vs. maximum summer surface (0.3 to 4-m mean) temperature in Zone 1, 1997-2012. Spearman correlation results (rs) are based on all data 1997-2012. Pearson correlation results (r) are based on data from 1997-2012 excluding 2004 to allow assumption of a normal distribution for generation flow.

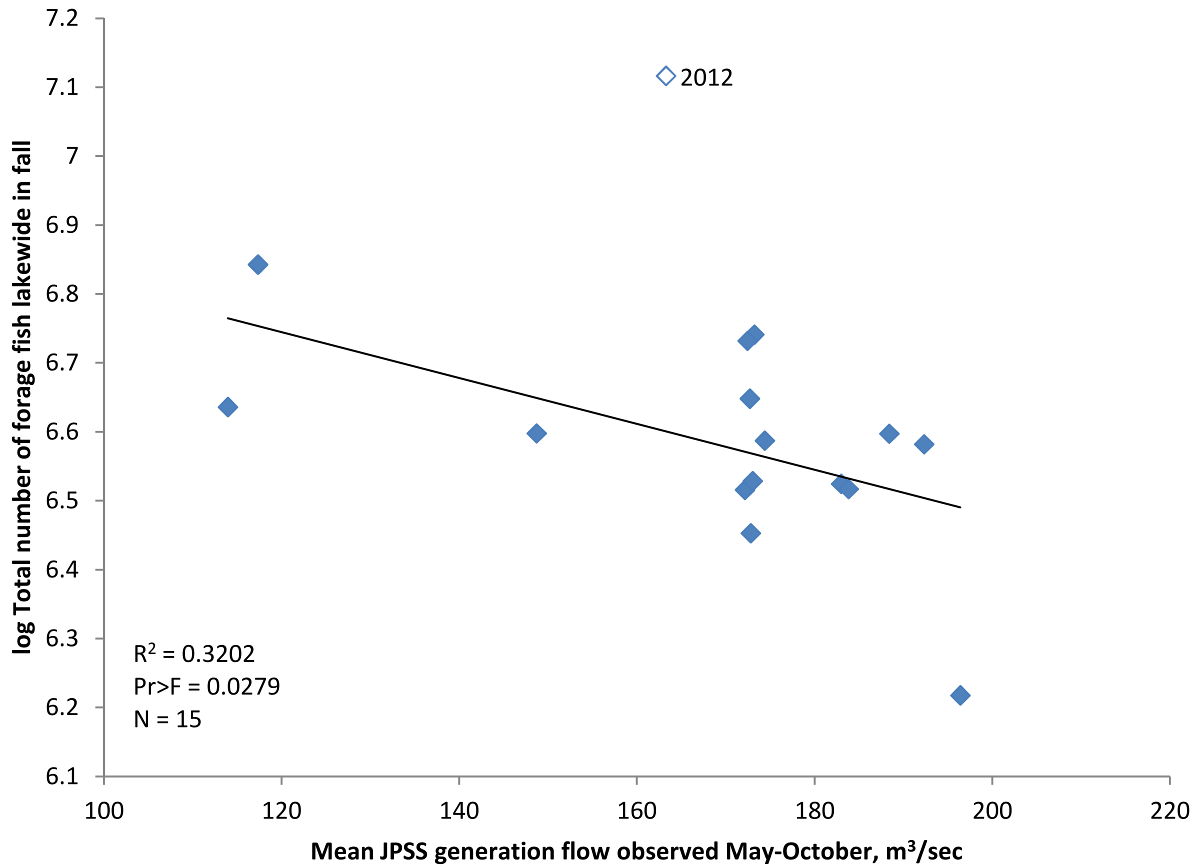


Figure 53. log Total forage fish lakewide in fall on Lake Jocassee vs. mean JPSS generation flow observed May-October, 1997-2012. Regression analysis does not include data for 2012 (see text).

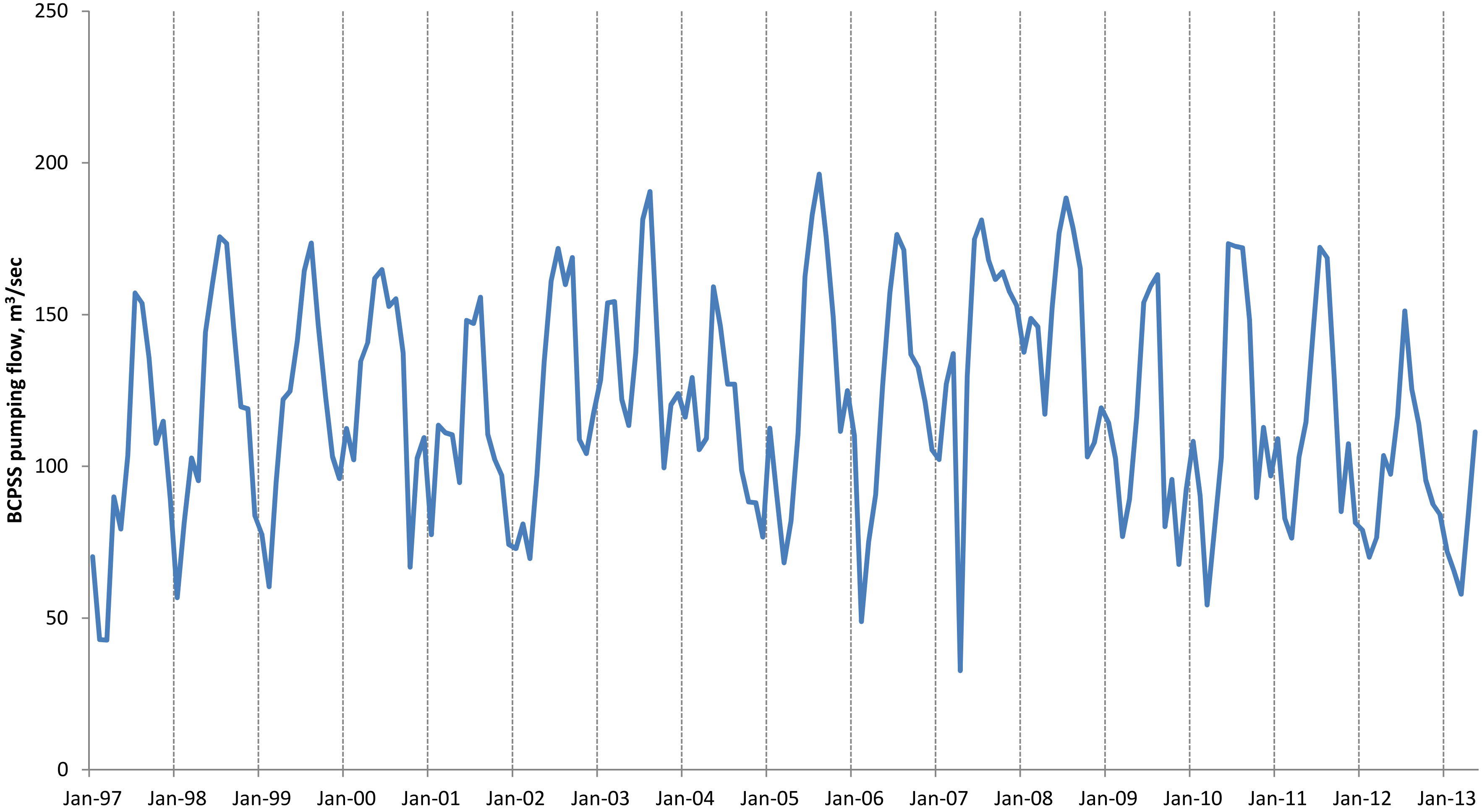


Figure 54. Monthly mean pumping flow at Bad Creek Pumped Storage Station, January 1997 through May 2013.

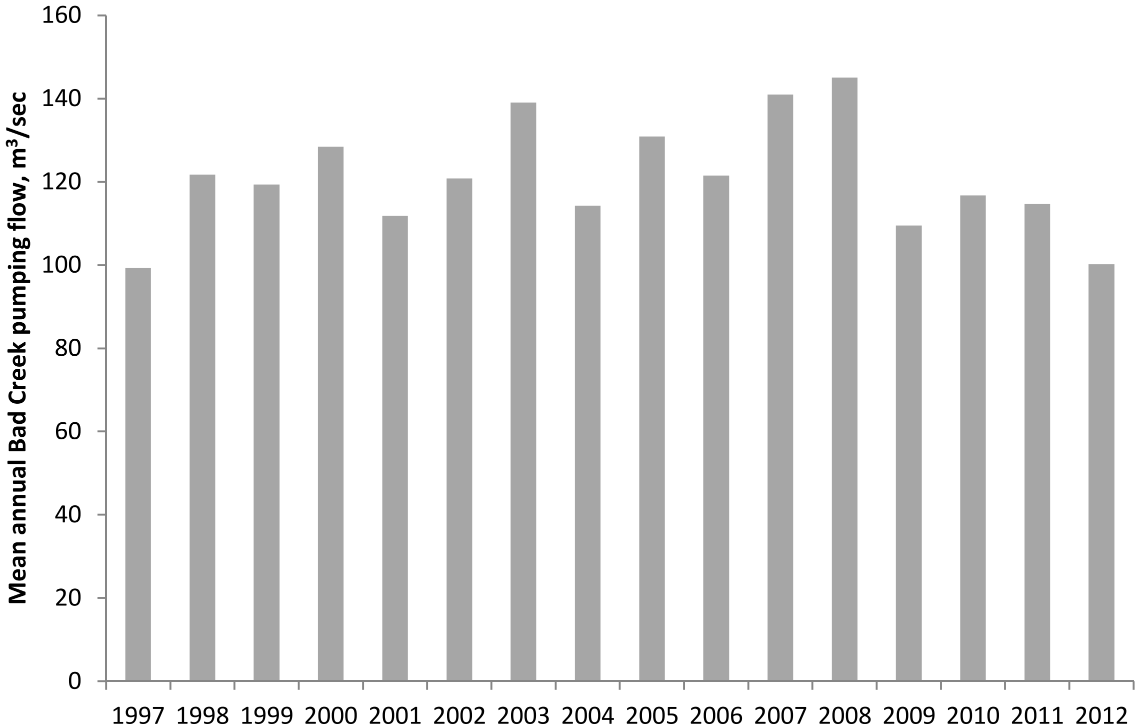


Figure 55. Mean annual pumping flows at Bad Creek Pumped Storage Station, 1997-2012.

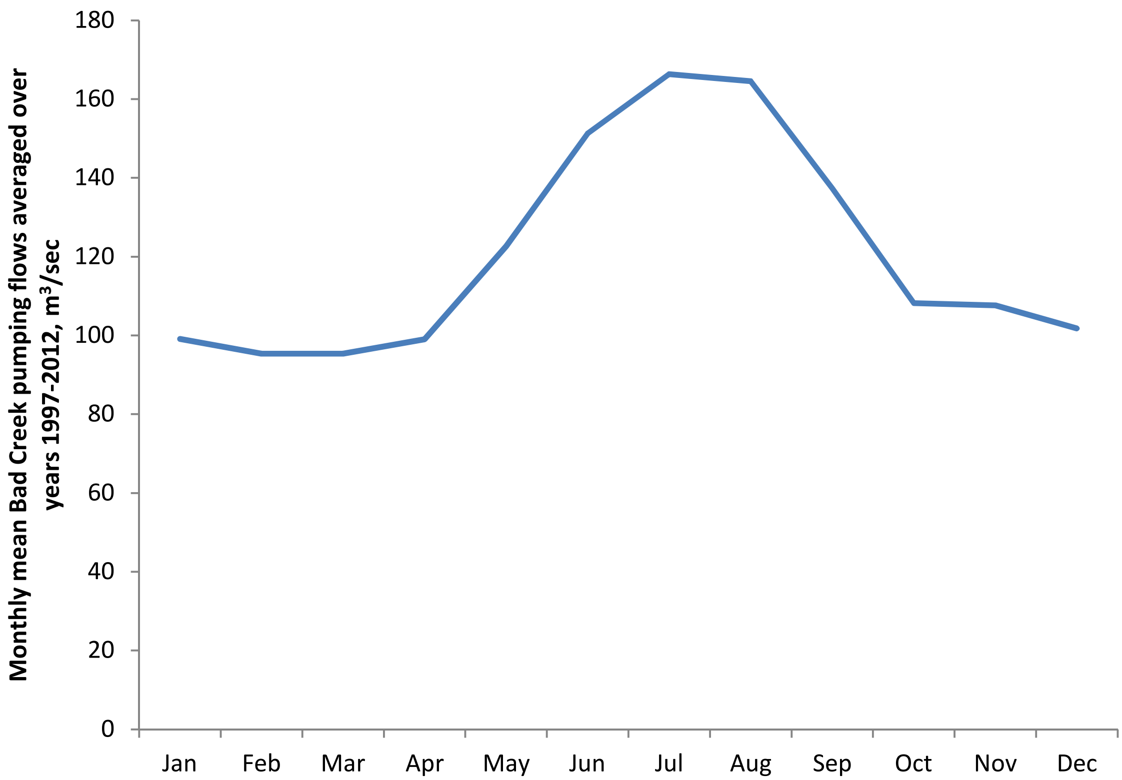


Figure 56. Mean seasonal variation in pumping flows at Bad Creek Pumped Storage Station, based on data for 1997 through 2012.

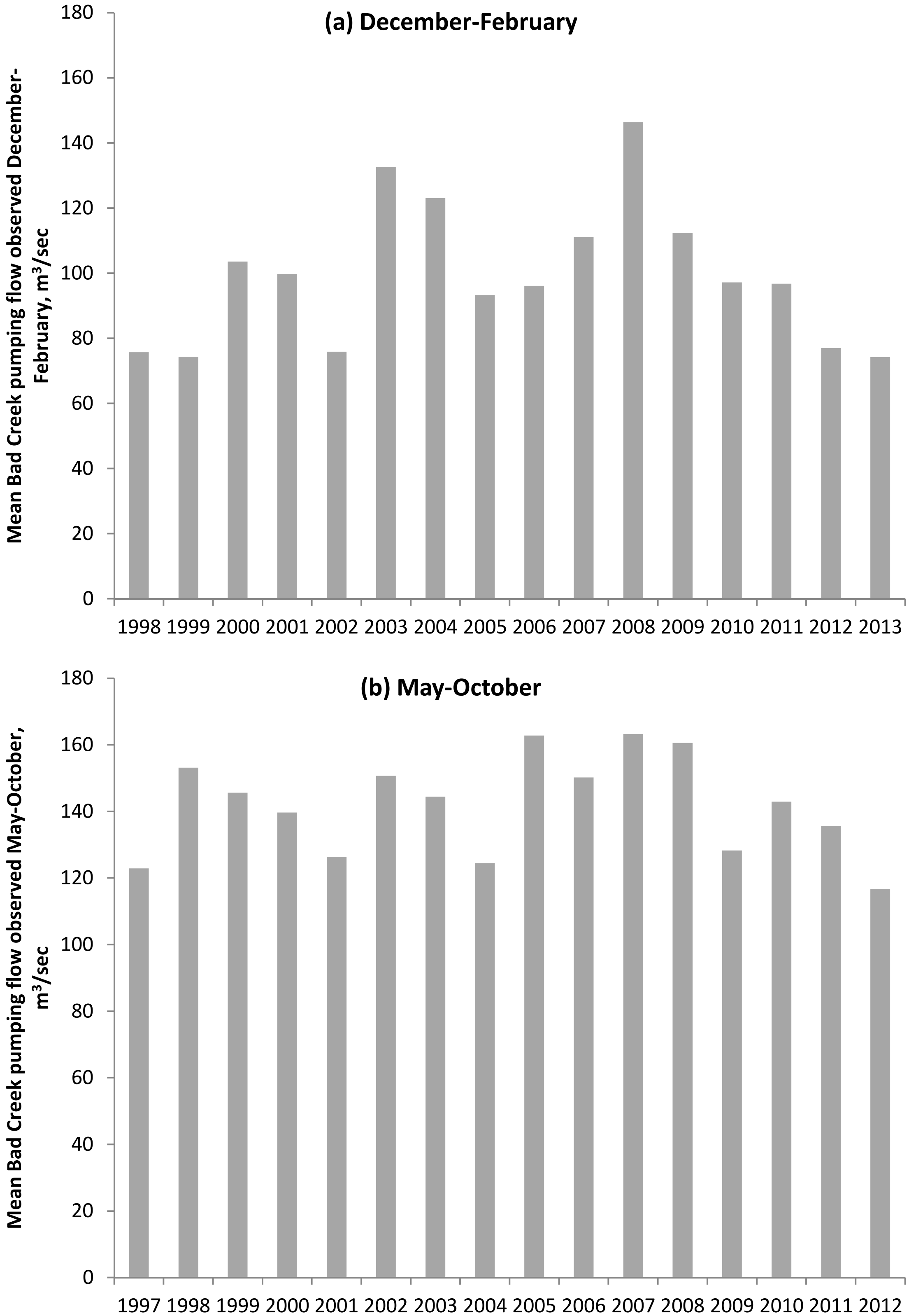


Figure 57. Mean BCPSS pumping flows for (a) December-February and (b) May-October, 1997-2013.

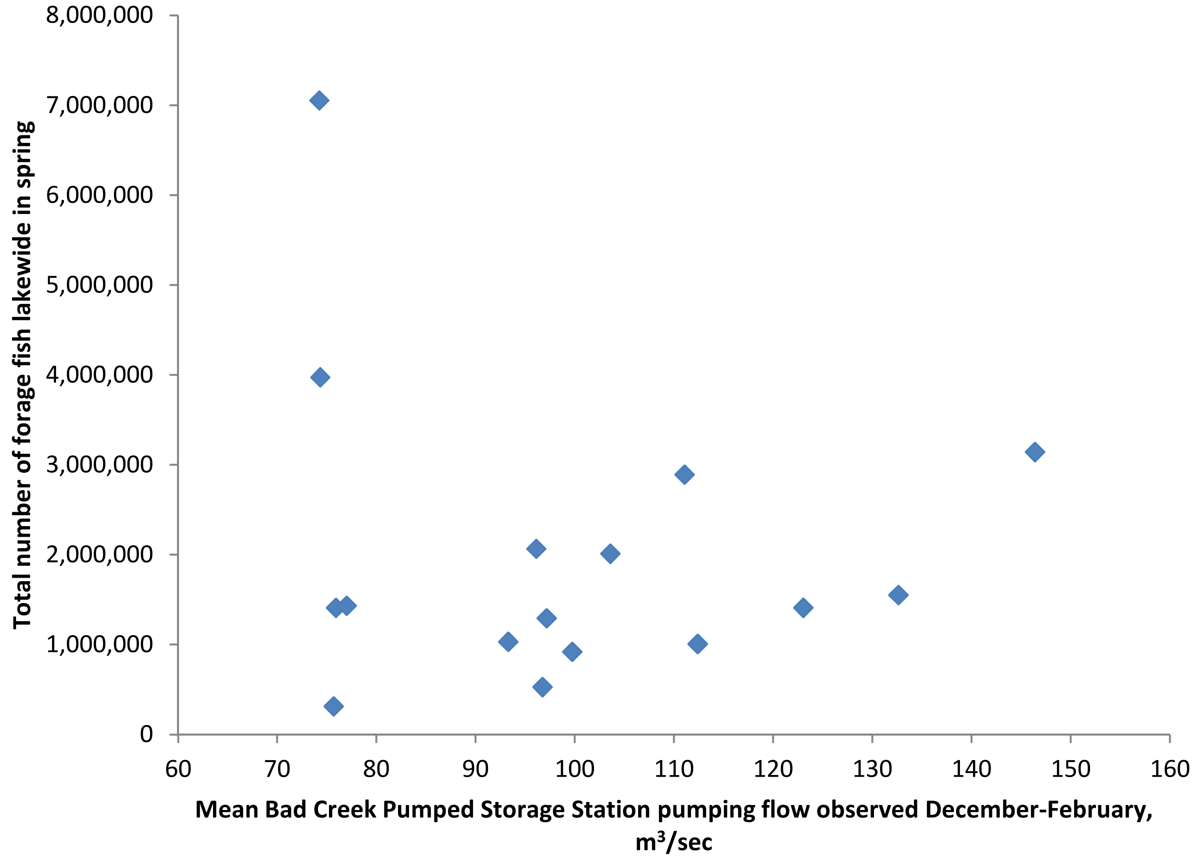


Figure 58. Total number of forage fish lakewide in spring on Lake Jocassee vs. mean Bad Creek Pumped Storage Station pumping flow observed December-February, 1998-2013.

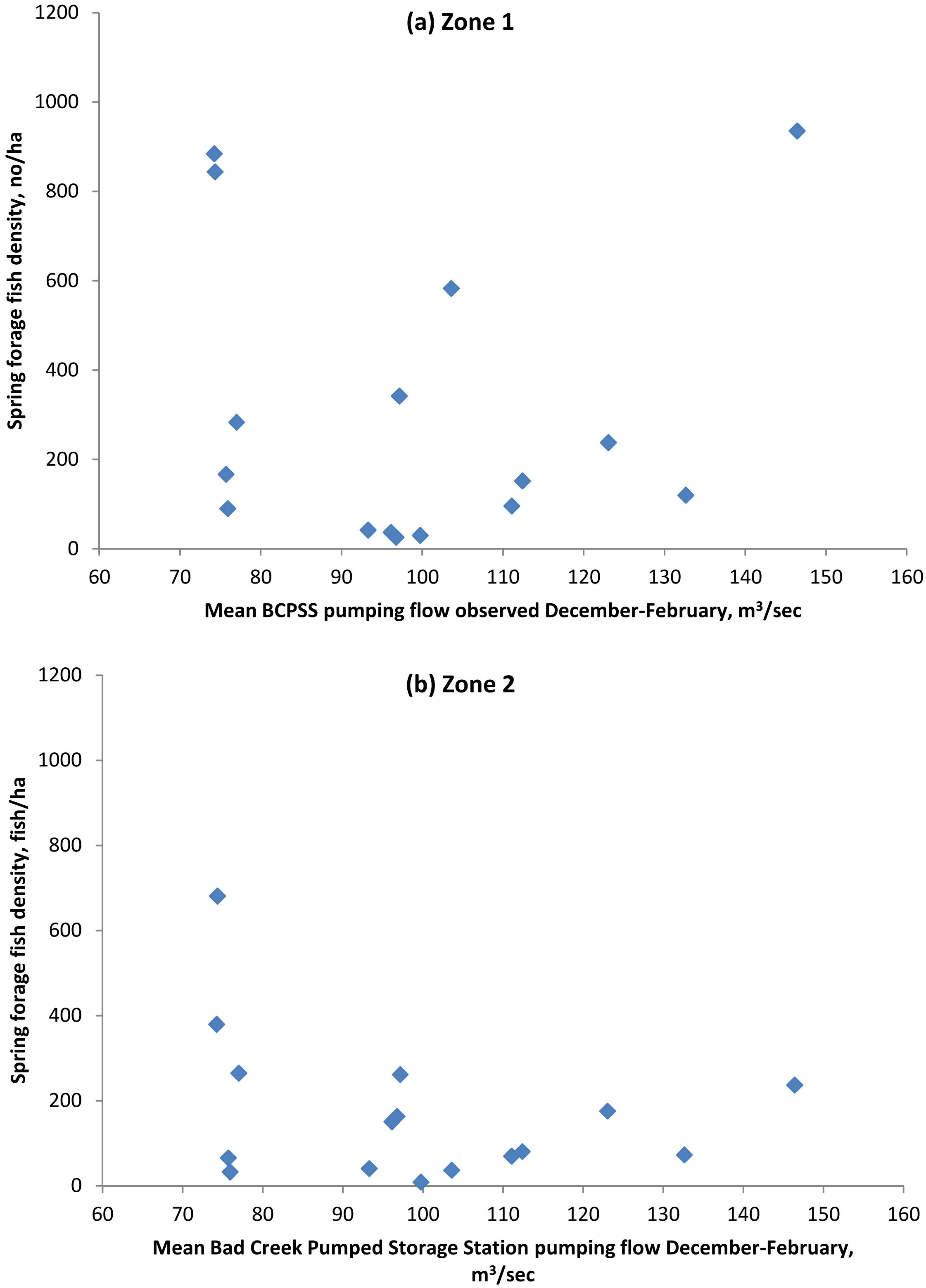
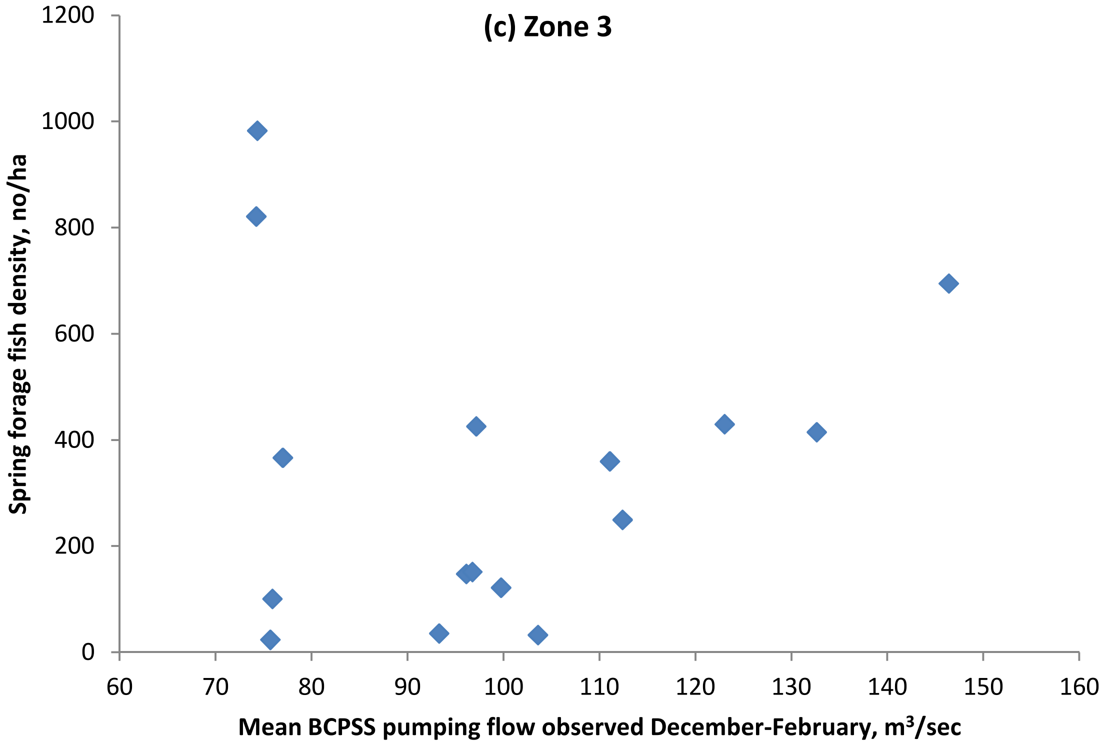


Figure 59 (page 1 of 2). Spring forage fish density in zones on Lake Jocassee vs. mean BCPSS pumping flows observed December-February, 1998-2013. Note scale when comparing locations.



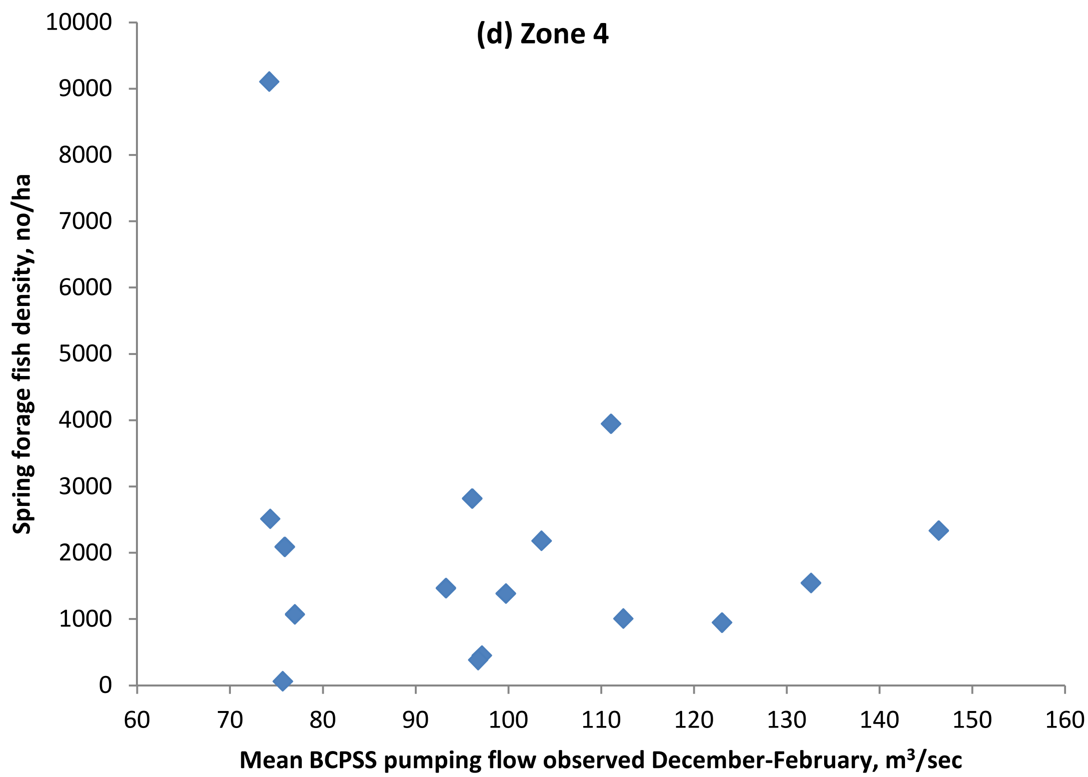


Figure 59 (page 2 of 2). Spring forage fish density in zones on Lake Jocassee vs. mean BCPSS pumping flows observed December-February, 1998-2013. Note scale when comparing locations.

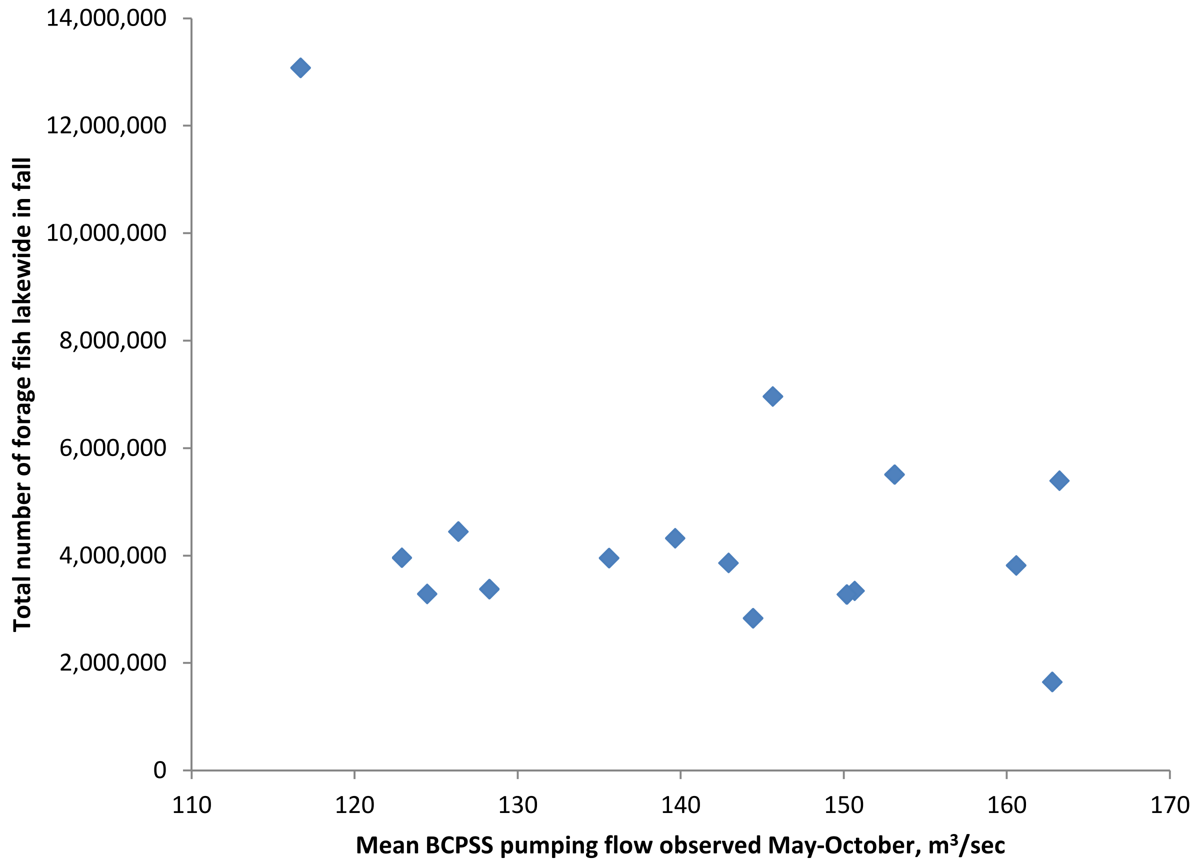
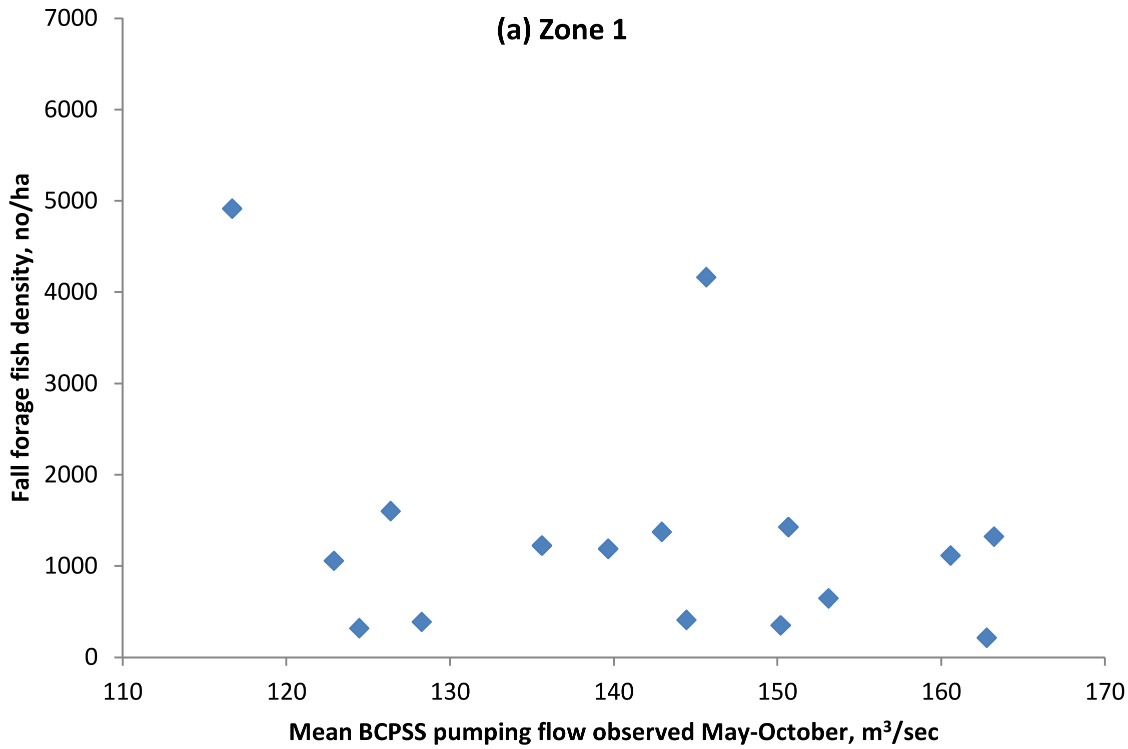


Figure 60. Total number of forage fish lakewide in fall on Lake Jocassee vs. mean Bad Creek Pumped Storage Station pumping flow observed May-October, 1997-2012.



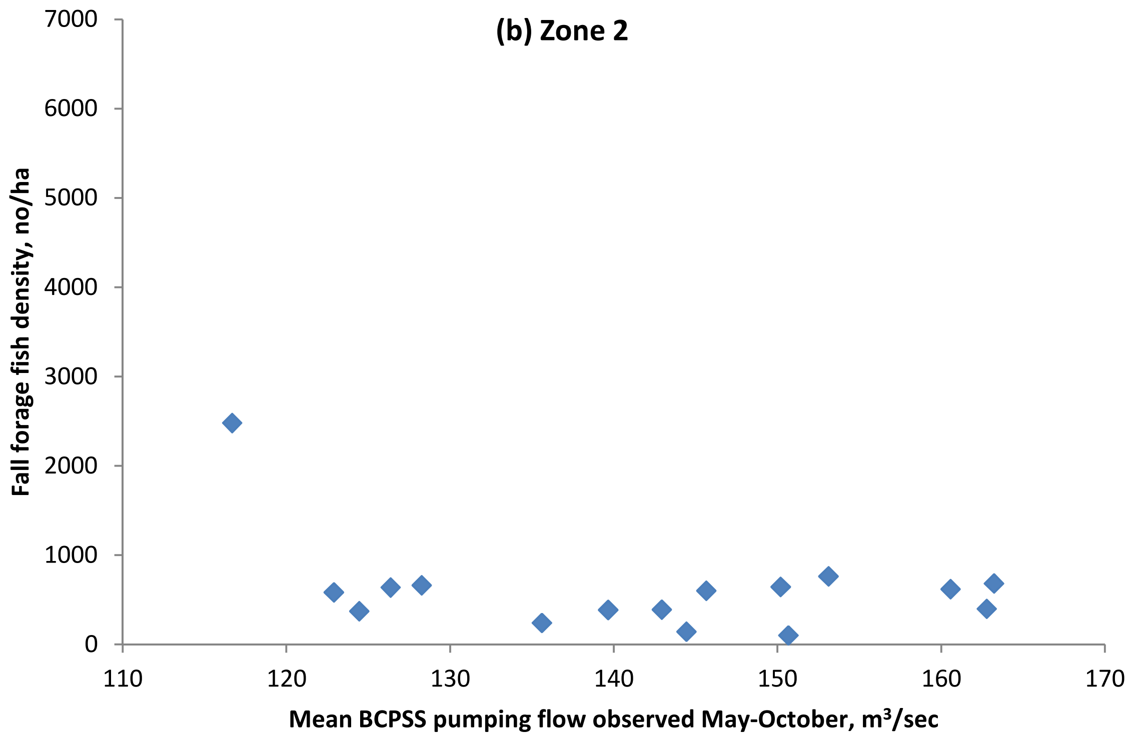
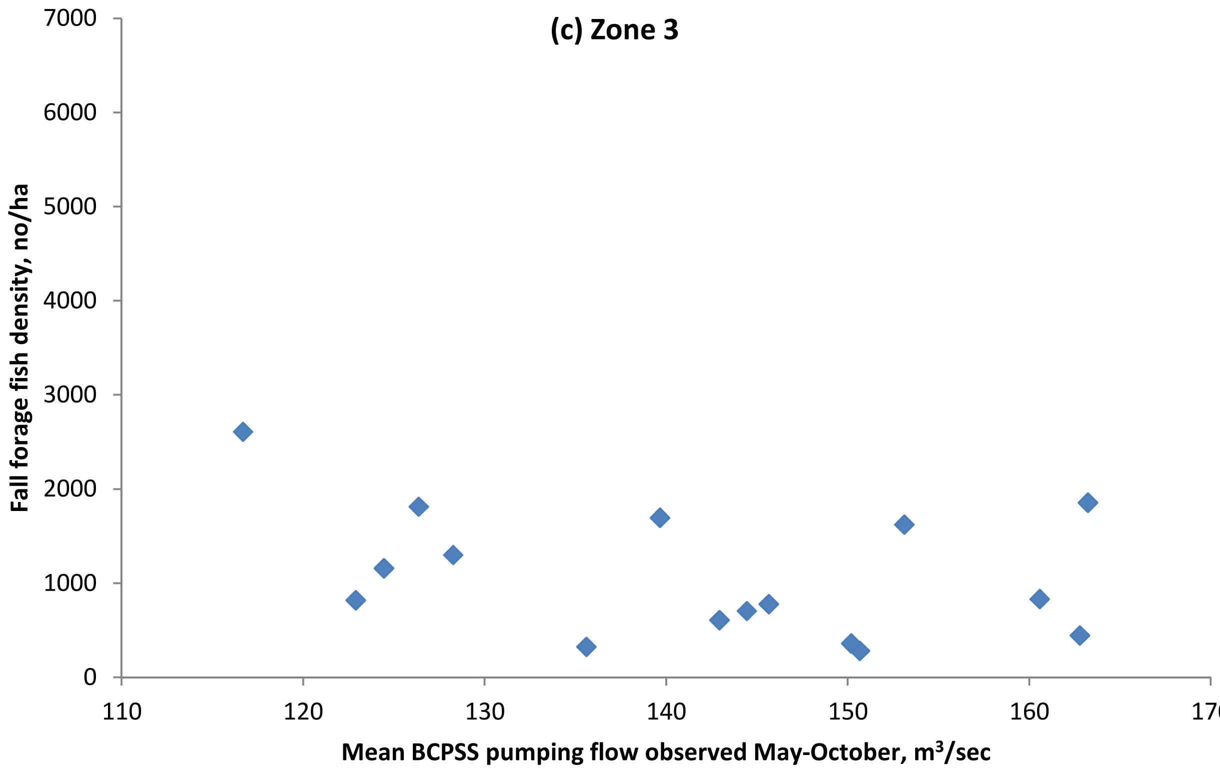


Figure 61 (page 1 of 2). Fall forage fish densities in zones of Lake Jocassee vs. mean pumping flows observed May-October at Bad Creek Pumped Storage Station, 1997-2012.



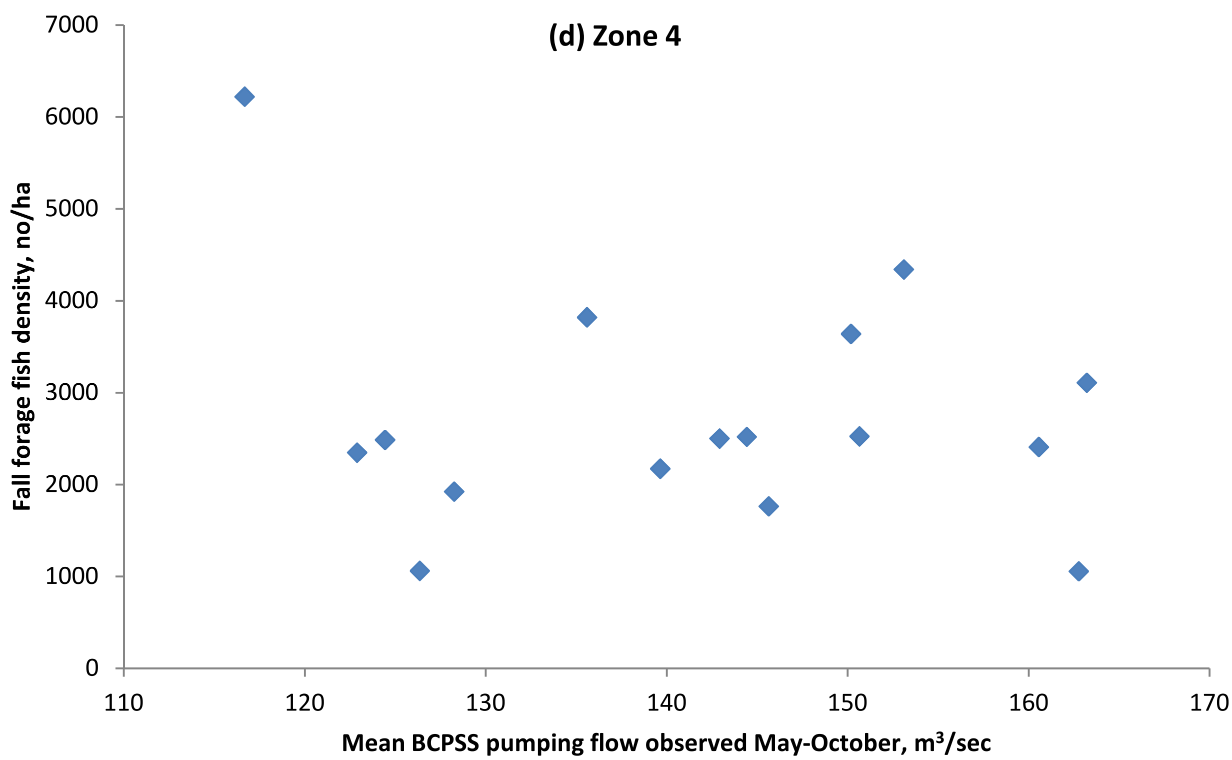


Figure 61 (page 2 of 2). Fall forage fish densities in zones of Lake Jocassee vs. mean pumping flows observed May-October at Bad Creek Pumped Storage Station, 1997-2012.

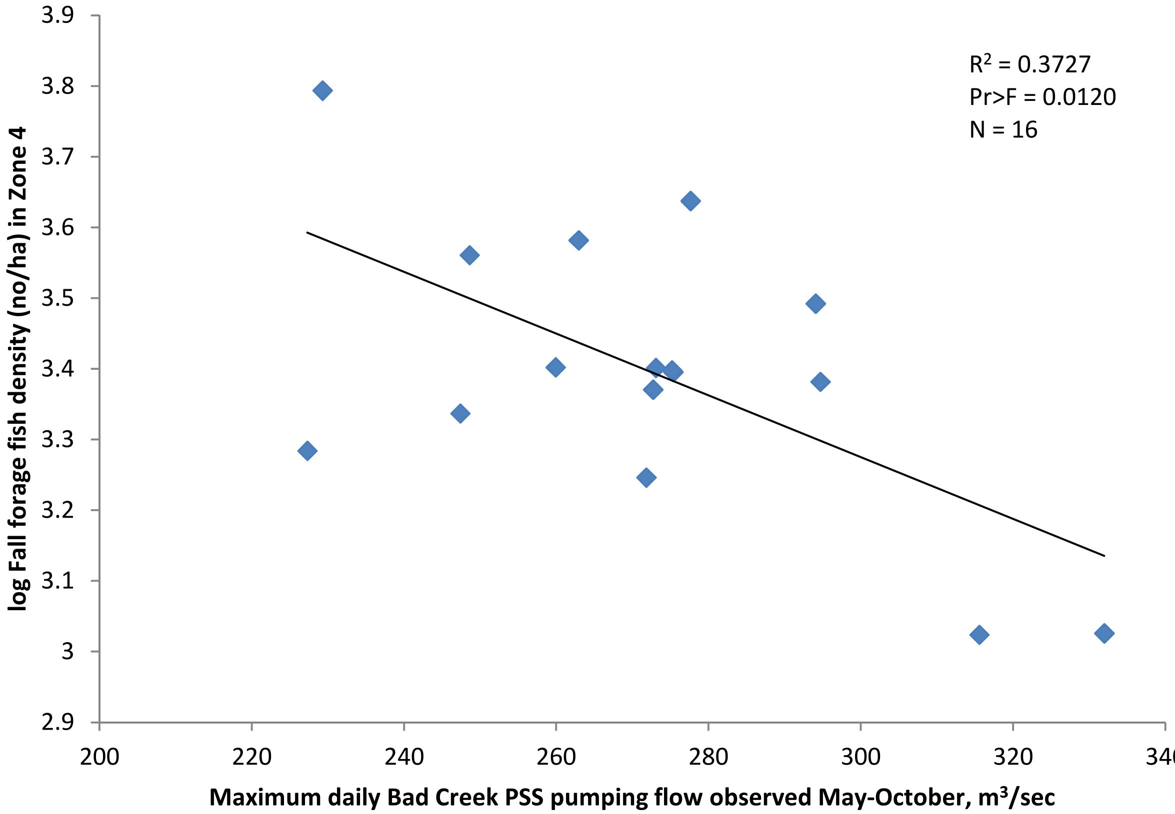


Figure 62. log Fall forage fish density in Zone 4 of Lake Jocassee vs. maximum daily BCPSS pumping flow observed May-October, 1997-2012.

Guide to Abbreviations and Variable Names in Appendix Tables

- 'C' in front of any of the following variables indicates that the variable was centered prior to analysis by subtracting the mean value of the variable for the data set from the original variable value.
- 'log' in front of any of the following variables indicates that the variable was $\log_{10}$-transformed
- 'LW' in front of any of the following variables indicates that the value is lakewide

AllPredkg	Sum of biomass (kg per 40 gill net sets) for all predatory species in gill net data
AllPrednum	Sum of numbers (per 40 gill net sets) for all predatory species in gill net data
BLBkg	Black bass biomass, kg
BLBnum	Black bass numbers
Dep	Dependent variable
FallDensZ1	Fall forage fish density in Zone 1, no/ha
FallDensZ2	Fall forage fish density in Zone 2, no/ha
FallDensZ3	Fall forage fish density in Zone 3, no/ha
FallDensZ4	Fall forage fish density in Zone 4, no/ha
FallFish	Total number of forage fish lakewide in fall
Indep	Independent variable
Interaction	Interaction variable calculated as the product of the centered independent variables
JanFebTemp	Mean surface (0-4 m) temperature January-February
LMBkg	Largemouth bass biomass, kg
LMBnum	Largemouth bass numbers

Max30dayDecFebBCPump: Maximum 30-day average BCPSS pumping flow observed Dec-Feb, m^3/sec
Max30dayDecFebJocGen: Maximum 30-day average JPSS generation flow observed Dec-Feb, m^3/sec
Max30dayDecFebLL: Lowest 30-day average lake level observed Dec-Feb, meters below full pool
Max30dayMayOctBCPump: Maximum 30-day average BCPSS pumping flow observed May-Oct, m^3/sec
Max30dayMayOctJocGen: Maximum 30-day average JPSS generation flow observed May-Oct, m^3/sec
Max30dayMayOctLL: Lowest 30-day average lake level observed May-Oct, meters below full pool
MaxDailyDecFebBCPump: Maximum daily BCPSS pumping flow observed Dec-Feb, m^3/sec
MaxDailyDecFebJocGen: Maximum daily JPSS generation flow observed Dec-Feb, m^3/sec
MaxDailyDecFebLL: Lowest daily lake level observed Dec-Feb, meters below full pool
MaxDailyMayOctBCPump: Maximum daily BCPSS pumping flow observed May-Oct, m^3/sec
MaxDailyMayOctJocGen: Maximum daily JPSS generation flow observed May-Oct, m^3/sec
MaxDailyMayOctLL: Lowest daily lake level observed May-Oct, meters below full pool
MaxLWTemp: Maximum summer surface (0.3 to 4-m mean) lakewide mean temperature, C
MaxTempZ1: Maximum summer surface (0.3 to 4-m mean) zonal mean temperature in Zone 1, C
MaxTempZ2: Maximum summer surface (0.3 to 4-m mean) zonal mean temperature in Zone 2, C
MaxTempZ3: Maximum summer surface (0.3 to 4-m mean) zonal mean temperature in Zone 3, C
MaxTempZ4: Maximum summer surface (0.3 to 4-m mean) zonal mean temperature in Zone 4, C
MeanDecFebBCPump: Mean BCPSS pumping flow observed Dec-Feb, m^3/sec
MeanDecFebJocGen: Mean JPSS generation flow observed Dec-Feb, m^3/sec
MeanDecFebLL: Mean lake level observed Dec-Feb, meters below full pool
MeanMayOctBCPump: Mean BCPSSpumping flow observed May-Oct, m^3/sec
MeanMayOctJocGen: Mean JPSS generation flow observed May-Oct, m^3/sec
MeanMayOctLL: Mean lake level observed May-Oct, meters below full pool

MinTemp	Minimum annual surface (0-4 m) temperature, C
REBkg	Redeye bass biomass, kg
REBnum	Redeye bass, number

SPEC: Test for homoscedasticity of variance (prob>chi-square) – deviations were significant where prob>chi-square≤0.0500

SprDensZ1	Spring forage fish density in Zone 1, no/ha
SprDensZ2	Spring forage fish density in Zone 2, no/ha

SprDensZ3	Spring forage fish density in Zone 3, no/ha
SprDensZ4	Spring forage fish density in Zone 4, no/ha
SprFish	Total number of forage fish lakewide in spring
TROUTkg	Trout (brown plus rainbow) biomass, kg
TROUTnum	Trout (brown plus rainbow) numbers
VIF	Variance Inflation Factor to test for multicollinearity, an issue if VIF≥10

Appendix Table 1. Linear regression analyses relating log spring forage fish lakewide numbers (logSprFish) and log spring forage fish densities (no/ha) in zones (logSprDens*Zn*) to the mean, lowest daily, and lowest 30-day moving average lake level observed December-February, where lake level is expressed as meters below full pool (positive number), using data from 1998-2013 (year is associated with January-February).

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1998-2013	Lakewide	Dep: logSprFish Indep: MeanDecFebLL	0.0870	0.2673	16	Intercept: <0.0001 MayOctLL: 0.2673	0.8856	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: MeanDecFebLL	0.0258	0.5523	16	Intercept: <0.0001 MayOctLL: 0.5523	0.6627	(none)	(none)
1998-2013	2	Dep: logSprDensZ2 Indep: MeanDecFebLL	0.0326	0.5035	16	Intercept: <0.0001 MayOctLL: 0.5035	0.4670	(none)	(none)
1998-2013	3	Dep: logSprDensZ3 Indep: MeanDecFebLL	0.0573	0.3720	16	Intercept: <0.0001 MayOctLL: 0.3720	0.2050	(none)	(none)
1998-2013	4	logSprDensZ4 = 2.80073 + 0.07909 MeanDecFebLL	0.1968	0.0852	16	Intercept: <0.0001 MayOctLL: 0.0852	0.5657	**1998 (SR=-2.518)**	(none)
1998-2013 (excl 1998)	4	Dep: logSprDensZ4 Indep: MeanDecFebLL	0.0785	0.3117	15	Intercept: <0.0001 MayOctLL: 0.3117	0.9498	(none)	(none)
1998-2013	Lakewide	Dep: logSprFish Indep: MaxDailyDecFebLL (lowest)	0.1141	0.2008	16	Intercept: <0.0001 MayOctLL: 0.2008	0.9606	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: MaxDailyDecFebLL (lowest)	0.0217	0.5865	16	Intercept: <0.0001 MayOctLL: 0.5865	0.2682	(none)	(none)
1998-2013	2	Dep: logSprDensZ2 Indep: MaxDailyDecFebLL (lowest)	0.0247	0.5608	16	Intercept: <0.0001 MayOctLL: 0.5608	0.2341	(none)	(none)
1998-2013	3	Dep: logSprDensZ3 Indep: MaxDailyDecFebLL (lowest)	0.0876	0.2657	16	Intercept: <0.0001 MayOctLL: 0.2657	0.0718	(none)	(none)
1998-2013	4	logSprDensZ4 = 2.69952 + 0.07997 MaxDailyDecFebLL (lowest)	0.2353	0.0569	16	Intercept: <0.0001 MayOctLL: 0.0569	0.5422	(none)	(none)
1998-2013	Lakewide	Dep: logSprFish Indep: Max30dayDecFebLL (lowest)	0.1084	0.2130	16	Intercept: <0.0001 MayOctLL: 0.2130	0.9613	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: Max30dayDecFebLL (lowest)	0.0188	0.6130	16	Intercept: <0.0001 MayOctLL: 0.6130	0.3450	(none)	(none)
1998-2013	2	Dep: logSprDensZ2 Indep: Max30dayDecFebLL (lowest)	0.0335	0.4975	16	Intercept: <0.0001 MayOctLL: 0.4975	0.3303	(none)	(none)
1998-2013	3	Dep: logSprDensZ3 Indep: Max30dayDecFebLL (lowest)	0.0688	0.3263	16	Intercept: <0.0001 MayOctLL: 0.3263	0.1022	(none)	(none)

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1998-2013	4	logSprDensZ4 = 2.74057 + 0.08246 Max30dayDecFebLL (lowest)	0.2364	0.0562	16	Intercept: <0.0001 MayOctLL: 0.0562	0.5243	(none)	(none)

Appendix Table 2. Linear regressions of fall forage fish lakewide numbers and fall forage fish densities (no/ha) in zones, on the mean, lowest daily, and lowest 30-day moving average lake level observed May-October. Lake level is expressed as meters below full pool (positive number).

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1997-2012	Lakewide	Dep: logFallFish Indep: MeanMayOctLL	0.1896	0.0918	16	Intercept: <0.0001 MayOctLL: 0.0918	0.2143	(none)	(none)
1997-2012	1	logFallDensZ1 = 2.68564 + 0.08596 MeanMayOctLL	0.3155	**0.0236**	16	Intercept: <0.0001 MayOctLL: **0.0236**	0.7774	(none)	(none)
1997-2012	2	Dep: logFallDensZ2 Indep: MeanMayOctLL	0.0460	0.4249	16	Intercept: <0.0001 MayOctLL: 0.4249	0.2598	**2002 (-2.649)**	(none)
1997-2012 (excl 2002)	2	logFallDensZ2 = 2.52462 + 0.06233 MeanMayOctLL	0.3057	**0.0326**	15	Intercept: <0.0001 MayOctLL: **0.0326**	0.2659	(none)	(none)
1997-2012	3	Dep: logFallDensZ3 Indep: MeanMayOctLL	0.0179	0.6211	16	Intercept: <0.0001 MayOctLL: 0.6211	0.0952	(none)	(none)
1997-2012	4	Dep: logFallDensZ4 Indep: MeanMayOctLL	0.0410	0.4520	16	Intercept: <0.0001 MayOctLL: 0.4520	0.8392	(none)	(none)
1997-2012	Lakewide	Dep: logFallFish Indep: MaxDailyMayOctLL (lowest)	0.1452	0.1454	16	Intercept: <0.0001 MayOctLL: 0.1454	0.9898	**2012 (2.515)**	(none)
1997-2012 (excl 2012)	Lakewide	Dep: logFallFish Indep: MaxDailyMayOctLL (lowest)	0.0946	0.2648	15	Intercept: <0.0001 MayOctLL: 0. 2648	0.3622	(none)	(none)
1997-2012	1	logFallDensZ1 = 2.56586 + 0.07394 MaxDailyMayOctLL (lowest)	0.2928	**0.0304**	16	Intercept: <0.0001 MayOctLL: **0.0304**	0.2290	(none)	(none)
1997-2012	2	Dep: logFallDensZ2 Indep: MaxDailyMayOctLL (lowest)	0.0335	0.4973	16	Intercept: <0.0001 MayOctLL: 0.4973	0.2932	(none)	(none)
1997-2012	3	Dep: logFallDensZ3 Indep: MaxDailyMayOctLL (lowest)	0.0069	0.7596	16	Intercept: <0.0001 MayOctLL: 0.7596	0.1463	(none)	(none)
1997-2012	4	Dep: logFallDensZ4 Indep: MaxDailyMayOctLL (lowest)	0.0127	0.6778	16	Intercept: <0.0001 MayOctLL: 0.6778	0.8774	(none)	(none)
1997-2012	Lakewide	Dep: logFallFish Indep: Max30dayMayOctLL (lowest)	0.1642	0.1195	16	Intercept: <0.0001 MayOctLL: 0.1195	0.7368	(none)	(none)
1997-2012	1	logFallDensZ1 = 2.58207 + 0.07884 Max30dayMayOctLL (lowest)	0.3192	**0.0226**	16	Intercept: <0.0001 MayOctLL: **0.0226**	0.3827	(none)	(none)
1997-2012	2	Dep: logFallDensZ2 Indep: Max30dayMayOctLL (lowest)	0.0324	0.5050	16	Intercept: <0.0001 MayOctLL: 0.5050	0.2722	(none)	(none)
1997-2012	3	Dep: logFallDensZ3 Indep: Max30dayMayOctLL (lowest)	0.0053	0.7878	16	Intercept: <0.0001 MayOctLL: 0.7878	0.1503	(none)	(none)

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1997-2012	4	Dep: logFallDensZ4 Indep: Max30dayMayOctLL (lowest)	0.0225	0.5796	16	Intercept: <0.0001 MayOctLL: 0.5796	0.9240	(none)	(none)

Appendix Table 3. Linear regressions of total numbers of forage fish lakewide in fall on numbers and biomass (kg) of potential predators per 40 gill net sets, based on gill net data 1999-2012 supplied by Rankin (2013).

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	LW	logFallFish logBTRnum	0.0503	0.4410	14	Intercept: <0.0001 BTRnum: 0.4410	0.2659	(none)	(none)
1999-2012	LW	logFallFish logBTRkg	0.0136	0.6914	14	Intercept: <0.0001 BTRkg: 0.6914	0.2455	(none)	(none)
1999-2012	LW	logFallFish logTROUTnum	0.0586	0.4044	14	Intercept: <0.0001 TROUTnum: 0.4044	0.2676	(none)	(none)
1999-2012	LW	logFallFish logTROUTkg	0.0117	0.7131	14	Intercept: <0.0001 TROUTkg: 0.7131	0.2566	(none)	(none)
1999-2012	LW	logFallFish logBLBnum	0.0032	0.8485	14	Intercept: <0.0001 BLBnum: 0.8485	0.5526	**2012 (SR=2.597)**	(none)
1999-2012	LW	logFallFish logBLBkg	0.0032	0.8467	14	Intercept: <0.0001 BLBkg: 0.8467	0.5176	**2012 (SR=2.698)**	(none)
1999-2012	LW	logFallFish logAllPrednum	0.0012	0.9053	14	Intercept: 0.0021 AllPrednum: 0.9053	0.4164	**2012 (SR=2.507)**	(none)
1999-2012	LW	logFallFish logAllPredkg	0.0000	0.9886	14	Intercept: <0.0001 AllPredkg: 0.9886	0.2053	**2012 (SR=2.589)**	(none)
1999-2012	LW	logFallFish REBnum	0.0230	0.6048	14	Intercept: <0.0001 REBnum: 0.6048	0.4844	**2012 (SR=2.516)**	(none)
1999-2012	LW	logFallFish logREBkg	0.0429	0.4776	14	Intercept: <0.0001 REBkg: 0.4776	0.5128	**2012 (SR=2.509)**	(none)
1999-2012	LW	logFallFish LMBnum	0.1743	0.1375	14	Intercept: <0.0001 LMBnum: 0.1375	0.9188	**2012 (SR=2.745)**	(none)
1999-2012	LW	logFallFish LMBkg	0.0869	0.3062	14	Intercept: <0.0001 LMBkg: 0.3062	0.9625	**2012 (SR=2.617)**	**2008 (CD=3.566)**
1999-2012	LW	logFallFish logWCTnum	0.0236	0.5999	14	Intercept: <0.0001 WCTnum: 0.5999	0.2925	(none)	(none)
1999-2012	LW	logFallFish logWCTkg	0.0467	0.4582	14	Intercept: <0.0001 WCTkg: 0.4582	0.4443	(none)	(none)

Appendix Table 4. Linear regressions of total numbers of forage fish lakewide in fall on numbers and biomass (kg) of potential predators per 40 gill net sets, based on gill net data 1999-2012 supplied by Rankin (2013), with data for 2012 excluded (identified as outlying in linear regressions in Appendix Table 3).

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012 (excl 2012)	LW	logFallFish logBLBnum	0.0933	0.3101	13	Intercept: <0.0001 BLBnum: 0.3101	0.3414	**2005 (SR=-2.515)**	(none)
1999-2012 (excl 2012)	LW	logFallFish logBLBkg	0.1858	0.1414	13	Intercept: <0.0001 BLBkg: 0.1414	0.3846	(none)	(none)
1999-2012 (excl 2012)	LW	logFallFish logAllPrednum	0.0120	0.7212	13	Intercept: 0.0003 AllPrednum: 0.7212	0.3941	(none)	(none)
1999-2012 (excl 2012)	LW	logFallFish logAllPredkg	0.0837	0.3377	13	Intercept: <0.0001 AllPredkg: 0.3377	0.1962	(none)	(none)
1999-2012 (excl 2012)	LW	logFallFish REBnum	0.0411	0.5066	13	Intercept: <0.0001 REBnum: 0.5066	0.3200	(none)	(none)
1999-2012 (excl 2012)	LW	logFallFish logREBkg	0.0550	0.4407	13	Intercept: <0.0001 REBkg: 0.4407	0.3456	(none)	(none)
1999-2012 (excl 2012)	LW	logFallFish = 6.41033 + 0.02629 LMBnum	0.3620	**0.0296**	13	Intercept: <0.0001 LMBnum: **0.0296**	0.1532	(none)	(none)
1999-2012 (excl 2012)	LW	logFallFish LMBkg	0.1862	0.1410	13	Intercept: <0.0001 LMBkg: 0.1410	0.1813	(none)	**2008 (CD=5.237)**

Appendix Table 5. Linear regression analyses relating log spring forage fish lakewide numbers (logSprFish) and log spring forage fish densities (no/ha) in zones (logSprDens*Zn*) to the mean, maximum daily, and maximum 30-day moving average generation flow at Jocassee Pumped Storage Station observed December-February, 1998-2013. Generation flow is expressed as m^3/sec.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1998-2013	Lakewide	Dep: logSprFish Indep: MeanDecFebJocGen	0.0050	0.7947	16	Intercept: <0.0001 DecFebGen: 0.7947	0.1842	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: MeanDecFebJocGen	0.0382	0.4682	16	Intercept: 0.0004 DecFebGen: 0.4682	0.6656	(none)	(none)
1998-2013	2	Dep: logSprDensZ2 Indep: MeanDecFebJocGen	0.1062	0.2180	16	Intercept: 0.0007 DecFebGen: 0.2180	0.4045	(none)	(none)
1998-2013	3	Dep: logSprDensZ3 Indep: MeanDecFebJocGen	0.0589	0.3652	16	Intercept: 0.0002 DecFebGen: 0.3652	0.2070	(none)	(none)
1998-2013	4	Dep: logSprDensZ4 Indep: MeanDecFebJocGen	0.0015	0.8852	16	Intercept: <0.0001 DecFebGen: 0.8852	0.2995	**1998 (SR=-2.715)**	(none)
1998-2013 (excl 1998)	4	Dep: logSprDensZ4 Indep: MeanDecFebJocGen	0.0089	0.7381	15	Intercept: <0.0001 DecFebGen: 0.7381	0.2795	(none)	(none)
1998-2013	Lakewide	Dep: logSprFish Indep: MaxDailyDecFebJocGen	0.0311	0.5135	16	Intercept: <0.0001 DecFebGen: 0.5135	0.6946	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: MaxDailyDecFebJocGen	0.1453	0.1452	16	Intercept: 0.0178 DecFebGen: 0.1452	0.3591	(none)	(none)
1998-2013	2	Dep: logSprDensZ2 Indep: MaxDailyDecFebJocGen	0.1429	0.1489	16	Intercept: 0.0156 DecFebGen: 0.1489	0.3925	(none)	(none)
1998-2013	3	Dep: logSprDensZ3 Indep: MaxDailyDecFebJocGen	0.0491	0.4096	16	Intercept: 0.0033 DecFebGen: 0.4096	0.3673	(none)	(none)
1998-2013	4	Dep: logSprDensZ4 Indep: MaxDailyDecFebJocGen	0.0006	0.9290	16	Intercept: <0.0001 DecFebGen: 0.9290	0.5945	**1998 (SR=-2.726)**	(none)
1998-2013 (excl 1998)	4	Dep: logSprDensZ4 Indep: MaxDailyDecFebJocGen	0.0168	0.6448	15	Intercept: <0.0001 DecFebGen: 0.6448	0.7811	(none)	(none)
1998-2013	Lakewide	Dep: logSprFish Indep: Max30dayDecFebJocGen	0.0087	0.7308	16	Intercept: <0.0001 DecFebGen: 0.7308	0.2657	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: Max30dayDecFebJocGen	0.0307	0.5161	16	Intercept: 0.0008 DecFebGen: 0.5161	0.5251	(none)	(none)
1998-2013	2	Dep: logSprDensZ2 Indep: Max30dayDecFebJocGen	0.0507	0.4018	16	Intercept: 0.0009 DecFebGen: 0.4018	0.4072	(none)	(none)
1998-2013	3	Dep: logSprDensZ3 Indep: Max30dayDecFebJocGen	0.0509	0.4009	16	Intercept: 0.0004 DecFebGen: 0.4009	0.2212	(none)	(none)
1998-2013	4	Dep: logSprDensZ4 Indep: Max30dayDecFebJocGen	0.0007	0.9201	16	Intercept: <0.0001 DecFebGen: 0.9201	0.3140	**1998 (SR=-2.712)**	(none)
1998-2013 (excl 1998)	4	Dep: logSprDensZ4 Indep: Max30dayDecFebJocGen	0.0059	0.7860	15	Intercept: <0.0001 DecFebGen: 0.7860	0.2814	(none)	(none)

Appendix Table 6. Linear regression analyses relating log fall forage fish lakewide numbers (logFallFish) and log fall forage fish densities (no/ha) in zones (logFallDens*Zn*) to the mean, maximum daily, and maximum 30-day moving average generation flow at Jocassee Pumped Storage Station observed December-February, 1998-2013. Generation flow is expressed as m^3/sec. Regressions were repeated where significant outlying or highly influential observations were identified.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1997-2012	Lakewide	Dep: logFallFish Indep: MeanMayOctJocGen	0.2010	0.0816	16	Intercept: <0.0001 MayOctGen: 0.0816	0.9156	**2012 (SR=2.799)**	(none)
1997-2012 (excl 2012)	Lakewide	logFallFish = 7.14429 – 0.00333 MeanMayOctJocGen	0.3202	**0.0279**	15	Intercept: <0.0001 MayOctGen: **0.0279**	0.5163	(none)	(none)
1997-2012	1	logFallDensZ1 = 4.28240 – 0.00776 MeanMayOctJocGen	0.2276	0.0617	16	Intercept: <0.0001 MayOctGen: 0.0617	0.7041	(none)	(none)
1997-2012	2	Dep: logFallDensZ2 Indep: MeanMayOctJocGen	0.0382	0.4683	16	Intercept: 0.0001 MayOctGen: 0.4683	0.3940	(none)	(none)
1997-2012	3	Dep: logFallDensZ3 Indep: MeanMayOctJocGen	0.1142	0.2006	16	Intercept: <0.0001 MayOctGen: 0.2006	0.3647	(none)	(none)
1997-2012	4	Dep: logFallDensZ4 Indep: MeanMayOctJocGen	0.0012	0.8986	16	Intercept: <0.0001 MayOctGen: 0.8986	0.4885	(none)	(none)
1997-2012	Lakewide	Dep: logFallFish Indep: MaxDailyMayOctJocGen	0.1565	0.1293	16	Intercept: <0.0001 MayOctGen: 0.1293	0.8371	**2012 (SR=2.564)**	(2004) (CD=3.23)
1997-2012 (excl 2012)	Lakewide	Dep: logFallFish Indep: MaxDailyMayOctJocGen	0.1355	0.1771	15	Intercept: <0.0001 MayOctGen: 0.1771	0.8337	**2005 (SR=-2.659)**	(none)
1997-2012	1	logFallDensZ1 = 4.49088 – 0.00359 MaxDailyMayOctJocGen	0.3682	**0.0127**	16	Intercept: <0.0001 MayOctGen: **0.0127**	0.8593	(none)	**2004 (CD=3.869)**
1997-2012 (excl 2004)	1	logFallDensZ1 = 5.84017 – 0.00693 MaxDailyMayOctJocGen	0.4347	**0.0075**	15	Intercept: <0.0001 MayOctGen: **0.0075**	0.7488	(none)	(none)
1997-2012	2	Dep: logFallDensZ2 Indep: MaxDailyMayOctJocGen	0.0703	0.3212	16	Intercept: <0.0001 MayOctGen: 0.3212	0.6767	(none)	(none)
1997-2012	3	Dep: logFallDensZ3 Indep: MaxDailyMayOctJocGen	0.0058	0.7787	16	Intercept: <0.0001 MayOctGen: 0.7787	0.4331	(none)	(none)
1997-2012	4	Dep: logFallDensZ4 Indep: MaxDailyMayOctJocGen	0.0001	0.9664	16	Intercept: <0.0001 MayOctGen: 0.9664	0.5295	(none)	(none)
1997-2012	Lakewide	Dep: logFallFish Indep: Max30dayMayOctJocGen	0.0922	0.2530	16	Intercept: <0.0001 MayOctGen: 0.2530	0.6256	**2012 (SR=2.577)**	(none)
1997-2012 (excl 2012)	Lakewide	Dep: logFallFish Indep: Max30dayMayOctJocGen	0.0777	0.3143	15	Intercept: <0.0001 MayOctGen: 0.3143	0.5490	**2005 (SR=-2.511)**	(none)
1997-2012	1	Dep: logFallDensZ1 Indep: Max30dayMayOctJocGen	0.0721	0.3147	16	Intercept: 0.0001 MayOctGen: 0.3147	0.4845	(none)	(none)

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1997-2012	2	Dep: logFallDensZ2 Indep: Max30dayMayOctJocGen	0.0086	0.7327	16	Intercept: 0.0003 MayOctGen: 0.7327	0.2930	(none)	(none)
1997-2012	3	logFallDensZ3 = 3.97878 – 0.00432 Max30dayMayOctJocGen	0.2312	0.0594	16	Intercept: <0.0001 MayOctGen: 0.0594	0.5202	(none)	(none)
1997-2012	4	Dep: logFallDensZ4 Indep: Max30dayMayOctJocGen	0.0003	0.9503	16	Intercept: <0.0001 MayOctGen: 0.9503	0.4980	(none)	(none)

Appendix Table 7. Linear regression analyses of log spring forage fish lakewide numbers (logSprFish) and log spring forage fish densities (no/ha) in zones (logSprDens*Zn*) on mean, maximum daily, and maximum 30-day moving average pumping flows (m^3/sec) observed December-February at Bad Creek Pumped Storage Station, 1998-2013. Pumping variables were calculated based on daily mean pumping flows. Regressions were repeated excluding any significant outlying or highly influential observations.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1998-2013	Lakewide	Dep: logSprFish Indep: MeanDecFebBCPump	0.0056	0.7835	16	Intercept: <0.0001 DecFebPump: 0.7835	0.2308	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: MeanDecFebBCPump	0.0009	0.9105	16	Intercept: 0.0058 DecFebPump: 0.9105	0.8617	(none)	(none)
1998-2013	2	Dep: log SprDensZ2 Indep: MeanDecFebBCPump	0.0097	0.7164	16	Intercept: 0.0020 DecFebPump: 0.7164	0.2739	(none)	(none)
1998-2013	3	Dep: log SprDensZ3 Indep: MeanDecFebBCPump	0.0575	0.3710	16	Intercept: 0.0114 DecFebPump: 0.3710	0.1037	(none)	(none)
1998-2013	4	Dep: log SprDensZ4 Indep: MeanDecFebBCPump	0.0114	0.6936	16	Intercept: 0.0003 DecFebPump: 0.6936	0.3059	**1998 (SR=-2.721)**	(none)
1998-2013 (excl 1998)	4	Dep: log SprDensZ4 Indep: MeanDecFebBCPump	0.0239	0.5822	15	Intercept: <0.0001 DecFebPump: 0.5822	0.4196	(none)	(none)
1998-2013	Lakewide	Dep: logSprFish Indep: MaxDailyDecFebBCPump	0.0709	0.3187	16	Intercept: <0.0001 DecFebPump: 0.3187	0.2726	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: MaxDailyDecFebBCPump	0.0085	0.7341	16	Intercept: 0.0939 DecFebPump: 0.7341	0.7687	(none)	(none)
1998-2013	2	Dep: log SprDensZ2 Indep: MaxDailyDecFebBCPump	0.0190	0.6106	16	Intercept: 0.1179 DecFebPump: 0.6106	0.3783	(none)	(none)
1998-2013	3	Dep: log SprDensZ3 Indep: MaxDailyDecFebBCPump	0.0545	0.3842	16	Intercept: 0.1505 DecFebPump: 0.3842	0.8172	(none)	(none)

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1998-2013	4	Dep: log SprDensZ4 Indep: MaxDailyDecFebBCPump	0.0351	0.4869	16	Intercept: 0.0201 DecFebPump: 0.4869	0.3117	**1998 (SR=-2.661)**	(none)
1998-2013 (excl 1998)	4	Dep: log SprDensZ4 Indep: MaxDailyDecFebBCPump	0.0006	0.9288	15	Intercept: 0.0007 DecFebPump: 0.9288	0.5215	(none)	(none)
1998-2013	Lakewide	Dep: logSprFish Indep: Max30dayDecFebBCPump	0.0119	0.6874	16	Intercept: <0.0001 DecFebPump: 0.6874	0.2195	(none)	(none)
1998-2013	1	Dep: logSprDensZ1 Indep: Max30dayDecFebBCPump	0.0030	0.8400	16	Intercept: 0.0083 DecFebPump: 0.8400	0.9721	(none)	(none)
1998-2013	2	Dep: log SprDensZ2 Indep: Max30dayDecFebBCPump	0.0064	0.7678	16	Intercept: 0.0063 DecFebPump: 0.7678	0.1868	(none)	(none)
1998-2013	3	Dep: log SprDensZ3 Indep: Max30dayDecFebBCPump	0.0352	0.4868	16	Intercept: 0.0252 DecFebPump: 0.4868	0.1943	(none)	(none)
1998-2013	4	Dep: log SprDensZ4 Indep: Max30dayDecFebBCPump	0.0242	0.5655	16	Intercept: 0.0017 DecFebPump: 0.5655	0.2621	**1998 (SR=-2.689)**	(none)
1998-2013 (excl 1998)	4	Dep: log SprDensZ4 Indep: Max30dayDecFebBCPump	0.0112	0.7075	15	Intercept: <0.0001 DecFebPump: 0.7075	0.3318	(none)	(none)

Appendix Table 8. Linear regression analyses of log fall forage fish lakewide numbers (logFallFish) and log fall forage fish densities (no/ha) in zones (logFallDens*Zn*) on mean, maximum daily, and maximum 30-day moving average pumping flows (m^3/sec) observed May-October at Bad Creek Pumped Storage Station, 1997-2012. Pumping variables were calculated based on daily mean pumping flows.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1997-2012	Lakewide	Dep: logLakewideNum Indep: MeanMayOctBCPump	0.1408	0.1522	16	Intercept: <0.0001 MayOctPump: 0.1522	0.1793	(none)	(none)
1997-2012	1	Dep: logZone1noha Indep: MeanMayOctBCPump	0.0609	0.3569	16	Intercept: 0.0012 MayOctPump: 0.3569	0.6571	(none)	(none)
1997-2012	2	Dep: logZone2noha Indep: MeanMayOctBCPump	0.0757	0.3024	16	Intercept: 0.0005 MayOctPump: 0.3024	0.9445	(none)	(none)
1997-2012	3	Dep: logZone3noha Indep: MeanMayOctBCPump	0.1244	0.1803	16	Intercept: <0.0001 MayOctPump: 0.1803	0.4706	(none)	(none)
1997-2012	4	Dep: logZone4noha Indep: MeanMayOctBCPump	0.0163	0.6374	16	Intercept: <0.0001 MayOctPump: 0.6374	0.3029	(none)	(none)
1997-2012	Lakewide	Dep: logLakewideNum Indep: MaxDailyMayOctBCPump	0.1192	0.1904	16	Intercept: <0.0001 MayOctPump: 0.1904	0.1027	(none)	(none)
1997-2012	1	Dep: logZone1noha Indep: MaxDailyMayOctBCPump	0.0165	0.6356	16	Intercept: 0.0037 MayOctPump: 0.6356	0.2896	(none)	(none)
1997-2012	2	Dep: logZone2noha Indep: MaxDailyMayOctBCPump	0.0158	0.6427	16	Intercept: 0.0022 MayOctPump: 0.6427	0.3507	(none)	(none)
1997-2012	3	Dep: logZone3noha Indep: MaxDailyMayOctBCPump	0.0002	0.9543	16	Intercept: 0.0018 MayOctPump: 0.9543	0.4372	(none)	(none)
1997-2012	4	logZone4noha = 4.58616 – 0.00437 MaxDailyMayOctBCPump	0.3727	**0.0120**	16	Intercept: <0.0001 MayOctPump: **0.0120**	0.4259	(none)	(none)
1997-2012	Lakewide	Dep: logLakewideNum Indep: Max30dayMayOctBCPump	0.1478	0.1414	16	Intercept: <0.0001 MayOctPump: 0.1414	0.1235	(none)	(none)
1997-2012	1	Dep: logZone1noha Indep: Max30dayMayOctBCPump	0.0403	0.4562	16	Intercept: 0.0080 MayOctPump: 0.4562	0.1437	(none)	(none)
1997-2012	2	Dep: logZone2noha Indep: Max30dayMayOctBCPump	0.1097	0.2101	16	Intercept: 0.0015 MayOctPump: 0.2101	0.8341	(none)	(none)
1997-2012	3	logZone3noha = 4.78935 – 0.01028 Max30dayMayOctBCPump	0.2395	0.0543	16	Intercept: <0.0001 MayOctPump: 0.0543	0.0837	(none)	(none)
1997-2012	4	Dep: logZone4noha Indep: Max30dayMayOctBCPump	0.0301	0.5202	16	Intercept: <0.0001 MayOctPump: 0.5202	0.2295	(none)	(none)

Appendix Table 9. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and December-February lake level (mean, lowest daily, lowest 30-day average), based on data collected 1998-2013. Lake level is expressed as meters below full pool.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: MeanDecFebBCpump	0.0875	0.5515	16	Intercept: <0.0001 LakeLevel: 0.2997 BCPump: 0.9379	1.035	0.4950	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: MaxDailyDecFebBCpump	0.2242	0.1921	16	Intercept: <0.0001 LakeLevel: 0.1331 BCPump: 0.1535	1.096	0.6044	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: Max30dayDecFebBCpump	0.0982	0.5107	16	Intercept: <0.0001 LakeLevel: 0.2849 BCPump: 0.6946	1.000	0.4014	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: MeanDecFebBCpump	0.1141	0.4551	16	Intercept: <0.0001 LakeLevel: 0.2292 BCPump: 0.9911	1.056	0.5166	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: MaxDailyDecFebBCpump	0.2546	0.1481	16	Intercept: <0.0001 LakeLevel: 0.0968 BCPump: 0.1415	1.084	0.6355	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: Max30dayDecFebBCpump	0.1211	0.4323	16	Intercept: <0.0001 LakeLevel: 0.2262 BCPump: 0.7527	1.006	0.3992	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: MeanDecFebBCpump	0.1085	0.4741	16	Intercept: <0.0001 LakeLevel: 0.2423 BCPump: 0.9775	1.044	0.5142	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: MaxDailyDecFebBCpump	0.2583	0.1434	16	Intercept: <0.0001 LakeLevel: 0.0931 BCPump: 0.1290	1.106	0.6300	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: Max30dayDecFebBCpump	0.1174	0.4440	16	Intercept: <0.0001 LakeLevel: 0.2345 BCPump: 0.7214	1.002	0.4187	(none)	(none)

Appendix Table 10. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and December-February lake level (mean, lowest daily, lowest 30-day average), with an interaction variable calculated as the product of the two independent variables. To prevent multicollinearity, variables were centered prior to calculating interaction term. Regressions were carried out with centered variables. Lake level is expressed as meters below full pool.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: MeanDecFebBCpump Indep: Interaction	0.1119	0.6866	16	Intercept: <0.0001 LakeLevel: 0.3342 BCPump: 0.7830 Inter: 0.5760	1.193	0.6535	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: MaxDailyDecFebBCpump Indep: Interaction	0.2771	0.2564	16	Intercept: <0.0001 LakeLevel: 0.1361 BCPump: 0.4039 Inter: 0.3669	1.433	0.5479	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: Max30dayDecFebBCpump Indep: Interaction	0.1735	0.4980	16	Intercept: <0.0001 LakeLevel: 0.2892 BCPump: 0.4897 Inter: 0.3165	1.111	0.3860	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: MeanDecFebBCpump Indep: Interaction	0.1586	0.5411	16	Intercept: <0.0001 LakeLevel: 0.2300 BCPump: 0.7564 Inter: 0.4411	1.271	0.5380	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: MaxDailyDecFebBCpump Indep: Interaction	0.3162	0.1920	16	Intercept: <0.0001 LakeLevel: 0.0831 BCPump: 0.3792 Inter: 0.3189	1.377	0.5738	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: Max30dayDecFebBCpump Indep: Interaction	0.2268	0.3607	16	Intercept: <0.0001 LakeLevel: 0.1798 BCPump: 0.4410 Inter: 0.2244	1.191	0.2744	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: MeanDecFebBCpump Indep: Interaction	0.1427	0.5891	16	Intercept: <0.0001 LakeLevel: 0.2695 BCPump: 0.7724 Inter: 0.5022	1.231	0.6953	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: MaxDailyDecFebBCpump Indep: Interaction	0.3211	0.1848	16	Intercept: <0.0001 LakeLevel: 0.0814 BCPump: 0.3517 Inter: 0.3127	1.395	0.5817	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: Max30dayDecFebBCpump Indep: Interaction	0.2129	0.3939	16	Intercept: <0.0001 LakeLevel: 0.2180 BCPump: 0.4512 Inter: 0.2510	1.150	0.3096	(none)	(none)

Appendix Table 11. Multiple regression analyses of spring forage fish density (no/ha) in Zone 2 on variables for December-February BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and December-February lake level (mean, lowest daily, lowest 30-day average), based on data collected 1998-2013. Lake level is expressed as meters below full pool.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
2	1998-2013	Dep: logSprDensZ2 Indep: MeanDecFebLL Indep: MeanDecFebBCpump	0.0370	0.7825	16	Intercept: 0.0024 LakeLevel: 0.5542 BCPump: 0.8102	1.035	0.1561	(none)	(none)
2	1998-2013	Dep: logSprDensZ2 Indep: MeanDecFebLL Indep: MaxDailyDecFebBCpump	0.0404	0.7649	16	Intercept: 0.1152 LakeLevel: 0.5996 BCPump: 0.7501	1.096	0.7770	(none)	(none)
2	1998-2013	Dep: logSprDensZ2 Indep: MeanDecFebLL Indep: Max30dayDecFebBCpump	0.0387	0.7738	16	Intercept: 0.0068 LakeLevel: 0.5206 BCPump: 0.7785	1.000	0.2590	(none)	(none)
2	1998-2013	Dep: logSprDensZ2 Indep: MaxDailyDecFebLL Indep: MeanDecFebBCpump	0.0289	0.8267	16	Intercept: 0.0026 LakeLevel: 0.6212 BCPump: 0.8180	1.056	0.1640	(none)	(none)
2	1998-2013	Dep: logSprDensZ2 Indep: MaxDailyDecFebLL Indep: MaxDailyDecFebBCpump	0.0344	0.7968	16	Intercept: 0.1251 LakeLevel: 0.6570 BCPump: 0.7248	1.084	0.5478	(none)	(none)
2	1998-2013	Dep: logSprDensZ2 Indep: MaxDailyDecFebLL Indep: Max30dayDecFebBCpump	0.0294	0.8236	16	Intercept: 0.0074 LakeLevel: 0.5884 BCPump: 0.8062	1.006	0.2023	(none)	(none)
2	1998-2013	Dep: logSprDensZ2 Indep: Max30dayDecFebLL Indep: MeanDecFebBCpump	0.0374	0.7805	16	Intercept: 0.0024 LakeLevel: 0.5514 BCPump: 0.8219	1.044	0.1888	(none)	(none)
2	1998-2013	Dep: logSprDensZ2 Indep: Max30dayDecFebLL Indep: MaxDailyDecFebBCpump	0.0408	0.7628	16	Intercept: 0.1161 LakeLevel: 0.5960 BCPump: 0.7580	1.106	0.6415	(none)	(none)
2	1998-2013	Dep: logSprDensZ2 Indep: Max30dayDecFebLL Indep: Max30dayDecFebBCpump	0.0387	0.7736	16	Intercept: 0.0068 LakeLevel: 0.5202 BCPump: 0.7945	1.002	0.2555	(none)	(none)

Appendix Table 12. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and winter surface (0-4 m) temperature (C) (minimum, January-February mean), based on data collected 1998-2013. Where outlying or highly influential observations were identified regressions were rerun, excluding those observations.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish MeanDecFebBCPump LWMinTemp	0.2237	0.2189	15	Intercept: 0.0330 BCPump: 0.4383 MinTemp: 0.0907	1.095	0.6036	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebBCPump LWMinTemp	0.2808	0.1384	15	Intercept: 0.0407 BCPump: 0.2236 MinTemp: 0.0892	1.008	0.2280	**2013 (SR=2.526)**	(none)
LW	1998-2013 (excl 2013)	logSprFish = 2.87486 + 0.00536 MaxDailyDecFebBCPump + 0.18956 LWMinTemp	0.5271	**0.0163**	14	Intercept: 0.0150 BCPump: **0.0173** MinTemp: **0.0453**	1.003	0.3501	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebBCPump LWMinTemp	0.2165	0.2314	15	Intercept: 0.0260 BCPump: 0.4823 MinTemp: 0.1016	1.033	0.5958	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebBCPump LWJanFebTemp	0.3206	0.0811	16	Intercept: 0.0512 BCPump: 0.2262 JanFebTmp: **0.0289**	1.185	0.7125	**2013 (SR=2.576)**	(none)
LW	1998-2013 (excl 2013)	logSprFish = 2.54921 + 0.00763 MeanDecFebBCPump + 0.26864 LWJanFebTemp	0.5326	**0.0104**	15	Intercept: 0.0236 BCPump: **0.0201** JanFebTmp: **0.0055**	1.168	0.1629	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebBCPump LWJanFebTemp	0.3342	0.0711	16	Intercept: 0.0276 BCPump: 0.1899 JanFebTmp: **0.0411**	1.009	0.5895	**2013 (SR=2.574)**	(none)
LW	1998-2013 (excl 2013)	logSprFish = 2.89803 + 0.00452 MaxDailyDecFebBCPump + 0.20059 LWJanFebTemp	0.5411	**0.0093**	15	Intercept: 0.0072 BCPump: **0.0178** JanFebTmp: **0.0178**	1.004	0.6118	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebBCPump LWJanFebTemp	0.2995	0.0988	16	Intercept: 0.0311 BCPump: 0.2979 JanFebTmp: **0.0379**	1.081	0.7026	**2013 (SR=2.605)**	(none)
LW	1998-2013 (excl 2013)	logSprFish = 2.75780 + 0.00753 Max30dayDecFebBCPump + 0.23812 LWJanFebTemp	0.5297	**0.0108**	15	Intercept: 0.0127 BCPump: **0.0209** JanFebTmp: **0.0088**	1.066	0.3158	(none)	(none)

Appendix Table 13. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average); winter surface (0-4 m) temperature (C) (minimum, January-February mean); and an interaction variable, calculated as the product of the centered independent variables for pumping and temperature, based on data collected 1998-2013. Independent variables in these regressions have been centered.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish CMeanDecFebBCPump CLWMinTemp Interaction	0.2700	0.3068	15	Intercept: <0.0001 BCPump: 0.3303 MinTemp: 0.1006 Inter: 0.4213	1.222	0.8246	(none)	(none)
LW	1998-2013	logSprFish CMaxDailyDecFebBCPump CLWMinTemp Incteraction	0.3511	0.1749	15	Intercept: <0.0001 BCPump: 0.1344 MinTemp: 0.0573 Inter: 0.2983	1.280	0.6189	**2013 (SR=2.523)**	(none)
LW	1998-2013 (excl 2013)	logSprFish = 6.10355 + 0.00644 CMaxDailyDecFebBCPump + 0.23262 CLWMinTemp – 0.00437 Interaction	0.6160	**0.0186**	14	Intercept: <0.0001 BCPump: **0.0078** MinTemp: **0.0201** Inter: 0.1590	1.268	0.3224	(none)	(none)
LW	1998-2013	logSprFish CMax30dayDecFebBCPump CLWMinTemp Interaction	0.2780	0.2915	15	Intercept: <0.0001 BCPump: 0.5086 MinTemp: 0.1075 Inter: 0.3538	1.035	0.7889	(none)	(none)
LW	1998-2013	logSprFish CMeanDecFebBCPump CLWJanFebTemp Interaction	0.3737	0.1201	16	Intercept: <0.0001 BCPump: 0.2097 JanFebTmp: **0.0349** Inter: 0.3330	1.191	0.8973	**2013 (SR=2.556)**	(none)
LW	1998-2013 (excl 2013)	LogSprFish CMeanDecFebBCPump CLWJanFebTemp Interaction	0.5990	**0.0150**	15	Intercept: <0.0001 BCPump: **0.0164** JanFebTmp: **0.0061** Inter: 0.2042	1.174	0.3043	(none)	(none)
LW	1998-2013	logSprFish CMaxDailyDecFebBCPump CLWJanFebTemp Interaction	0.3959	0.0987	16	Intercept: <0.0001 BCPump: 0.1180 JanFebTmp: **0.0290** Inter: 0.2900	1.166	0.8295	**2013 (SR=2.528)**	(none)
LW	1998-2013 (excl 2013)	logSprFish CMaxDailyDecFebBCPump CLWJanFebTemp Interaction	0.6030	**0.0143**	15	Intercept: <0.0001 BCPump: **0.0103** JanFebTmp: **0.0110** Inter: 0.2168	1.154	0.4625	(none)	(none)

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish CMax30dayDecFebBCPump CLWJanFebTemp Interaction	0.3843	0.1095	16	Intercept: <0.0001 BCPump: 0.2869 JanFebTmp: **0.0308** Inter: 0.2230	1.085	0.8332	**2013 (SR=2.525)**	(none)
LW	1998-2013 (excl 2013)	logSprFish CMax30dayDecFebBCPump CLWJanFebTemp Interaction	0.5945	**0.0159**	15	Intercept: <0.0001 BCPump: **0.0214** JanFebTmp: **0.0070** Inter: 0.2115	1.071	0.3472	(none)	(none)

Appendix Table 14. Multiple regression analyses of spring forage fish density (no/ha) in Zone 2 on variables for December-February BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and winter surface (0-4 m) zonal temperature (C) (minimum, January-February mean), based on data collected 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
2	1998-2013	logSprDens MeanDecFebBCPump ZoneMinTemp	0.2001	0.2620	15	Intercept: 0.7335 BCPump: 0.8075 MinTemp: 0.1450	1.101	0.6463	(none)	(none)
2	1998-2013	logSprDens MaxDailyDecFebBCPump ZoneMinTemp	0.1996	0.2628	15	Intercept: 0.5490 BCPump: 0.8174 MinTemp: 0.1102	1.003	0.5159	(none)	(none)
2	1998-2013	logSprDens Max30dayDecFebBCPump ZoneMinTemp	0.2133	0.2370	15	Intercept: 0.8121 BCPump: 0.6157 MinTemp: 0.1350	1.036	0.6061	(none)	(none)
2	1998-2013	logSprDens MeanDecFebBCPump ZoneJanFebTemp	0.1859	0.2627	16	Intercept: 0.5469 BCPump: 0.7359 JanFebTmp: 0.1174	1.213	0.5050	(none)	(none)
2	1998-2013	logSprDens MaxDailyDecFebBCPump ZoneJanFebTemp	0.2051	0.2249	16	Intercept: 0.4498 BCPump: 0.5207 JanFebTmp: 0.1047	1.004	0.7250	(none)	(none)
2	1998-2013	logSprDens Max30dayDecFebBCPump ZoneJanFebTemp	0.1803	0.2746	16	Intercept: 0.6104 BCPump: 0.8658 JanFebTmp: 0.1207	1.090	0.4167	(none)	(none)

Appendix Table 15. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and December-February lake level (mean, lowest daily, lowest 30-day average), based on data collected 1998-2013. Lake level is expressed as meters below full pool.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: MeanDecFebJocGen	0.1098	0.4695	16	Intercept: <0.0001 LakeLevel: 0.2379 JocGen: 0.5741	1.069	0.3788	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: MaxDailyDecFebJocGen	0.1189	0.4390	16	Intercept: <0.0001 LakeLevel: 0.2755 JocGen: 0.5047	1.000	0.6209	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebLL Indep: Max30dayDecFebJocGen	0.1090	0.4722	16	Intercept: <0.0001 LakeLevel: 0.2479 JocGen: 0.5809	1.033	0.4279	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: MeanDecFebJocGen	0.1357	0.3877	16	Intercept: <0.0001 LakeLevel: 0.1844 JocGen: 0.5784	1.049	0.4190	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: MaxDailyDecFebJocGen	0.1466	0.3568	16	Intercept: <0.0001 LakeLevel: 0.2075 JocGen: 0.4937	1.000	0.6965	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebLL Indep: Max30dayDecFebJocGen	0.1331	0.3953	16	Intercept: <0.0001 LakeLevel: 0.1953 JocGen: 0.6025	1.017	0.4614	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: MeanDecFebJocGen	0.1332	0.3948	16	Intercept: <0.0001 LakeLevel: 0.1888 JocGen: 0.5522	1.066	0.4080	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: MaxDailyDecFebJocGen	0.1441	0.3637	16	Intercept: <0.0001 LakeLevel: 0.2129 JocGen: 0.4748	1.001	0.6370	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebLL Indep: Max30dayDecFebJocGen	0.1306	0.4027	16	Intercept: <0.0001 LakeLevel: 0.2001 JocGen: 0.5747	1.027	0.4523	(none)	(none)

Appendix Table 16. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average); December-February lake level (meters below full pool) (mean, lowest daily, lowest 30-day average); and an interaction variable calculated as the product of the centered independent variables. Independent variables are centered in this analysis. Analyses are based on data collected 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	Dep: logSprFish Indep: CMeanDecFebLL Indep: CMeanDecFebJocGen Indep: Interaction	0.1117	0.6873	16	Intercept: <0.0001 LakeLevel: 0.3407 JocGen: 0.6357 Inter: 0.8752	1.338	0.6580	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMeanDecFebLL Indep: CMaxDailyDecFebJocGen Indep: Interaction	0.2894	0.2347	16	Intercept: <0.0001 LakeLevel: 0.8175 JocGen: 0.5457 Inter: 0.1155	2.177	0.5815	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMeanDecFebLL Indep: CMax30dayDecFebJocGen Indep: Interaction	0.1101	0.6925	16	Intercept: <0.0001 LakeLevel: 0.3064 JocGen: 0.6117 Inter: 0.9054	1.142	0.5013	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMaxDailyDecFebLL Indep: CMeanDecFebJocGen Indep: Interaction	0.1509	0.5639	16	Intercept: <0.0001 LakeLevel: 0.1980 JocGen: 0.5021 Inter: 0.6507	1.656	0.4593	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMaxDailyDecFebLL Indep: CMaxDailyDecFebJocGen Indep: Interaction	0.2308	0.3515	16	Intercept: <0.0001 LakeLevel: 0.6893 JocGen: 0.7099 Inter: 0.2742	2.770	0.4751	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMaxDailyDecFebLL Indep: CMax30dayDecFebJocGen Indep: Interaction	0.1491	0.5693	16	Intercept: <0.0001 LakeLevel: 0.1884 JocGen: 0.5338 Inter: 0.6426	1.339	0.4894	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMax30dayDecFebLL Indep: CMeanDecFebJocGen Indep: Interaction	0.1384	0.6023	16	Intercept: <0.0001 LakeLevel: 0.2265 JocGen: 0.5309 Inter: 0.7935	1.484	0.5267	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMax30dayDecFebLL Indep: CMaxDailyDecFebJocGen Indep: Interaction	0.2534	0.3024	16	Intercept: <0.0001 LakeLevel: 0.6605 JocGen: 0.6343 Inter: 0.2096	2.597	0.5930	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMax30dayDecFebLL Indep: CMax30dayDecFebJocGen Indep: Interaction	0.1366	0.6080	16	Intercept: <0.0001 LakeLevel: 0.2131 JocGen: 0.5511 Inter: 0.7779	1.213	0.5244	(none)	(none)

Appendix Table 17. Multiple regression analyses of spring forage fish density (no/ha) in Zone 1 on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and December-February lake level (meters below full pool) (mean, lowest daily, lowest 30-day average), based on data collected 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
1	1998-2013	Dep: logSprDensZ1 Indep: MeanDecFebLL Indep: MeanDecFebJocGen	0.0856	0.5591	16	Intercept: 0.0086 LakeLevel: 0.4267 JocGen: 0.3734	1.069	0.8726	(none)	(none)
1	1998-2013	Dep: logSprDensZ1 Indep: MeanDecFebLL Indep: MaxDailyDecFebJocGen	0.1721	0.2931	16	Intercept: 0.0441 LakeLevel: 0.5282 JocGen: 0.1536	1.000	0.4900	(none)	(none)
1	1998-2013	Dep: logSprDensZ1 Indep: MeanDecFebLL Indep: Max30dayDecFebJocGen	0.0687	0.6295	16	Intercept: 0.0080 LakeLevel: 0.4793 JocGen: 0.4528	1.033	0.7308	(none)	(none)
1	1998-2013	Dep: logSprDensZ1 Indep: MaxDailyDecFebLL Indep: MeanDecFebJocGen	0.0758	0.5991	16	Intercept: 0.0100 LakeLevel: 0.4800 JocGen: 0.3987	1.049	0.5847	(none)	(none)
1	1998-2013	Dep: logSprDensZ1 Indep: MaxDailyDecFebLL Indep: MaxDailyDecFebJocGen	0.1683	0.3017	16	Intercept: 0.0523 LakeLevel: 0.5588 JocGen: 0.1539	1.000	0.3018	(none)	(none)
1	1998-2013	Dep: logSprDensZ1 Indep: MaxDailyDecFebLL Indep: Max30dayDecFebJocGen	0.0600	0.6689	16	Intercept: 0.0087 LakeLevel: 0.5357 JocGen: 0.4795	1.017	0.4605	(none)	(none)
1	1998-2013	Dep: logSprDensZ1 Indep: Max30dayDecFebLL Indep: MeanDecFebJocGen	0.0749	0.6028	16	Intercept: 0.0091 LakeLevel: 0.4853 JocGen: 0.3905	1.066	0.6374	(none)	(none)
1	1998-2013	Dep: logSprDensZ1 Indep: Max30dayDecFebLL Indep: MaxDailyDecFebJocGen	0.1682	0.3020	16	Intercept: 0.0498 LakeLevel: 0.5598 JocGen: 0.1504	1.001	0.3348	(none)	(none)
1	1998-2013	Dep: logSprDensZ1 Indep: Max30dayDecFebLL Indep: Max30dayDecFebJocGen	0.0588	0.6742	16	Intercept: 0.0080 LakeLevel: 0.5440 JocGen: 0.4701	1.027	0.4627	(none)	(none)

Appendix Table 18. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and winter surface (0-4 m) temperature (C) (minimum, January-February mean), based on data collected 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish MeanDecFebJocGen LWMinTemp	0.1827	0.2981	15	Intercept: 0.0066 JocGen: 0.9287 MinTemp: 0.1314	1.009	0.6013	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen LWMinTemp	0.1864	0.2900	15	Intercept: 0.0062 JocGen: 0.8059 MinTemp: 0.1580	1.083	0.5315	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen LWMinTemp	0.1880	0.2867	15	Intercept: 0.0076 JocGen: 0.7739 MinTemp: 0.1287	1.001	0.5001	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen LWJanFebTemp	0.2465	0.1589	16	Intercept: 0.0057 JocGen: 0.6808 JanFebTmp: 0.0621	1.004	0.6060	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen LWJanFebTemp	0.2624	0.1383	16	Intercept: 0.0058 JocGen: 0.5085 JanFebTmp: 0.0646	1.001	0.6496	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen LWJanFebTemp	0.2632	0.1373	16	Intercept: 0.0082 JocGen: 0.5019 JanFebTmp: 0.0539	1.021	0.6200	(none)	(none)

Appendix Table 19. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average); winter surface (0-4 m) temperature (C) (minimum, January-February mean); and an interaction variable calculated as the product of the centered independent variable. Independent variables in these analyses have been centered. Analyses utilize data collected 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish CMeanDecFebJocGen CLWMinTemp Interaction	0.2519	0.3436	15	Intercept: <0.0001 JocGen: 0.6729 MinTemp: 0.1197 Inter: 0.3347	1.360	0.8128	(none)	(none)
LW	1998-2013	logSprFish CMaxDailyDecFebJocGen CLWMinTemp Interaction	0.1866	0.4993	15	Intercept: <0.0001 JocGen: 0.8119 MinTemp: 0.1820 Inter: 0.9587	1.099	0.6806	(none)	(none)
LW	1998-2013	logSprFish CMax30dayDecFebJocGen CLWMinTemp Interaction	0.2431	0.3626	15	Intercept: <0.0001 JocGen: 0.8655 MinTemp: 0.1284 Inter: 0.3899	1.299	0.7365	(none)	(none)
LW	1998-2013	logSprFish CMeanDecFebJocGen CLWJanFebTemp Interaction	0.3027	0.2126	16	Intercept: <0.0001 JocGen: 0.9446 JanFebTmp: 0.0871 Inter: 0.3444	1.273	0.6155	(none)	(none)
LW	1998-2013	logSprFish CMaxDailyDecFebJocGen CLWJanFebTemp Interaction	0.2811	0.2493	16	Intercept: <0.0001 JocGen: 0.4964 JanFebTmp: 0.1047 Inter: 0.5873	1.075	0.6451	(none)	(none)
LW	1998-2013	logSprFish CMax30dayDecFebJocGen CLWJanFebTemp Interaction	0.3211	0.1848	16	Intercept: <0.0001 JocGen: 0.8537 JanFebTmp: 0.0680 Inter: 0.3316	1.253	0.3714	(none)	(none)

Appendix Table 20. Multiple regression analyses of spring forage fish density (no/ha) in Zone 1 on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and winter surface (0-4 m) temperature (C) (minimum, January-February mean), based on data collected 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
1	1998-2013	logSprDens MeanDecFebJocGen MinTemp	0.1056	0.5120	15	Intercept: 0.8647 JocGen: 0.6310 MinTemp: 0.3238	1.010	0.5710	(none)	(none)
1	1998-2013	logSprDens MaxDailyDecFebJocGen MinTemp	0.1703	0.3262	15	Intercept: 0.9143 JocGen: 0.2952 MinTemp: 0.4668	1.095	0.4156	(none)	(none)
1	1998-2013	logSprDens Max30dayDecFebJocGen MinTemp	0.1050	0.5141	15	Intercept: 0.8352 JocGen: 0.6369 MinTemp: 0.3062	1.001	0.5204	(none)	(none)
1	1998-2013	logSprDens MeanDecFebJocGen JanFebTemp	0.1660	0.3073	16	Intercept: 0.6951 JocGen: 0.3683 JanFebTmp: 0.1816	1.014	0.5952	(none)	(none)
1	1998-2013	logSprDens MaxDailyDecFebJocGen JanFebTemp	0.2614	0.1395	16	Intercept: 0.5612 JocGen: 0.1269 JanFebTmp: 0.1765	1.000	0.4200	(none)	(none)
1	1998-2013	logSprDens Max30dayDecFebJocGen JanFebTemp	0.1703	0.2971	16	Intercept: 0.6328 JocGen: 0.3497 JanFebTmp: 0.1630	1.040	0.4575	(none)	(none)

Appendix Table 21. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and December-February BCPSS pumping flow (m^3/sec), based on data collected 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebJocGen Indep: MeanDecFebBCPump	0.0070	0.9554	16	Intercept: <0.0001 JocGen: 0.8936 BCPump: 0.8742	1.360	0.5089	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebJocGen Indep: MaxDailyDecFebBCPump	0.0711	0.6191	16	Intercept: <0.0001 JocGen: 0.9618 BCPump: 0.3537	1.108	0.5468	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MeanDecFebJocGen Indep: Max30dayDecFebBCPump	0.0120	0.9243	16	Intercept: <0.0001 JocGen: 0.9693 BCPump: 0.7658	1.472	0.6068	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebJocGen Indep: MeanDecFebBCPump	0.0311	0.8142	16	Intercept: <0.0001 JocGen: 0.5682 BCPump: 0.9880	1.246	0.4226	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebJocGen Indep: MaxDailyDecFebBCPump	0.0921	0.5337	16	Intercept: <0.0001 JocGen: 0.5916 BCPump: 0.3672	1.015	0.6360	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: MaxDailyDecFebJocGen Indep: Max30dayDecFebBCPump	0.0322	0.8081	16	Intercept: <0.0001 JocGen: 0.6100 BCPump: 0.9035	1.251	0.5852	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebJocGen Indep: MeanDecFebBCPump	0.0093	0.9411	16	Intercept: <0.0001 JocGen: 0.8285 BCPump:	1.544	0.4964	(none)	(none)

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
						0.9324				
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebJocGen Indep: MaxDailyDecFebBCPump	0.0710	0.6195	16	Intercept: <0.0001 JocGen: 0.9722 BCPump: 0.3675	1.112	0.5937	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: Max30dayDecFebJocGen Indep: Max30dayDecFebBCPump	0.0128	0.9194	16	Intercept: <0.0001 JocGen: 0.9135 BCPump: 0.8194	1.698	0.6333	(none)	(none)

Appendix Table 22. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average); December-February BCPSS pumping flow (m^3/sec); and an interaction variable calculated as the product of the centered independent variables. Independent variables are centered in these analyses. Regressions utilize data collected 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	Dep: logSprFish Indep: CMeanDecFebJocGen Indep: CMeanDecFebBCPump Indep: Interaction	0.0116	0.9859	16	Intercept: <0.0001 JocGen: 0.9524 BCPump: 0.9611 Inter: 0.8176	1.611	0.7569	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMeanDecFebJocGen Indep: CMaxDailyDecFebBCPump Indep: Interaction	0.0932	0.7480	16	Intercept: <0.0001 JocGen: 0.9964 BCPump: 0.3232 Inter: 0.5987	1.163	0.6473	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMeanDecFebJocGen Indep: CMax30dayDecFebBCPump Indep: Interaction	0.0123	0.9846	16	Intercept: <0.0001 JocGen: 0.9592 BCPump: 0.7712 Inter: 0.9560	1.604	0.6025	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMaxDailyDecFebJocGen Indep: CMeanDecFebBCPump Indep: Interaction	0.0344	0.9326	16	Intercept: <0.0001 JocGen: 0.6024 BCPump: 0.9123 Inter: 0.8443	1.655	0.6323	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMaxDailyDecFebJocGen Indep: CMaxDailyDecFebBCPump Indep: Interaction	0.1046	0.7106	16	Intercept: <0.0001 JocGen: 0.6828 BCPump: 0.3640 Inter: 0.6896	1.076	0.8312	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMaxDailyDecFebJocGen Indep: CMax30dayDecFebBCPump Indep: Interaction	0.0335	0.9351	16	Intercept: <0.0001 JocGen: 0.6203 BCPump: 0.8786 Inter: 0.9044	1.452	0.7303	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMax30dayDecFebJocGen Indep: CMeanDecFebBCPump Indep: Interaction	0.0095	0.9894	16	Intercept: <0.0001 JocGen: 0.8315 BCPump: 0.9261 Inter: 0.9580	1.775	0.8109	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMax30dayDecFebJocGen Indep: CMaxDailyDecFebBCPump Indep: Interaction	0.1024	0.7176	16	Intercept: <0.0001 JocGen: 0.9319 BCPump: 0.3403 Inter: 0.5292	1.133	0.7487	(none)	(none)
LW	1998-2013	Dep: logSprFish Indep: CMax30dayDecFebJocGen Indep: CMax30dayDecFebBCPump Indep: Interaction	0.0223	0.9635	16	Intercept: <0.0001 JocGen: 0.8206 BCPump: 0.8040 Inter: 0.7396	2.007	0.7174	(none)	(none)

Appendix Table 23. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average); December-February BCPSS pumping flow (m^3/sec); and December-February lake level (meters below full pool) (mean, lowest daily, and lowest 30-day average). These regressions utilized data from 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish MeanDecFebJocGen MeanDecFebBCpump MeanDecFebLL	0.1169	0.6706	16	Intercept: <0.0001 JocGen: 0.5392 BCPump: 0.7617 LakeLevel: 0.2452	1.640	0.3056	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen MeanDecFebBCpump Max30dayDecFebLL	0.1448	0.5825	16	Intercept: <0.0001 JocGen: 0.4889 BCPump: 0.6942 LakeLevel: 0.1896	1.653	0.5433	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen MeanDecFebBCpump MaxDailyDecFebLL	0.1482	0.5721	16	Intercept: <0.0001 JocGen: 0.5012 BCPump: 0.6817 LakeLevel: 0.1838	1.629	0.5803	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen Max30dayDecFebBCpump MeanDecFebLL	0.1102	0.6921	16	Intercept: <0.0001 JocGen: 0.6943 BCPump: 0.9400 LakeLevel: 0.2722	1.637	0.3558	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen Max30dayDecFebBCpump Max30dayDecFebLL	0.1332	0.6184	16	Intercept: <0.0001 JocGen: 0.6482 BCPump: 0.9964 LakeLevel: 0.2195	1.654	0.4942	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen Max30dayDecFebBCpump MaxDailyDecFebLL	0.1357	0.6107	16	Intercept: <0.0001 JocGen: 0.6602 BCPump: 0.9845 LakeLevel: 0.2146	1.634	0.5012	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen MaxDailyDecFebBCpump MeanDecFebLL	0.2275	0.3589	16	Intercept: <0.0001 JocGen: 0.8231 BCPump: 0.2012 LakeLevel: 0.1450	1.173	0.3406	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen MaxDailyDecFebBCpump Max30dayDecFebLL	0.2620	0.2852	16	Intercept: <0.0001 JocGen: 0.8106 BCPump: 0.1735 LakeLevel: 0.1035	1.182	0.3596	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen MaxDailyDecFebBCpump MaxDailyDecFebLL	0.2569	0.2954	16	Intercept: <0.0001 JocGen: 0.8503 BCPump: 0.1871 LakeLevel: 0.1089	1.168	0.3797	(none)	(none)

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish Max30dayDecFebJocGen MeanDecFebBCpump MeanDecFebLL	0.1187	0.6648	16	Intercept: <0.0001 JocGen: 0.5270 BCPump: 0.7234 LakeLevel: 0.2458	1.780	0.4222	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MeanDecFebBCpump Max30dayDecFebLL	0.1443	0.5841	16	Intercept: <0.0001 JocGen: 0.4922 BCPump: 0.6690 LakeLevel: 0.1940	1.802	0.6801	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MeanDecFebBCpump MaxDailyDecFebLL	0.1475	0.5742	16	Intercept: <0.0001 JocGen: 0.5055 BCPump: 0.6597 LakeLevel: 0.1883	1.809	0.7077	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen Max30dayDecFebBCpump MeanDecFebLL	0.1092	0.6957	16	Intercept: <0.0001 JocGen: 0.7079 BCPump: 0.9665 LakeLevel: 0.2769	1.803	0.3861	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen Max30dayDecFebBCpump Max30dayDecFebLL	0.1306	0.6267	16	Intercept: <0.0001 JocGen: 0.6775 BCPump: 0.9887 LakeLevel: 0.2265	1.809	0.6171	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen Max30dayDecFebBCpump MaxDailyDecFebLL	0.1331	0.6187	16	Intercept: <0.0001 JocGen: 0.6898 BCPump: 0.9729 LakeLevel: 0.2212	1.794	0.6592	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MaxDailyDecFebBCpump MeanDecFebLL	0.2263	0.3618	16	Intercept: <0.0001 JocGen: 0.8593 BCPump: 0.2023 LakeLevel: 0.1467	1.190	0.5339	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MaxDailyDecFebBCpump Max30dayDecFebLL	0.2599	0.2893	16	Intercept: <0.0001 JocGen: 0.8731 BCPump: 0.1731 LakeLevel: 0.1056	1.203	0.6855	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MaxDailyDecFebBCpump MaxDailyDecFebLL	0.2554	0.2985	16	Intercept: <0.0001 JocGen: 0.9110 BCPump: 0.1856 LakeLevel: 0.1104	1.187	0.7038	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MeanDecFebBCpump MeanDecFebLL	0.1235	0.6494	16	Intercept: <0.0001 JocGen: 0.4961 BCPump: 0.8076 LakeLevel: 0.2828	1.303	0.4795	(none)	(none)

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MeanDecFebBCpump Max30dayDecFebLL	0.1522	0.5601	16	Intercept: <0.0001 JocGen: 0.4468 BCPump: 0.7409 LakeLevel: 0.2151	1.327	0.5753	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MeanDecFebBCpump MaxDailyDecFebLL	0.1560	0.5488	16	Intercept: <0.0001 JocGen: 0.4551 BCPump: 0.7217 LakeLevel: 0.2075	1.338	0.5885	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen Max30dayDecFebBCpump MeanDecFebLL	0.1198	0.6612	16	Intercept: <0.0001 JocGen: 0.5977 BCPump: 0.9172 LakeLevel: 0.2961	1.251	0.5738	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen Max30dayDecFebBCpump Max30dayDecFebLL	0.1442	0.5843	16	Intercept: <0.0001 JocGen: 0.5514 BCPump: 0.9675 LakeLevel: 0.2341	1.257	0.6750	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen Max30dayDecFebBCpump MaxDailyDecFebLL	0.1466	0.5769	16	Intercept: <0.0001 JocGen: 0.5599 BCPump: 0.9919 LakeLevel: 0.2288	1.261	0.6645	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MaxDailyDecFebBCpump MeanDecFebLL	0.2421	0.3263	16	Intercept: <0.0001 JocGen: 0.6039 BCPump: 0.1879 LakeLevel: 0.1492	1.113	0.7714	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MaxDailyDecFebBCpump Max30dayDecFebLL	0.2795	0.2522	16	Intercept: <0.0001 JocGen: 0.5636 BCPump: 0.1590 LakeLevel: 0.1027	1.120	0.8064	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MaxDailyDecFebBCpump MaxDailyDecFebLL	0.2730	0.2640	16	Intercept: <0.0001 JocGen: 0.5912 BCPump: 0.1742 LakeLevel: 0.1096	1.100	0.8059	(none)	(none)

Appendix Table 24. Multiple regression analyses of spring forage fish lakewide numbers on variables for December-February JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average); December-February BCPSS pumping flow (m^3/sec); and winter surface (0-4 m) lakewide temperature (C) (minimum, mean January-February). These regressions utilized data from 1998-2013.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish MeanDecFebJocGen MeanDecFebBCpump MinTemp	0.2329	0.3852	15	Intercept: 0.0510 JocGen: 0.7227 BCPump: 0.4140 Temp: 0.0987	1.501	0.9293	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen MeanDecFebBCpump MeanJanFebTemp	0.3246	0.1798	16	Intercept: 0.0672 JocGen: 0.7932 BCPump: 0.2615 Temp: **0.0350**	1.658	0.8886	**2013** **(SR=2.602)**	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen Max30dayDecFebBCpump MinTemp	0.2245	0.4047	15	Intercept: 0.0401 JocGen: 0.7424 BCPump: 0.4577 Temp: 0.1099	1.451	0.8531	**2013** **(SR=2.511)**	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen Max30dayDecFebBCpump MeanJanFebTemp	0.3023	0.2134	16	Intercept: 0.0415 JocGen: 0.8328 BCPump: 0.3466 Temp: **0.0453**	1.607	0.8910	**2013** **(SR=2.680)**	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen MaxDailyDecFebBCpump MinTemp	0.2833	0.2816	15	Intercept: 0.0506 JocGen: 0.8494 BCPump: 0.2399 Temp: 0.1020	1.065	0.5021	(none)	(none)
LW	1998-2013	logSprFish MeanDecFebJocGen MaxDailyDecFebBCpump MeanJanFebTemp	0.3342	0.1667	16	Intercept: 0.0350 JocGen: 0.9830 BCPump: 0.2325 Temp: 0.0501	1.115	0.5806	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MeanDecFebBCpump MinTemp	0.2265	0.3999	15	Intercept: 0.0472 JocGen: 0.8445 BCPump: 0.4744 Temp: 0.1059	1.669	0.7582	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MeanDecFebBCpump MeanJanFebTemp	0.3206	0.1855	16	Intercept: 0.0627 JocGen: 0.9708 BCPump: 0.3338 Temp: 0.0370	1.821	0.8464	**2013** **(SR=2.585)**	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen Max30dayDecFebBCpump MinTemp	0.2185	0.4189	15	Intercept: 0.0370 JocGen: 0.8692 BCPump: 0.5257 Temp: 0.1164	1.631	0.6340	**2013** **(SR=2.537)**	(none)

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1998-2013	logSprFish Max30dayDecFebJocGen Max30dayDecFebBCpump MeanJanFebTemp	0.2996	0.2177	16	Intercept: 0.0389 JocGen: 0.9781 BCPump: 0.4452 Temp: 0.0467	1.801	0.8539	**2013 (SR=2.672)**	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MaxDailyDecFebBCpump MinTemp	0.2809	0.2861	15	Intercept: 0.0509 JocGen: 0.9804 BCPump: 0.2583 Temp: 0.1049	1.061	0.6316	(none)	(none)
LW	1998-2013	logSprFish Max30dayDecFebJocGen MaxDailyDecFebBCpump MeanJanFebTemp	0.3393	0.1600	16	Intercept: 0.0391 JocGen: 0.7659 BCPump: 0.2627 Temp: **0.0475**	1.128	0.7612	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MeanDecFebBCpump MinTemp	0.2253	0.4027	15	Intercept: 0.0518 JocGen: 0.8813 BCPump: 0.4727 Temp: 0.1264	1.448	0.8038	**2013 (SR=2.713)**	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MeanDecFebBCpump MeanJanFebTemp	0.3210	0.1850	16	Intercept: 0.0619 JocGen: 0.9334 BCPump: 0.3291 Temp: **0.0430**	1.574	0.8603	**2013 (SR=2.851)**	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen Max30dayDecFebBCpump MinTemp	0.2166	0.4234	15	Intercept: 0.0369 JocGen: 0.9645 BCPump: 0.5283 Temp: 0.1385	1.305	0.9214	**2013 (SR=2.776)**	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen Max30dayDecFebBCpump MeanJanFebTemp	0.3019	0.2140	16	Intercept: 0.0378 JocGen: 0.8445 BCPump: 0.4262 Temp: 0.0524	1.395	0.8852	**2013 (SR=2.871)**	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MaxDailyDecFebBCpump MinTemp	0.2863	0.2762	15	Intercept: 0.0510 JocGen: 0.7778 BCPump: 0.2406 Temp: 0.1313	1.089	0.4751	(none)	(none)
LW	1998-2013	logSprFish MaxDailyDecFebJocGen MaxDailyDecFebBCpump MeanJanFebTemp	0.3496	0.1471	16	Intercept: 0.0397 JocGen: 0.6035 BCPump: 0.2288 Temp: **0.0499**	1.024	0.6499	(none)	(none)

Appendix Table 25. Multiple regression analyses of fall forage fish lakewide numbers on variables for May-October BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and May-October lake level (meters below full pool) (mean, lowest daily, lowest 30-day average), based on data collected 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Maximum VIF	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish = 7.20595 + 0.03400 MeanMayOctLL – 0.00497 MeanMayOctBCpump	0.3366	0.0694	16	Intercept: <0.0001 LakeLevel: 0.0719 BCPump: 0.1135	0.2133	1.000	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: MeanMayOctLL Indep: MaxDailyMayOctBCpump	0.2748	0.1239	16	Intercept: <0.0001 LakeLevel: 0.1187 BCPump: 0.2384	0.6189	1.017	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: MeanMayOctLL Indep: Max30dayMayOctBCpump	0.2893	0.1086	16	Intercept: <0.0001 LakeLevel: 0.1317 BCPump: 0.1999	0.4176	1.029	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: MaxDailyMayOctLL Indep: MeanMayOctBCpump	0.3166	0.0842	16	Intercept: <0.0001 LakeLevel: 0.0904 BCPump: 0.0942	0.2915	1.009	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: MaxDailyMayOctLL Indep: MaxDailyMayOctBCpump	0.2374	0.1717	16	Intercept: <0.0001 LakeLevel: 0.1792 BCPump: 0.2319	0.5288	1.013	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: MaxDailyMayOctLL Indep: Max30dayMayOctBCpump	0.2783	0.1201	16	Intercept: <0.0001 LakeLevel: 0.1493 BCPump: 0.1455	0.4525	1.003	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: Max30dayMayOctLL Indep: MeanMayOctBCpump	0.3406	0.0667	16	Intercept: <0.0001 LakeLevel: 0.0686 BCPump: 0.0849	0.2865	1.011	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: Max30dayMayOctLL Indep: MaxDailyMayOctBCpump	0.2506	0.1534	16	Intercept: <0.0001 LakeLevel: 0.1550 BCPump: 0.2426	0.5915	1.018	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: Max30dayMayOctLL Indep: Max30dayMayOctBCpump	0.3010	0.0975	16	Intercept: <0.0001 LakeLevel: 0.1153 BCPump: 0.1347	0.4636	1.001	(none)	(none)

Appendix Table 26. Multiple regression analyses of fall forage fish lakewide numbers on variables for May-October BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average); May-October lake level (meters below full pool) (mean, lowest daily, lowest 30-day average); and an interaction term calculated as the product of the centered independent variables. Independent variables were centered prior to analysis. Regressions utilized data collected 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	Dep: logFallFish Indep: CMeanMayOctLL Indep: CMeanMayOctBCpump Indep: Interaction	0.4059	0.0901	16	Intercept: <0.0001 LakeLevel: 0.0656 BCPump: 0.1808 Inter: 0.2597	1.052	0.7590	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: CMeanMayOctLL Indep: CMaxDailyMayOctBCpump Indep: Interaction	0.2859	0.2408	16	Intercept: <0.0001 LakeLevel: 0.1227 BCPump: 0.4011 Inter: 0.6741	1.280	0.7760	**2005 (SR=-2.591)**	**2012 (CD=3.445)**
LW	1997-2012	Dep: logFallFish Indep: CMeanMayOctLL Indep: CMax30dayMayOctBCpump Indep: Interaction	0.3499	0.1468	16	Intercept: <0.0001 LakeLevel: 0.1314 BCPump: 0.2852 Inter: 0.3112	1.072	0.2455	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: CMaxDailyMayOctLL Indep: CMeanMayOctBCpump Indep: Interaction	0.3263	0.1774	16	Intercept: <0.0001 LakeLevel: 0.1004 BCPump: 0.1137 Inter: 0.6845	1.017	0.7343	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: CMaxDailyMayOctLL Indep: CMaxDailyMayOctBCpump Indep: Interaction	0.2527	0.3039	16	Intercept: <0.0001 LakeLevel: 0.2944 BCPump: 0.2227 Inter: 0.6294	1.559	0.3473	**2012 (SR=2.641)**	**2005 (CD=6.943)**
LW	1997-2012	Dep: logFallFish Indep: CMaxDailyMayOctLL Indep: CMax30dayMayOctBCpump Indep: Interaction	0.2818	0.2480	16	Intercept: <0.0001 LakeLevel: 0.1642 BCPump: 0.1671 Inter: 0.8121	1.008	0.6540	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: CMax30dayMayOctLL Indep: CMeanMayOctBCpump Indep: Interaction	0.3547	0.1410	16	Intercept: <0.0001 LakeLevel: 0.0745 BCPump: 0.1032 Inter: 0.6178	1.018	0.7786	(none)	(none)
LW	1997-2012	Dep: logFallFish Indep: CMax30dayMayOctLL Indep: CMaxDailyMayOctBCpump Indep: Interaction	0.2552	0.2988	16	Intercept: <0.0001 LakeLevel: 0.2279 BCPump: 0.2677 Inter: 0.7889	1.405	0.5870	**2012 (SR=2.634)**	**2005 (CD=5.936)**
LW	1997-2012	Dep: logFallFish Indep: CMax30dayMayOctLL Indep: CMax30dayMayOctBCpump Indep: Interaction	0.3067	0.2064	16	Intercept: <0.0001 LakeLevel: 0.1264 BCPump: 0.1565 Inter: 0.7592	1.008	0.6712	(none)	(none)

Appendix Table 27. Multiple regression analyses of fall forage fish density (no/ha) in Zone 2 on variables for May-October BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and May-October lake level (meters below full pool) (mean, lowest daily, lowest 30-day average), based on data collected 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
2	1997-2012	logFallDensZ2 = 3.42525 + 0.02775 MeanMayOctLL – 0.00595 MeanMayOctBCpump	0.1240	0.4230	16	Intercept: 0.0008 LakeLevel: 0.4126 BCPump: 0.3017	1.000	0.3575	**2002 (SR=-2.520)**	(none)
2	1997-2012	logFallDensZ2 = 2.89678 + 0.02548 MeanMayOctLL – 0.00113 MaxDailyMayOctBCpump	0.0558	0.6883	16	Intercept: 0.0052 LakeLevel: 0.4710 BCPump: 0.7191	1.017	0.6247	**2002 (SR=-2.602)**	(none)
2	1997-2012	logFall DensZ2 = 3.82534 + 0.02064 MeanMayOctLL – 0.00679 Max30dayMayOctBCpump	0.1357	0.3875	16	Intercept: 0.0036 LakeLevel: 0.5428 BCPump: 0.2664	1.029	0.4544	**2002 (SR=-2.609)**	(none)
2	1997-2012	logFall DensZ2 MaxDailyMayOctLL MeanMayOctBCpump	0.1201	0.4353	16	Intercept: 0.0008 LakeLevel: 0.4325 BCPump: 0.2785	1.009	0.1311	(none)	(none)
2	1997-2012	logFall DensZ2 MaxDailyMayOctLL MaxDailyMayOctBCpump	0.0447	0.7430	16	Intercept: 0.0059 LakeLevel: 0.5417 BCPump: 0.7034	1.013	0.4372	(none)	(none)
2	1997-2012	logFall DensZ2 MaxDailyMayOctLL Max30dayMayOctBCpump	0.1372	0.3831	16	Intercept: 0.0029 LakeLevel: 0.5310 BCPump: 0.2333	1.003	0.2039	(none)	(none)
2	1997-2012	logFall DensZ2 Max30dayMayOctLL MeanMayOctBCpump	0.1198	0.4364	16	Intercept: 0.0008 LakeLevel: 0.4342 BCPump: 0.2764	1.011	0.0985	(none)	(none)
2	1997-2012	logFall DensZ2 Max30dayMayOctLL MaxDailyMayOctBCpump	0.0429	0.7519	16	Intercept: 0.0059 LakeLevel: 0.5544 BCPump: 0.7111	1.018	0.4861	(none)	(none)
2	1997-2012	logFall DensZ2 Max30dayMayOctLL Max30dayMayOctBCpump	0.1379	0.3811	16	Intercept: 0.0027 LakeLevel: 0.5258 BCPump: 0.2292	1.001	0.2201	(none)	(none)

Appendix Table 28. Multiple regression analyses of fall forage fish lakewide numbers on variables for May-October JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and May-October lake level (meters below full pool) (mean, lowest daily, lowest 30-day average), based on data collected 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish = 7.16316 + 0.03649 MeanMayOctLL – 0.00398 MeanMayOctJocGen	0.4251	**0.0274**	16	Intercept: <0.0001 LakeLevel: **0.0423** JocGen: **0.0381**	1.007	0.3430	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctLL MaxDailyMayOctJocGen	0.2615	0.1395	16	Intercept: <0.0001 LakeLevel: 0.1972 JocGen: 0.2812	1.120	0.5230	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctLL Max30dayMayOctJocGen	0.2627	0.1379	16	Intercept: <0.0001 LakeLevel: 0.1065 JocGen: 0.2767	1.006	0.5534	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctLL MeanMayOctJocGen	0.3326	0.0722	16	Intercept: <0.0001 LakeLevel: 0.1334 JocGen: 0.0784	1.002	0.2939	**2012 (SR=2.647)**	(none)
LW	1997-2012	logFallFish MaxDailyMayOctLL MaxDailyMayOctJocGen	0.2179	0.2024	16	Intercept: <0.0001 LakeLevel: 0.3308 JocGen: 0.2914	1.174	0.7890	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctLL Max30dayMayOctJocGen	0.2417	0.1656	16	Intercept: <0.0001 LakeLevel: 0.1334 JocGen: 0.2209	1.000	0.3190	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctLL MeanMayOctJocGen	0.3503	0.0606	16	Intercept: <0.0001 LakeLevel: 0.1075 JocGen: 0.0757	1.002	0.2925	**2012 (SR=2.635)**	(none)
LW	1997-2012	logFallFish Max30dayMayOctLL MaxDailyMayOctJocGen	0.2310	0.1813	16	Intercept: <0.0001 LakeLevel: 0.2820 JocGen: 0.3071	1.178	0.7960	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctLL Max30dayMayOctJocGen	0.2601	0.1411	16	Intercept: <0.0001 LakeLevel: 0.1095 JocGen: 0.2167	1.000	0.3475	(none)	(none)

Appendix Table 29. Multiple regression analyses of fall forage fish lakewide numbers on variables for May-October JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average); May-October lake level (meters below full pool) (mean, lowest daily, lowest 30-day average); and an interaction term calculated as the product of the centered independent variables. Independent variables were centered prior to analysis. Regressions utilized data collected 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish MeanMayOctLL MeanMayOctJocGen Interaction	0.4318	0.0705	16	Intercept: <0.0001 LakeLevel: 0.0587 JocGen: **0.0440** Inter: 0.7140	1.307	0.6836	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctLL MaxDailyMayOctJocGen Interaction	0.4465	0.0610	16	Intercept: <0.0001 LakeLevel: 0.4407 JocGen: **0.0366** Inter: 0.0683	3.141	0.6075	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctLL Max30dayMayOctJocGen Interaction	0.2782	0.2545	16	Intercept: <0.0001 LakeLevel: 0.1071 JocGen: 0.2612 Inter: 0.6214	1.067	0.6568	**2012 (SR=2.613)**	(none)
LW	1997-2012	logFallFish MaxDailyMayOctLL MeanMayOctJocGen Interaction	0.3695	0.1245	16	Intercept: <0.0001 LakeLevel: 0.1799 JocGen: 0.0615 Inter: 0.4181	1.161	0.3912	**2012 (SR=2.695)**	(none)
LW	1997-2012	logFallFish MaxDailyMayOctLL MaxDailyMayOctJocGen Interaction	0.3091	0.2026	16	Intercept: <0.0001 LakeLevel: 0.3669 JocGen: 0.1181 Inter: 0.2321	2.279	0.5849	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctLL Max30dayMayOctJocGen Interaction	0.3995	0.0956	16	Intercept: <0.0001 LakeLevel: 0.0675 JocGen: **0.0479** Inter: 0.1011	1.718	0.5524	**2012 (SR=2.727)**	(none)
LW	1997-2012	logFallFish Max30dayMayOctLL MeanMayOctJocGen Interaction	0.3768	0.1169	16	Intercept: <0.0001 LakeLevel: 0.1600 JocGen: 0.0659 Inter: 0.4893	1.184	0.3965	**2012 (SR=2.677)**	(none)
LW	1997-2012	logFallFish Max30dayMayOctLL MaxDailyMayOctJocGen Interaction	0.3349	0.1658	16	Intercept: <0.0001 LakeLevel: 0.3206 JocGen: 0.1069 Inter: 0.1961	2.320	0.4786	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctLL Max30dayMayOctJocGen Interaction	0.3925	0.1017	16	Intercept: <0.0001 LakeLevel: 0.0671 JocGen: 0.0597 Inter: 0.1318	1.616	0.3315	**2012 (SR=2.725)**	(none)

Appendix Table 30. Multiple regression analyses of fall forage fish density (no/ha) in Zone 1 on variables for May-October JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and May-October lake level (meters below full pool) (mean, lowest daily, lowest 30-day average), based on data collected 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Maximum VIF	Outliers |SR|≥2.5	Significant Cook's D
1	1997-2012	logFallDensZ1 = 4.10702 + 0.09250 MeanMayOctLL – 0.00856 MeanMayOctJocGen	0.5905	**0.0030**	16	Intercept: <0.0001 LakeLevel: **0.0048** JocGen: **0.0112**	0.4452	1.007	(none)	(none)
1	1997-2012	log FallDensZ1 = 3.94976 + 0.06226 MeanMayOctLL – 0.00280 MaxDailyMayOctJocGen	0.5160	**0.0089**	16	Intercept: <0.0001 LakeLevel: 0.0678 JocGen: **0.0372**	0.7340	1.120	(none)	(2004) (CD=2.856)
1	1997-2012	log FallDensZ1 = 3.32253 + 0.08326 MeanMayOctLL – 0.00262 Max30dayMayOctJocGen	0.3662	0.0516	16	Intercept: 0.0002 LakeLevel: **0.0289** JocGen: 0.3262	0.4302	1.006	(none)	(none)
1	1997-2012	log FallDensZ1 = 3.82947 + 0.07137 MaxDailyMayOctLL – 0.00741 MeanMayOctJocGen	0.4999	**0.0111**	16	Intercept: <0.0001 LakeLevel: **0.0196** JocGen: **0.0372**	0.2389	1.002	(none)	(none)
1	1997-2012	log FallDensZ1 = 3.87126 + 0.04933 MaxDailyMayOctLL – 0.00277 MaxDailyMayOctJocGen	0.4792	**0.0144**	16	Intercept: <0.0001 LakeLevel: 0.1199 JocGen: 0.0503	0.2200	1.174	(none)	(none)
1	1997-2012	log FallDensZ1 = 3.33570 + 0.07464 MaxDailyMayOctLL – 0.00323 Max30dayMayOctJocGen	0.3703	**0.0495**	16	Intercept: 0.0002 LakeLevel: **0.0275** JocGen: 0.2280	0.2613	1.000	(none)	(none)
1	1997-2012	log FallDensZ1 = 3.84054 + 0.07615 Max30dayMayOctLL – 0.00738 MeanMayOctJocGen	0.5249	**0.0079**	16	Intercept: <0.0001 LakeLevel: **0.0136** JocGen: **0.0338**	0.2543	1.002	(none)	(none)
1	1997-2012	log FallDensZ1 = 3.84545 + 0.05412 Max30dayMayOctLL – 0.00270 MaxDailyMayOctJocGen	0.4959	**0.0116**	16	Intercept: <0.0001 LakeLevel: 0.0926 JocGen: 0.0524	0.2892	1.178	(none)	(none)
1	1997-2012	log FallDensZ1 = 3.34901 + 0.07942 Max30dayMayOctLL – 0.00322 Max30dayMayOctJocGen	0.3960	**0.0377**	16	Intercept: 0.0001 LakeLevel: **0.0204** JocGen: 0.2211	0.3215	1.000	(none)	(none)

Appendix Table 31. Multiple regression analyses of total forage fish lakewide in fall on variables for May-October JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average) and May-October BCPSS pumping flow (m^3/sec), based on data collected 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Maximum VIF	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish MeanMayOctJocGen MeanMayOctBCpump	0.2771	0.1214	16	Intercept: <0.0001 JocGen: 0.1415 BCPump: 0.2631	0.3197	1.061	**2012 (SR=2.586)**	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen MaxDailyMayOctBCpump	0.2473	0.1578	16	Intercept: <0.0001 JocGen: 0.1608 BCPump: 0.3875	0.3314	1.110	**2012 (SR=2.646)**	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen Max30dayMayOctBCpump	0.2984	0.0999	16	Intercept: <0.0001 JocGen: 0.1187 BCPump: 0.2020	0.2567	1.030	**2012 (SR=2.546)**	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MeanMayOctBCpump	0.3318	0.0728	16	Intercept: <0.0001 JocGen: 0.0760 BCPump: 0.0877	0.4663	1.011	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MaxDailyMayOctBCpump	0.2373	0.1719	16	Intercept: <0.0001 JocGen: 0.1794 BCPump: 0.2616	0.4190	1.028	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen Max30dayMayOctBCpump	0.3467	0.0628	16	Intercept: <0.0001 JocGen: 0.0681 BCPump: 0.0737	0.3824	1.015	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MeanMayOctBCpump	0.2065	0.2223	16	Intercept: <0.0001 JocGen: 0.3181 BCPump: 0.1942	0.5398	1.018	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MaxDailyMayOctBCpump	0.1763	0.2835	16	Intercept: <0.0001 JocGen: 0.3597 BCPump: 0.2700	0.1742	1.042	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen Max30dayMayOctBCpump	0.1854	0.2638	16	Intercept: <0.0001 JocGen: 0.4528 BCPump: 0.2443	0.4723	1.107	(none)	(none)

Appendix Table 32. Multiple regression analyses of fall forage fish lakewide numbers on variables for May-October JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average); May-October BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average); and an interaction term calculated as the product of the centered independent variables. Independent variables were centered prior to analysis. Regressions utilized data collected 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish MeanMayOctJocGen MeanMayOctBCpump Interaction	0.2900	0.2337	16	Intercept: <0.0001 JocGen: 0.1785 BCPump: 0.3928 Inter: 0.6486	1.222	0.4273	**2012 (SR=2.767)**	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen MaxDailyMayOctBCpump Interaction	0.3145	0.1944	16	Intercept: <0.0001 JocGen: 0.1015 BCPump: 0.6616 Inter: 0.2992	1.275	0.6163	**2012 (SR=2.913)**	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen Max30dayMayOctBCpump Interaction	0.3673	0.1269	16	Intercept: <0.0001 JocGen: 0.2112 BCPump: 0.1706 Inter: 0.2755	1.111	0.1558	**2012 (SR=2.631)**	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MeanMayOctBCpump Interaction	0.3360	0.1643	16	Intercept: <0.0001 JocGen: 0.2202 BCPump: 0.1035 Inter: 0.7858	3.081	0.7136	(none)	**2004 (CD=7.249)**
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MaxDailyMayOctBCpump Interaction	0.2680	0.2735	16	Intercept: <0.0001 JocGen: 0.2185 BCPump: 0.4898 Inter: 0.4917	1.291	0.3428	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen Max30dayMayOctBCpump Interaction	0.3990	0.0960	16	Intercept: <0.0001 JocGen: 0.0549 BCPump: 0.0615 Inter: 0.3272	2.059	0.6238	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MeanMayOctBCpump Interaction	0.2360	0.3398	16	Intercept: <0.0001 JocGen: 0.3859 BCPump: 0.1726 Inter: 0.5095	1.061	0.3975	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MaxDailyMayOctBCpump Interaction	0.1868	0.4611	16	Intercept: <0.0001 JocGen: 0.3871 BCPump: 0.3279 Inter: 0.7008	2.445	0.6503	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen Max30dayMayOctBCpump Interaction	0.1902	0.4518	16	Intercept: <0.0001 JocGen: 0.4502 BCPump: 0.2630 Inter: 0.7926	1.473	0.5067	(none)	(none)

Appendix Table 33. Multiple regression analyses of total number of forage fish lakewide in fall on variables for May-October JPSS generation flow (m^3/sec) (mean, maximum daily, maximum 30-day average); May-October BCPSS pumping flow (m^3/sec) (mean, maximum daily, maximum 30-day average); and May-October lake level (meters below full pool) (mean, lowest daily, and lowest 30-day average). These regressions utilized data from 1997-2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish = 7.59114 – 0.00342 MeanMayOctJocGen – 0.00368 MeanMayOctBCpump + 0.03647 MeanMayOctLL	0.5010	**0.0342**	16	Intercept: <0.0001 JocGen: 0.0701 BCPump: 0.2017 LakeLevel: **0.0387**	1.068	0.2198	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen MeanMayOctBCpump Max30dayMayOctLL	0.4554	0.0558	16	Intercept: <0.0001 JocGen: 0.1379 BCPump: 0.1542 LakeLevel: 0.0708	1.076	0.2675	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen MeanMayOctBCpump MaxDailyMayOctLL	0.4335	0.0694	16	Intercept: <0.0001 JocGen: 0.1415 BCPump: 0.1694 LakeLevel: 0.0937	1.074	0.3390	(none)	(none)
LW	1997-2012	logFallFish = 7.69002 – 0.00362 MeanMayOctJocGen – 0.00321 Max30dayMayOctBCpump + 0.03317 MeanMayOctLL	0.4772	**0.0444**	16	Intercept: <0.0001 JocGen: 0.0599 BCPump: 0.2954 LakeLevel: 0.0656	1.067	0.7010	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen Max30dayMayOctBCpump Max30dayMayOctLL	0.4409	0.0645	16	Intercept: <0.0001 JocGen: 0.1088 BCPump: 0.1887 LakeLevel: 0.1059	1.032	0.7166	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen Max30dayMayOctBCpump MaxDailyMayOctLL	0.4200	0.0790	16	Intercept: <0.0001 JocGen: 0.1126 BCPump: 0.2036 LakeLevel: 0.1388	1.033	0.7166	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen MaxDailyMayOctBCpump MeanMayOctLL	0.4448	0.0621	16	Intercept: <0.0001 JocGen: 0.0794 BCPump: 0.5268 LakeLevel: 0.0611	1.140	0.6257	(none)	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen MaxDailyMayOctBCpump Max30dayMayOctLL	0.3785	0.1152	16	Intercept: <0.0001 JocGen: 0.1420 BCPump: 0.4751 LakeLevel: 0.1374	1.128	0.6149	**2012 (SR=2.501)**	(none)
LW	1997-2012	logFallFish MeanMayOctJocGen MaxDailyMayOctBCpump MaxDailyMayOctLL	0.3641	0.1303	16	Intercept: <0.0001 JocGen: 0.1480 BCPump: 0.4555 LakeLevel: 0.1634	1.122	0.6342	**2012 (SR=2.507)**	(none)

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish Max30dayMayOctJocGen MeanMayOctBCpump MeanMayOctLL	0.3856	0.1083	16	Intercept: <0.0001 JocGen: 0.3475 BCPump: 0.1474 LakeLevel: 0.0861	1.024	0.2944	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MeanMayOctBCpump Max30dayMayOctLL	0.4067	0.0894	16	Intercept: <0.0001 JocGen: 0.2701 BCPump: 0.1107 LakeLevel: 0.0672	1.029	0.4428	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MeanMayOctBCpump MaxDailyMayOctLL	0.3836	0.1101	16	Intercept: <0.0001 JocGen: 0.2757 BCPump: 0.1223 LakeLevel: 0.0881	1.027	0.4413	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen Max30dayMayOctBCpump MeanMayOctLL	0.3230	0.1821	16	Intercept: <0.0001 JocGen: 0.4549 BCPump: 0.3219 LakeLevel: 0.1443	1.133	0.5649	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen Max30dayMayOctBCpump Max30dayMayOctLL	0.3429	0.1554	16	Intercept: <0.0001 JocGen: 0.3988 BCPump: 0.2424 LakeLevel: 0.1156	1.109	0.3976	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen Max30dayMayOctBCpump MaxDailyMayOctLL	0.3212	0.1847	16	Intercept: <0.0001 JocGen: 0.4010 BCPump: 0.2588 LakeLevel: 0.1473	1.111	0.3493	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MaxDailyMayOctBCpump MeanMayOctLL	0.3224	0.1830	16	Intercept: <0.0001 JocGen: 0.3769 BCPump: 0.3245 LakeLevel: 0.1337	1.056	0.1163	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MaxDailyMayOctBCpump Max30dayMayOctLL	0.3155	0.1929	16	Intercept: <0.0001 JocGen: 0.3069 BCPump: 0.3438 LakeLevel: 0.1441	1.063	0.1371	(none)	(none)
LW	1997-2012	logFallFish Max30dayMayOctJocGen MaxDailyMayOctBCpump MaxDailyMayOctLL	0.3018	0.2141	16	Intercept: <0.0001 JocGen: 0.3134 BCPump: 0.3292 LakeLevel: 0.1975	1.058	0.1354	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MeanMayOctBCpump MeanMayOctLL	0.4323	0.0702	16	Intercept: <0.0001 JocGen: 0.1803 BCPump: 0.0816 LakeLevel: 0.1705	1.132	0.3742	(none)	(none)

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MeanMayOctBCpump Max30dayMayOctLL	0.4237	0.0762	16	Intercept: <0.0001 JocGen: 0.2130 BCPump: 0.0683 LakeLevel: 0.1916	1.183	0.6127	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MeanMayOctBCpump MaxDailyMayOctLL	0.4070	0.0892	16	Intercept: <0.0001 JocGen: 0.2012 BCPump: 0.0742 LakeLevel: 0.2410	1.180	0.6822	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen Max30dayMayOctBCpump MeanMayOctLL	0.4010	0.0943	16	Intercept: <0.0001 JocGen: 0.1606 BCPump: 0.1204 LakeLevel: 0.3176	1.178	0.7733	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen Max30dayMayOctBCpump Max30dayMayOctLL	0.4014	0.0939	16	Intercept: <0.0001 JocGen: 0.1815 BCPump: 0.0894 LakeLevel: 0.3156	1.204	0.5844	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen Max30dayMayOctBCpump MaxDailyMayOctLL	0.3873	0.1066	16	Intercept: <0.0001 JocGen: 0.1697 BCPump: 0.0936 LakeLevel: 0.3903	1.203	0.6087	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MaxDailyMayOctBCpump MeanMayOctLL	0.3286	0.1742	16	Intercept: <0.0001 JocGen: 0.3461 BCPump: 0.2947 LakeLevel: 0.2255	1.139	0.8727	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MaxDailyMayOctBCpump Max30dayMayOctLL	0.3008	0.2157	16	Intercept: <0.0001 JocGen: 0.3714 BCPump: 0.2952 LakeLevel: 0.3170	1.196	0.8103	(none)	(none)
LW	1997-2012	logFallFish MaxDailyMayOctJocGen MaxDailyMayOctBCpump MaxDailyMayOctLL	0.2913	0.2316	16	Intercept: <0.0001 JocGen: 0.3586 BCPump: 0.2870 LakeLevel: 0.3581	1.194	0.7759	(none)	(none)

Appendix Table 34. Multiple regression analyses of total number of forage fish lakewide in fall on combinations of independent variables for gill net abundance of numbers (fish per 40 gill net sets) and biomass (kg per 40 gill net sets) of trout (brown trout plus rainbow trout) and numbers and biomass of black basses; and variables for mean May-October JPSS generation flow (m^3/sec); mean May-October BCPSS pumping flow (m^3/sec); and mean May-October lake level (meters below full pool). These regressions utilized data from 1997 through 2012.

Zone	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
LW	1997-2012	logFallFish logTROUTnum MeanMayOctJocGen	0.3118	0.1280	14	Intercept: <0.0001 TROUT: 0.2781 JocGen: 0.0694	1.008	0.7955	**2012 (SR=2.522)**	(none)
LW	1997-2012	logFallFish logTROUTkg MeanMayOctJocGen	0.2872	0.1553	14	Intercept: <0.0001 TROUT: 0.3690 JocGen: 0.0636	1.070	0.9215	**2012 (SR=2.577)**	(none)
LW	1997-2012	logFallFish logTROUTnum MeanMayOctBCPump	0.2975	0.1434	14	Intercept: <0.0001 TROUT: 0.2622 BCPump: 0.0792	1.014	0.2264	(none)	(none)
LW	1997-2012	logFallFish logTROUTkg MeanMayOctBCPump	0.2352	0.2289	14	Intercept: <0.0001 TROUT: 0.5472 BCPump: 0.1005	1.014	0.3028	(none)	(none)
LW	1997-2012	logFallFish logTROUTnum MeanMayOctLL	0.3832	0.0701	14	Intercept: <0.0001 TROUT: 0.2362 LakeLevel: **0.0349**	1.010	0.4339	(none)	(none)
LW	1997-2012	logFallFish logTROUTkg MeanMayOctLL	0.3564	0.0886	14	Intercept: <0.0001 TROUT: 3284 LakeLevel: **0.0336**	1.063	0.2286	(none)	(none)
LW	1997-2012	logFallFish logBLBnum MeanMayOctJocGen	0.2508	0.2043	14	Intercept: <0.0001 BLB: 0.5944 JocGen: 0.0830	1.032	0.4993	**2012 (SR=2.613)**	(none)
LW	1997-2012	logFallFish logBLBkg MeanMayOctJocGen	0.2319	0.2343	14	Intercept: <0.0001 BLB: 0.8835 JocGen: 0.0977	1.041	0.3198	**2012 (SR=2.704)**	(none)
LW	1997-2012	logFallFish logBLBnum MeanMayOctBCPump	0.2497	0.2060	14	Intercept: <0.0001 BLB: 0.4527 BCPump: 0.0838	1.346	0.2702	(none)	(none)
LW	1997-2012	logFallFish logBLBkg MeanMayOctBCPump	0.3395	0.1022	14	Intercept: <0.0001 BLB: 0.1676 BCPump: **0.0374**	1.416	0.3381	(none)	(none)
LW	1997-2012	logFallFish logBLBnum MeanMayOctLL	0.3301	0.1104	14	Intercept: <0.0001 BLB: 0.4650 LakeLevel: **0.0408**	1.056	0.1025	(none)	(none)
LW	1997-2012	logFallFish logBLBkg MeanMayOctLL	0.3018	0.1387	14	Intercept: <0.0001 BLB: 0.7537 LakeLevel: 0.0529	1.066	0.1892	(none)	(none)

Appendix Table 35. Multiple regression analyses of total number of forage fish lakewide in fall in Lake Jocassee on maximum summer surface (mean in top four meters of water column) lakewide temperature (C). Lakewide temperature was calculated as the mean of surface (0.3 to 4-m mean) mean temperatures in forage fish sampling zones.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1997-2012	Lakewide	Dep: logFallFish Indep: MaxLWTemp	0.1713	0.1251	15	Intercept: 0.1036 Temp: 0.1251	0.6144	**2012 (SR=2.765)**	(none)
1997-2012 excl 2012	Lakewide	logFallFish = 3.32467 + 0.12052 MaxLWTemp	0.3425	**0.0279**	14	Intercept: 0.0256 Temp: **0.0279**	**0.0109**	(none)	(none)

Appendix Table 36. Multiple regression analyses of fall forage fish densities (no/ha) in forage fish sampling zones of Lake Jocassee on maximum summer surface (mean in top four meters of water column) zonal mean temperature (C).

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1997-2012	1	logFallDens = -7.00535 + 0.37418 MaxTempZ1	0.4244	**0.0063**	16	Intercept: 0.0407 Temp: **0.0063**	0.1771	(none)	(none)
1997-2012	2	Dep: logFallDens Indep: MaxTempZ2	0.0083	0.7461	15	Intercept: 0.3390 Temp: 0.7461	0.4978	(none)	(none)
1997-2012	3	Dep: logFallDens Indep: MaxTempZ3	0.0119	0.6988	15	Intercept: 0.1469 Temp: 0.6988	0.1460	(none)	(none)
1997-2012	4	Dep: logFallDens Indep: MaxTempZ4	0.0963	0.2603	15	Intercept: 0.6187 Temp: 0.2603	0.7179	(none)	(none)

CHAPTER 3

TRENDS IN THE PELAGIC FORAGE FISH COMMUNITY OF LAKE KEOWEE, SOUTH CAROLINA

SPRING 1999 – SPRING 2013

October 2013

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CHAPTER THREE

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INTRODUCTION

This report documents characteristics of the pelagic forage fish community of Lake Keowee, South Carolina, based on hydroacoustics and purse seine data collected by Duke Energy, spring 1999 through spring 2013. Variation in spring and fall forage fish abundance and distribution is analyzed in relation to environmental parameters and operational flows at Jocassee Pumped Storage Station and Keowee Hydroelectric Station.

The pelagic forage fish community of Lake Keowee consists of two species: threadfin shad (*Dorosoma petenense*) and blueback herring (*Alosa aestivalis*). Both species have been established in Lake Keowee since the 1970s. Threadfin shad are found from Central America to Indiana, with northern distribution limited by a lower temperature tolerance of 7-14 C. Threadfin shad tend to school near the surface in pelagic areas of reservoirs (Tomelleri and Eberle 1990; Hassan-Williams and Bonner 2008). The reported life span of threadfin shad is two to three years (Etnier and Starnes 1993), although the South Carolina Department of Natural Resources (SCDNR) noted that few threadfin shad in South Carolina reservoirs survive longer than one year. Spawning of threadfin shad typically occurs in May and June in South Carolina reservoirs (SCDNR 2009). Threadfin shad are capable of both filter- and particulate-feeding. In a study on Lake Jocassee, North and South Carolina, 24 to 32% of the diet of threadfin shad consisted of phytoplankton, with the remainder consisting of small zooplankton (Davis and Foltz 1991).

Distribution of anadromous blueback herring ranges from Florida to Nova Scotia. Landlocked populations of blueback herring have become common in reservoirs of the southeastern United States (Wheeler et al. 2004). Blueback herring tolerate temperatures as low as 2 C (Pardue 1983); during stratified periods, blueback herring in southeastern reservoirs tend to prefer cool (13 to 24 C), deep water with dissolved oxygen concentrations exceeding 3 mg/L (Dennerline and Degan 1999; Goodrich 2002). Life spans of blueback herring in landlocked reservoirs range from two to four years (Wheeler et al. 2004). Blueback herring are predominantly sight-feeding size-selective predators (Pardue 1983; Davis and Foltz 1991). Davis and Foltz (1991) reported that blueback herring in Lake Jocassee consumed primarily larger copepods and cladocerans.

STUDY AREA

Lake Keowee, located in northwestern South Carolina, was impounded in the late 1960s. The lake consists of two basins connected by a canal: the Keowee River basin and the Little River basin (Figure 3-1). Surface area of the Keowee River basin at full pool is 3,270 ha, and that of the Little River basin is 4,160 ha. Both basins are characterized by a mean depth of approximately 16 m (Table 3-1). The headwaters of the Keowee River above Lake Keowee were impounded in 1971, creating Lake Jocassee (Barwick et al. 2007).

Three electric generating facilities utilize water from Lake Keowee. Oconee Nuclear Station (ONS), a baseload generating facility located at the juncture of the Keowee River and Little River basins, employs a once-through condenser cooling water system. Water is withdrawn from the Little River basin and discharged to the Keowee River basin. A skimmer wall restricts water intake to depths below 20 meters below full pool. Jocassee Pumped Storage Station (JPSS) pumps water from Lake Keowee during off-peak hours for storage in Lake Jocassee, and discharges water from Lake Jocassee to Lake Keowee for generation during hours of peak demand. Keowee Hydroelectric Station (Keowee HS), at the downstream terminus of the Keowee River basin, utilizes water from Lake Keowee to generate electricity, discharging downstream to Lake Hartwell. Mean monthly generation flows at Keowee HS and pumping flows at JPSS are plotted for the study period in Figure 3-2.

Lake Keowee is a warm monomictic reservoir which is typically thermally stratified from March/April through September/October. By August, a deep thermocline has typically developed at a depth of about 28 meters below full pool; waters below this depth may become anoxic depending on meteorological conditions (Barwick et al. 2007). Based on data collected 1999 through 2012, surface (0.3 m) temperatures measured at locations on Lake Keowee ranged from 8.0 to 34.9 C. A surface thermal plume was evident in the Keowee River basin due to discharge of heated water from the Oconee Nuclear Station condenser cooling water system. In terms of productivity, the lake has been described as oligo- to oligomesotrophic, with median annual nutrient concentrations of 0.008 mg phosphorus per liter and 0.200 mg nitrogen per liter, and mean chlorophyll concentrations of 0.4 to 9.4 mg/m^3, based on data collected 1993-2005

(Barwick et al. 2007). As noted above, the pelagic forage fish community in Lake Keowee consists of threadfin shad and blueback herring. Species in Lake Keowee which are likely to prey on these forage fish include largemouth bass (*Micropterus salmoides*), spotted bass (*Micropterus punctulatus*), redeye bass (*Micropterus coosae*), smallmouth bass (*Micropterus dolomieu*), and black crappie (*Pomoxis nigromaculatus*).

METHODS

Sources and treatment of data

Pelagic forage fish abundance – Duke Energy carried out hydroacoustics sampling employing multiplexing, side-scan, and down-looking transducers to monitor the abundance of pelagic forage fish in Lake Keowee (Barwick et al. 2007). Sampling was conducted in spring (March) and fall (November or early December). This report analyzes hydroacoustics data collected spring 1999 through spring 2013 (no spring samples were collected in 2000). Results are reported as total forage fish numbers for Lake Keowee, and as forage fish densities (fish/ha) for the Keowee River and Little River basins of Lake Keowee.

Pelagic forage fish species composition – Purse seine sampling to characterize the species composition of the forage fish community was conducted in conjunction with fall hydroacoustics sampling, using a 122 x 9 m purse seine with a mesh size of 4.8 mm (Barwick et al. 2007). Purse seine samples were collected near the Oconee Nuclear Station discharge from 1999 through 2002; near Fall Creek Landing in the upper reaches of the Keowee River basin from 2003 through 2006; and from both of these areas from 2007 through 2012. Purse seine samples were collected in the Little River basin in 2011 and 2012. Results of purse seine sampling are reported as percent of total catch consisting of threadfin shad and blueback herring.

Age structure of pelagic forage fish populations – Lengths of forage fish collected in purse seine samples were measured to the nearest millimeter. Age classes were identified for each species based on modes in length-frequency distributions, for each year and location sampled. Median lengths of young-of-the-year (YOY) fish were reported as a measure of growth.

Littoral abundance of predatory fish – During the forage fish study period, Duke Energy conducted spring shoreline electrofishing in 1999, 2002, 2005, 2008, 2010, and 2011. Electrofishing methods are documented in Barwick et al. (2007). Three areas of Lake Keowee were sampled: mid- to downlake on the Little River basin; uplake on the Keowee River basin; and mid- to downlake on the Keowee River basin (Figure 3-3). Ten 300-m shoreline transects were sampled in each of these areas. Transects were selected to represent all habitat types. For the purposes of the current study, electrofishing results were reported as fish/km and kg/km for the species likely to prey on pelagic forage fish: largemouth bass, spotted bass, redeye bass, smallmouth bass, hybrid black bass, and black crappie.

Temperature and oxygen – Temperature and dissolved oxygen were measured monthly by Duke Energy from 1999 through May 2013. Measurements were made at 1-m intervals throughout the water column at three locations in the Little River basin (500, 501, 502) and five locations in the Keowee River basin (504, 505, 506, 507, 508) (Figure 3-1). Surface temperature in this report refers to mean temperature in the top five meters of the water column.

Chlorophyll – Chlorophyll samples were collected by Duke Energy monthly over the study period at depths of 0.3, 5, and 10 meters. Chlorophyll data were averaged over the top ten meters of the water column for analysis in this report. Basinwide mean chlorophyll concentrations analyzed in relation to forage fish were calculated using data from Locations 500 and 502 to characterize the Little River basin, and from Locations 504 and 505 to characterize the Keowee River basin (Figure 3-1). Lakewide means were calculated as the average of basinwide means. Data from additional locations were available for the years 2011 and 2012, and spatial variation in chlorophyll concentrations was characterized using this more comprehensive data set (Locations 500, 501, 502, 504, 505, 506, and 507).

Zooplankton – From 1999 through 2011, Duke Energy collected zooplankton samples quarterly at Location 502 in the Little River basin and Location 508 in the Keowee River basin (Figure 3-1). Samples were collected in bottom-to-surface net tows; bottom depths averaged 27.5 m at Location 502 and 24.0 m at Location 508 over this period. In 2012, Location 500 in the Little River basin and Locations 505 and 507 in the Keowee River basin were sampled in addition to

Locations 502 and 508, and bottom depths for all net tows were standardized to 20 m. Variables analyzed in relation to forage fish included densities of copepods, cladocerans, total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton (sum of copepod, cladoceran, and rotifer density). Annual lakewide estimates of zooplankton density were calculated as the average of data collected at Locations 502 and 508.

Analytical methods for temperature, oxygen, chlorophyll, and zooplankton are described in Barwick et al. (2007).

Keowee Hydroelectric Station generation flows – Duke Energy provided hourly generation data for Keowee Hydroelectric Station. Data were converted from megawatt-hours (MWH) to cubic feet per second (cfs) using a conversion factor of 113 cfs per MWH, supplied by Duke Energy. Data were then converted to m^3/sec by dividing cfs (ft^3/sec) by 35.314444 (ft^3/m^3).

Lake level – Duke Energy provided hourly lake level data for Lake Keowee, expressed as 100 minus feet below full pool. Data for Hour 24 were utilized in this report to characterize daily lake levels and to calculate daily changes in lake level. Lake level data in this report are expressed as meters below full pool (positive number). Conversion from feet to meters utilized a conversion factor of 3.280833 ft/m.

Jocassee Pumped Storage Station generation and pumping data – Hourly generation and pumping data for Jocassee Pumped Storage Station expressed as megawatt-hours (MWH) were supplied by Duke Energy. In data for 1999 through 2007, generation rates expressed as MWH were multiplied by 49 to obtain hourly average flows from Lake Jocassee to Lake Keowee in cubic feet per second (cfs). Pumping rates expressed as MWH were multiplied by 37.73 to obtain hourly pumping flows from Lake Keowee to Lake Jocassee in cfs. These conversion factors were also applied to data for Units 1 and 2 at JPSS for the years 2008 through 2010. Conversion from MWH to cfs for Units 3 and 4 for the years 2008 through 2010 was accomplished using conversion factors of 44 cfs/MWH for generation and 35 cfs/MWH for pumping. For the years 2011 through 2013, conversion from MWH to cfs for the entire station was accomplished using conversion factors of 44 cfs/MWH for generation flow, and 35 cfs/MWH for pumping flow. Conversion factors for MWH to flow were provided by Duke Energy. Operational flows were converted from cfs to m^3/sec using a conversion factor of 35.314444 ft^3/m^3.

Statistical methods

Statistical analyses were carried out using the SAS system of statistical analysis, Release 9.2 on the XP-PRO platform, produced by SAS Institute, Inc., Cary, NC (copyright 2002-2008). Results of statistical analyses were designated as significant at a reference probability of $P \leq 0.0500$.

Univariate analysis including calculation of the Shapiro-Wilk statistic (W) was carried out on all data sets to determine the probability that data were normally distributed. Data were assumed to come from a normal distribution where prob<W≥0.0500. Data were $\log_{10}$-transformed where useful to allow assumption of a normal distribution for parametric analyses and to reduce positive skew in data. Where values of zero were present for a variable which required log-transformation, a constant value was added to each observation to allow log-transformation (Norman and Streiner 2008). Where data were severely negatively skewed, power transformation was used to reduce skew (Kleinbaum et al. 1998). Individual observations were identified in univariate analysis as outliers where the observation was less than the 25% quartile (low outlier) or greater than the 75% quartile (high outlier) by between 1.5 and 3 times the interquartile range. Observations were identified as extreme outliers where the data point was less than the 25% quartile (extreme low outlier) or greater than the 75% quartile (extreme high outlier) by more than 3 times the interquartile range (SAS Institute, Inc. 1990).

Characterization of long-term temporal trends in parameters was carried out with time series analysis, consisting of linear regressions of annual data on year. Seasonal and spatial variation was examined with nonparametric analysis of variance.

Spring forage fish lakewide numbers and spring forage fish densities in basins of Lake Keowee were analyzed in relation to winter environmental conditions and operational regimes. Winter Keowee HS generation flow, JPSS pumping flow, and Lake Keowee lake level were characterized with three variables each: mean, maximum daily, and maximum 30-day average observed December-February. These variables were intended to quantify the influence of general winter conditions (mean); short-term high flow or low lake level (maximum daily); and sustained high flows or low lake levels (maximum 30-day average) occurring during the winter. Thirty-day averages were moving averages calculated daily for the current and previous 30 days; the maximum 30-day average observed December 30 through the end of February was chosen to characterize sustained periods of high flow or low lake level. For parameters for which December-February data were used to characterize winter conditions, the year with which winter data are associated is the year in which January-February measurements were made.

Fall forage fish lakewide numbers and densities in forage fish sampling zones were analyzed in relation to conditions during spring forage fish spawning (May-June) and in relation to conditions during the period between spring spawning and fall forage fish sampling (May-October). Keowee HS generation flow, JPSS pumping flow, and Lake Keowee lake level observed May-October were characterized with three variables each: mean, maximum daily, and maximum 30-day average. These variables were intended to quantify the influence of general conditions (mean); short-term high flow or low lake level (maximum daily); and sustained high flows or low lake levels (maximum 30-day average), for the period May-October. Thirty-day averages were moving averages calculated daily for the current and previous 30 days; the maximum 30-day average observed May 30 through October 31 was chosen to characterize sustained periods of high flow or low lake level.

Relationships of forage fish parameters to environmental and operational parameters were initially examined with Spearman rank order correlation analysis. These relationships were examined in greater detail where appropriate with Pearson correlation analysis, and linear and multiple regression analysis. Data for spring forage fish lakewide numbers and spring forage fish densities in the Keowee River and Little River basins, as well as data for fall forage fish density in the Little River basin, were log-transformed to allow assumption of a normal distribution for parametric analyses. Data for independent variables were log-transformed where useful to allow assumption of a normal distribution or to reduce positive skewness; regression analysis does not require that independent variables be normally distributed, although it is desirable (Tabachnick and Fidell 1983; Norman and Streiner 2008).

Multiple regression analyses with two independent variables were carried out to investigate combined influences of environmental and operational parameters on forage fish abundance in Lake Keowee. Because the number of observations available for analysis was generally limited to 14 based on the number of years forage fish were sampled, multiple regression analyses with more than two independent variables were not carried out, as the recommended minimum sample size for multiple regression analyses is five times the number of independent variables, or 15 for a multiple regression with three independent variables (Norman and Streiner 2008; Garson 2010). It should be noted that regression models which exclude variables quantifying important influences on the dependent variable may be subject to specification error, potentially causing biased estimates of model parameters (Freund et al. 2006).

Independent variables are considered to have interactive effects on the dependent variable, where the effect of one independent variable changes at different levels of the other independent variable (Norman and Streiner 2008; Garson 2010). While it would be useful to investigate whether some independent variables in this study exerted interactive influences on forage fish in Lake Keowee, multiple regression analyses intended to detect interactive influences of independent variables were not carried out, as addition of a third variable to quantify interaction would be required; sample size was not considered large enough to perform analyses with three terms.

Combined influences of environmental and operational parameters on pelagic forage fish abundance in Lake Keowee were investigated with multiple regression analyses of variables related to operations, temperature, and food availability as follows:

Spring forage fish:
- Winter JPSS pumping flow and Keowee HS generation flow
- Winter JPSS pumping flow and lake level
- Winter Keowee HS generation flow and lake level
- Winter JPSS pumping flow and winter temperature
- Winter JPSS pumping flow and chlorophyll
- Winter Keowee HS generation flow and chlorophyll
- Winter JPSS pumping flow and zooplankton
- Winter Keowee HS generation flow and zooplankton
- Winter chlorophyll and predation (abundance of black basses)
- Winter zooplankton and predation (abundance of black basses)

Fall forage fish:
- May-October JPSS pumping flow and Keowee HS generation flow
- May-October JPSS pumping flow and lake level
- May-October Keowee HS generation flow and lake level
- May-October JPSS pumping flow and temperature
- May-October JPSS pumping flow and chlorophyll
- May-October Keowee HS generation flow and chlorophyll
- May-October JPSS pumping flow and zooplankton
- May-October Keowee HS generation flow and zooplankton
- May-October chlorophyll and predation (abundance of black basses)
- May-October zooplankton and predation (abundance of black basses)

Outlying observations in regression analysis were identified where the absolute value of the studentized residual statistic exceeded 2.5 (Freund et al. 2006). Highly influential data points, observations that disproportionately influence the outcome of regression analysis, were identified where values of the Cook's D statistic exceeded a critical value for the F statistic, using a reference probability of 0.05. Helsel and Hirsch (2002) define the critical F value as follows:

$$\text{Critical Cook's D} = F_{(p+1,n-p)}$$

where

p = number of coefficients in regression equation (2 for linear regression)
n = number of observations

Where outlying or highly influential data points were identified in linear regression analyses, regressions were repeated, excluding outlying or highly influential data. Both initial and follow-up results were reported. Multiple regressions where outlying observations were identified were not routinely repeated, due to relatively small number of observations available for analysis (see below), and to the potential loss of information associated with excluding an observation with no known reason to do so. It should be kept in mind that statistical identification of an observation as an outlier does not of itself indicate error in the observation, and exclusion of outliers could lead to a loss of information about variability of parameters.

Not infrequently in these analyses, the significance or lack thereof of a given regression analysis was dependent on the inclusion or exclusion of one observation, likely as a result of the relatively small number of observations available for analysis (see discussion of sample size below). Regressions where significance is dependent on inclusion of a single observation cannot be considered robust; similarly, regressions where significance depends on exclusion of a single observation must be interpreted with caution, as the excluded observation may contain important information about the relationship being investigated and results may therefore be biased (Kleinbaum et al. 1998).

The SPEC option in the SAS procedure PROC REG (SAS institute, Inc. 1990) was utilized to test for homoscedasticity of variance in regression analysis. Deviations from homoscedasticity were designated as statistically significant where prob>chi-square≤0.0500) (Christiansen 1997). Kleinbaum et al. (1998) indicated that minor deviations from homoscedasticity do not generally affect regression results. Minor deviations from homoscedasticity were rarely noted in the analyses reported here and major deviations did not occur.

Multicollinearity, or correlations among independent variables in multiple regression analysis, may produce unrealistic results regarding the contribution of individual independent variables to explaining variance in the dependent variable. In multiple regression analyses, the potential for multicollinearity was examined with the variance inflation factor (VIF). VIF values greater than 10 indicate a problem with multicollinearity (Helsel and Hirsch 2002; Norman and Streiner 2008). All VIF values in this study were substantially less than 10.

The number of observations available in this study was relatively small for multiple regression analysis, with N for most analyses equal to 14 or less. As sample size decreases, the influence of each individual observation becomes greater, potentially producing unrealistic results (Kleinbaum et al. 1998). In the current study, at times the significance or lack of significance of a regression result depended on the presence or absence of a single observation, indicating that a relationship may not have been robust. While this does not invalidate the results of these analyses, it does suggest that additional observations would allow results to be interpreted with greater confidence.

PELAGIC FORAGE FISH COMMUNITY CHARACTERISTICS

Based on data collected spring 1999 through spring 2013, total numbers of pelagic forage fish on Lake Keowee ranged from 399,809 to 6,154,803 in spring, and from 2,080,344 to 16,936,544 in fall (Table 3-2). Lakewide, forage fish densities averaged 272 fish/ha in spring and 1,251 fish/ha in fall.

Seasonal variation – Forage fish abundance in Lake Keowee was significantly higher in fall than in spring (Figure 3-4). Total numbers of forage fish lakewide averaged 1,919,522 in spring and 8,831,503 in fall (Table 3-2), a statistically significant difference based on nonparametric analysis of variance (prob>chi-square<0.0001). Statistically significant seasonal variation was detected in each basin of Lake Keowee as well. Forage fish density in the Keowee River basin averaged 295 fish/ha in spring and 1,073 fish/ha in fall (prob>chi-square<0.0001); forage fish density in the Little River basin averaged 253 fish/ha in spring and 1,394 fish/ha in fall (prob>chi-square<0.0001).

Spatial variation – Forage fish densities did not differ significantly between the Keowee River and Little River basins, in either spring (prob>chi-square=0.9817) or fall (prob>chi-square=0.4082) (Figures 3-5 and 3-6).

Long-term temporal variation – In spring data, highest forage fish numbers and basin densities occurred in the years 1999 and 2001 (Figures 3-4 and 3-5). Time series analysis of spring forage fish data collected 1999 through 2013 detected long-term declines in spring forage fish lakewide numbers (Pr>F=0.0133), and in spring forage fish densities in the Keowee River basin (Pr>F=0.0177) and the Little River basin (Pr>F=0.0130). However, graphically, spring forage fish abundance appeared to stabilize following the year 2001 (Figures 3-4 and 3-5). Time series analysis of data collected 2002-2013 detected no long-term linear upward or downward trends in spring forage fish lakewide numbers (Pr>F=0.5891) or densities in the Keowee River basin (Pr>F=0.9975) or the Little River basin (Pr>F=0.4063).

In fall data, time series analysis of data collected 1999-2012 detected a significant tendency for lakewide numbers of forage fish in fall to decline over time (Pr>F=0.0107) (Figure 3-4). Similarly, significant, declining trends were detected in forage fish density data for the Keowee River basin (Pr>F=0.0026) and the Little River basin (Pr>F=0.0315) (Figure 3-6).

Lowest forage fish numbers of the study period were observed in 2010, in both spring and fall data. Forage fish numbers observed in spring and fall 2011 and 2012, as well as forage fish numbers observed in spring 2013, increased over those observed in 2010 (Figure 3-4).

Community composition – Fall purse seine sampling was carried out to characterize the relative community composition of the forage fish community. Purse seine samples were collected in the lower Keowee River basin near the Oconee Nuclear Station discharge from 1999 through 2002 and from 2007 through 2012; in the upper Keowee River basin from 2003 through 2012; and in the upper Little River basin in 2011 and 2012.

The pelagic forage fish community of Lake Keowee consists of blueback herring and threadfin shad. The relative abundance of these two species varied spatially. Threadfin shad dominated the community in the lower Keowee River basin, averaging 87% of the total purse sample. In contrast, blueback herring comprised 82% of the forage fish community in the upper Keowee River basin, on average (Table 3-3). Differences between the lower and upper Keowee River basin in community composition were consistent (Figure 3-7) and statistically significant (prob>chi-square=0.0002). Differences in community composition within the Keowee River basin may have been related at least in part to differences in the thermal preferences of threadfin shad and blueback herring, as winter temperatures in the lower basin of Lake Keowee were significantly warmer in winter due to thermal discharges from Oconee Nuclear Station.

In purse seine samples collected in the Little River basin in 2011 and 2012, blueback herring accounted for 71% of the forage fish community, on average (Table 3-3; Figure 3-7).

No significant long-term upward or downward linear trends were detected in time series analysis of percent composition of the pelagic forage fish community over the study period, for either the upper or lower Keowee River basin (Figure 3-7).

Age structure – Length-frequency plots of forage fish lengths measured in purse seine samples were used to classify fish as young-of-the-year (YOY) based on length (see Methods). On average, fall populations of blueback herring consisted of 96% YOY fish in the lower Keowee River basin; 98% in the upper Keowee River basin; and 96% in the Little River basin (Table 3-4). Similarly, fall populations of threadfin shad consisted on average of 98% YOY fish in the lower Keowee River basin; 99% in the upper Keowee River basin; and 100% in the upper Little River basin (Table 3-5).

YOY growth rates – Lengths of YOY fish measured in fall were analyzed as a surrogate for growth rates (Tables 3-4 and 3-5). Differences among years in median lengths of YOY fish were statistically significant for both blueback herring and threadfin shad based on nonparametric analysis of variance. No long-term temporal trends in YOY lengths were detected for either blueback herring or threadfin shad.

Spatial variation was evident in lengths of YOY blueback herring. Median lengths of blueback herring in the upper Keowee River basin (Fall Creek Landing) averaged 73.9 mm, as compared to 65.2 mm in the lower Keowee River basin (ONS discharge area), a statistically significant difference based on data collected 2007-2012 (prob>chi-square=0.0250). Too few observations in the upper Keowee River basin were available to analyze spatial differences in median YOY lengths of threadfin shad.

RELATIONSHIPS OF FORAGE FISH ABUNDANCE TO ENVIRONMENTAL AND OPERATIONAL PARAMETERS

Forage fish abundance on Lake Keowee was analyzed in relation to factors related to habitat (temperature, oxygen, lake level); food availability (chlorophyll, zooplankton); predation; and operations at Jocassee Pumped Storage Station (pumping flow) and Keowee Hydroelectric Station (generation flow). Potential effects of environmental and operational parameters on forage fish abundance in spring and fall were investigated through graphical analysis, correlation analysis, and linear and multiple regression analysis.

Temperature and oxygen

The following analysis of forage fish abundance in relation to temperature and oxygen is based on vertical profiles of temperature and dissolved oxygen carried out at meter intervals monthly from January 1999 through May 2013, at the following locations on Lake Keowee: 500, 501, 502, 504, 505, 506, 507, and 508 (Figure 3-1). Surface temperatures in the following discussion refer to the average temperature in the top five meters of the water column.

Temperature regime – Surface (0-5 m mean) temperatures on Lake Keowee over the study period ranged from 8.0 to 33.7 C (Tables 3-6 and 3-7). Mean seasonal variation in surface temperature is plotted for locations on Lake Keowee in Figure 3-8.

Statistically significant spatial variation in minimum winter surface temperature was evident in both basins of Lake Keowee, based on temperature data collected 1999-2013. In the Little River basin, minimum winter temperature averaged 10.3 and 10.7 C at Locations 500 and 501 respectively, significantly lower than at Location 502 in the lower basin, where minimum winter temperature averaged 12.5 C (Table 3-6; Figure 3-8). In the Keowee River basin, winter temperatures were influenced by thermal discharges from Oconee Nuclear Station. Average minimum winter surface temperatures ranged from 10.6 C at Location 507 in the upper reaches of the basin, to 16.0 C at Location 504, in the vicinity of the ONS discharge (Table 3-7; Figure 3-8). No long-term linear temporal upward or downward trends in minimum annual temperature were detected over the forage fish period, with the exception that a weak tendency was detected for minimum annual temperature to decline over time at Location 507 in the upper reaches of the Keowee River basin (R^2=0.3686; Pr>F=0.0476; N=11) (Figure 3-9).

Annual maximum surface temperatures measured over the forage fish study period averaged 30.3 C in the Little River basin based on data collected at Locations 500, 501, and 502; annual maximum temperatures did not exhibit significant spatial variation within the Little River basin. Annual maximum surface temperatures averaged 31.2 C in the Keowee River basin based on data collected at Locations 504, 505, 506, 507, and 508, significantly higher than the Little River basin. Significant spatial variation was evident in summer maximum surface temperatures observed in the Keowee River basin. Average maximum annual temperatures ranged from 28.4 C at Location 507 in the upper reaches of the Keowee River basin to 32.6 C at Location 508 in the vicinity of the ONS discharge (Table 3-7; Figure 3-8). Maximum annual temperature did not exhibit long-term upward or downward linear trends at any location over the forage fish study period (Figure 3-9).

Effect of winter minimum temperature – At temperatures below about 14 C, threadfin shad may exhibit reduced mobility, potentially increasing susceptibility to impingement and entrainment; mortality may occur at temperatures below 9-12 C (Griffith 1978; Burgess 1980; McLean et al. 1982, 1985). Blueback herring, in contrast, tolerate temperatures as low as 2 C (Lee et al. 1980; Page and Burr 1991).

Basinwide average minimum winter temperatures in the Little River basin ranged from 8.7 C to 13.0 C (Table 3-6). Spring forage fish density in the Little River basin exhibited no significant relationship to minimum winter surface temperatures observed basinwide or in the upper (Locations 500, 501) or lower (Location 502) regions of the Little River basin, in Spearman and Pearson correlation analysis of data collected 1999-2013. Similarly, spring forage fish numbers lakewide showed no relationship to minimum winter surface temperature in the Little River basin, in either correlation or linear regression analysis (Appendix Table 1).

Because winter temperatures exhibited significant spatial variation in the Keowee River basin, spring forage fish lakewide numbers and densities in the Keowee River basin were analyzed in relation to minimum winter temperatures observed in the lower Keowee River basin (mean of temperatures observed at Locations 504 and 508); the middle Keowee River basin (mean of temperatures observed at Locations 505 and 506); and the upper Keowee River basin (temperature observed at Location 507).

Neither spring forage fish lakewide numbers nor forage fish density in the Keowee River basin were significantly correlated with minimum winter temperatures in the lower or middle Keowee River basin, in either Spearman or Pearson correlation analysis. Significant, positive Spearman correlations were detected between spring forage fish density in the Keowee River basin and minimum winter temperature in the upper reaches of the Keowee River basin (r_s=0.83; P=0.0032; N=10) (Figure 3-10); similarly, total spring forage fish numbers lakewide were positively correlated with minimum winter temperature in the upper reaches of the Keowee River basin (r_s=0.73; P=0.0158; N=10) in Spearman correlation analysis (Figure 3-11). However, neither of these correlations was significant in Pearson correlation analysis. Linear regression analyses were performed in a further attempt to clarify relationships of spring forage fish lakewide numbers and density in the Keowee River basin to minimum winter temperature. No significant models were produced by these analyses, and no outlying or highly influential observations were identified (Appendix Table 1).

Analysis of the potential influence of low winter temperature on spring forage fish abundance was complicated by the fact that the forage fish community consisted of two species with differing thermal preferences. Potential impacts on individual species could not be analyzed, as population data were not available at the species level. However, minimum winter temperatures in the lower region of the Keowee River basin never fell below 13.3 C (Table 3-6), indicating that a thermal refuge was always present for threadfin shad in winter.

The possibility that spring forage fish abundance in Lake Keowee was influenced by combined effects of low winter temperatures below the Jocassee dam and winter JPSS pumping flow is examined in a later section of this report.

Effect of summer maximum temperature –Threadfin shad have been observed to congregate in surface waters where temperatures exceed 30 C (Schael et al. 1995); blueback herring, in contrast, tend to avoid temperatures greater than 25 C, and prefer habitat with temperatures between 13 and 24 C where oxygen concentrations exceed 3 mg/L (Dennerline and Degan 1999; Goodrich 2002).

Because of the substantial variation in surface temperature observed among locations on Lake Keowee, particularly in the Keowee River basin, annual maximum lakewide surface temperatures were not calculated. Fall forage fish data were analyzed in relation to annual maximum surface temperatures observed in the Little River basin (averaged over Locations 500, 501, 502); and in the lower, middle, and upper regions of the Keowee River basin. Maximum annual temperatures for the lower Keowee River basin were calculated as the average of maximum annual temperatures observed at Locations 504 and 508; annual temperatures for the middle Keowee River basin were calculated as the average of maximum annual temperatures observed at Locations 505 and 506; and maximum annual temperature in the upper Keowee River basin was that observed at Location 507.

In the Little River basin of Lake Keowee, fall forage fish density was negatively correlated with maximum basinwide summer surface temperature in both Spearman (r_s= -0.62; P=0.0186; N=14) and Pearson (r= -0.57; P=0.0335; N=14; forage fish density log-transformed) correlation analysis. Linear regression analysis detected a significant tendency for fall forage fish density in the Little River basin to decline as maximum summer temperature increased:

(1)
logFallDensLit = 11.47181 – 0.27681 MaxTempLit

$R^2 = 0.3244$
Pr>F = 0.0335
N = 14
Prob>|t| for intercept = 0.0066
Prob>|t| for maximum temperature = 0.0335
Data set: Little River basin, 1999-2012
Outlying or highly influential observations: (none)

where logFallDensLit = log Fall forage fish density in the Little River basin, no/ha

MaxTempLit = maximum annual surface (0-5m) temperature in the Little River basin, C, calculated as average of maximum temperatures observed at Locations 500, 501, 502

Thus maximum summer surface temperature in the Little River basin potentially explained 32% of variance in fall forage fish density, with lower densities observed following higher maximum temperatures (Figure 3-12). This tendency possibly reflects an effect of high temperature on the distribution of blueback herring in response to the preference of blueback herring for cooler, well-oxygenated habitat during the summer (see below). A significant tendency was also detected for total number of forage fish lakewide in fall to decline with increasing maximum annual temperature in the Little River basin (Figure 3-13), in both Spearman (r_s= -0.55; P=0.0408; N=14) and Pearson (r= -0.56; P=0.0359; N=14) correlation analysis, and in linear regression analysis:

(2)
FallFish = 139,547,156 – 4,308,293 MaxTempLit

R^2 = 0.3174
Pr>F = 0.0359
N = 14
Prob>|t| for intercept = 0.0268
Prob>|t| for maximum temperature = 0.0359
Data set: Little River basin maximum temperature, Lake Keowee lakewide fall forage fish number, 1999-2012
Outlying or highly influential observations: (none)

where FallFish = total number of forage fish lakewide in fall
MaxTempLit = maximum annual surface (0-5 m) temperature in the Little River basin, C, calculated as average of maximum temperatures observed at Locations 500, 501, 502

A similar tendency for fall forage fish density to decline with increasing maximum summer temperature was detected in data for the Keowee River basin. Based on Spearman correlation analysis, fall forage fish density in the Keowee River basin was negatively correlated with summer maximum temperatures in both the lower Keowee River basin (r_s= -0.59; P=0.0251; N=14) and the middle Keowee River basin (r_s= -0.72; P=0.0035; N=14). The negative relationship between fall forage fish density and summer maximum temperature in the middle Keowee River basin was also evident in Pearson correlation analysis (r= -0.64; P=0.0144; N=14) and in linear regression analysis:

(3)
FallDensKeo = 13,841 – 406.90853 MaxTempMiddleKeo
R^2 = 0.4051
Pr>F = 0.0144
N = 14
Prob>|t| for intercept = 0.0092
Prob>|t| for maximum temperature = 0.0144
Data set: Keowee basin, 1999-2012
Outlying or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
MaxTempMiddleKeo = maximum annual surface (0-5 m) temperature observed in the middle Keowee River basin, C, calculated as the mean of maximum annual temperatures at Locations 505 and 506

Variation in summer maximum surface temperature in the middle Keowee River basin could potentially explain 41% of variance in fall forage fish density in the Keowee River basin, with fall forage fish density tending to be lower following hotter summers (Figure 3-12).

Total numbers of forage fish lakewide in fall were negatively correlated with summer maximum temperatures in the middle Keowee River basin in Spearman correlation analysis (r_s= -0.56; P=0.0389; N=14) (Figure 3-13); this relationship was not statistically significant in Pearson correlation analysis or in linear regression analysis (Appendix Table 2).

Late summer temperature-oxygen habitat constraints – As noted above, threadfin shad exhibit a preference for warmer, well-oxygenated water in summer, and would therefore be expected to have an abundance of favorable habitat on Lake Keowee in summer. Blueback herring, in contrast, tend to prefer habitat with temperatures between 13 and 24 C and dissolved oxygen concentrations exceeding 3 mg/L. The relationships detected above between forage fish densities and maximum summer surface temperature may reflect a relationship between blueback herring abundance and available habitat in late summer.

Based on a slightly expanded habitat range defined by temperature ≤26 C and dissolved oxygen ≥2.5 mg/L, available preferred habitat for blueback herring in late summer is plotted for selected locations in Figures 3-14 through 3-17. With the exception of 2004, an unusual year in that the lake began to cool in August, virtually no preferred habitat for blueback herring was available by September in the Little River basin. In the Keowee River basin, preferred blueback herring habitat as defined was restricted or virtually nonexistent in 9 of 14 years in the lower (Location 504) and middle (Location 505) Keowee River basin and in 5 of 14 years in the upper Keowee River basin (Location 507) (Figures 3-15 through 3-17).

The negative relationship detected in linear regression analysis between summer surface maximum temperature in the middle Keowee River basin and fall forage fish densities in the Keowee River basin is at least potentially related to shrinking of available suitable habitat for blueback herring during warmer summers. Summer surface maximum temperatures observed at Location 505 in the middle Keowee River basin were significantly, negatively correlated with the vertical thickness of a layer of suitable blueback herring habitat available in September at Location 505, defining suitable habitat as described above ($r = -0.76$; $P=0.0015$; $N=14$; vertical thickness of habitat layer log-transformed). Because no population estimates were available for individual species, direct effects of restricted habitat on fall populations of blueback herring could not be statistically analyzed.

Effect of temperature during spring spawning season – Initial abundance, growth, and survival of larval clupeids have been observed to respond positively to warmer temperatures and greater food availability during the spawning season (Betsill and Van Den Avyle 1997; Michaletz 1997; Claramunt and Wahl 2000). In the current study, Spearman and Pearson correlation analyses detected no significant relationships between mean surface temperatures observed in May and June and fall forage fish density in either basin of Lake Keowee, based on data collected 1999-2012.

Correlation analyses were also performed between mean May-June surface temperature and growth of YOY blueback herring and threadfin shad. Median lengths of YOY blueback herring and threadfin shad in fall purse seine samples were employed as a measure of growth. As noted previously, fall purse seine samples collected in the upper Keowee River basin were dominated by blueback herring, while those collected in the lower basin in the vicinity of Oconee Nuclear Station consisted primarily of threadfin shad. Median lengths of YOY blueback herring collected at the Fall Creek Landing location in the upper reaches of the Keowee River basin were subjected to correlation analysis with mean May-June temperatures at Location 507. Positive correlations were detected in both Spearman (r_s=0.66; P=0.0392; N=10) and Pearson (r=0.65; P=0.0404; N=10) correlation analyses, suggesting that growth rates of YOY blueback herring may have been influenced by temperature during spawning. No significant relationships were detected in correlation analysis of median lengths of YOY threadfin shad in the lower Keowee River basin and mean May-June surface temperatures at Location 504.

Effect of temperature on forage fish species distribution – As noted previously, blueback herring tended to dominate the pelagic forage fish community upstream in the Keowee River basin, accounting for an average of 82% of fish in fall purse seine samples collected 1999-2012. Threadfin shad, in contrast, accounted for an average of 87% of fall purse seine samples collected in the vicinity of Oconee Nuclear Station. These distributions are consistent with temperature preferences of these species. From 1999-2012, mean May-October surface temperatures at Location 504, near the ONS discharge, ranged from 27.2 to 29.5 C, in the range avoided by blueback herring but consistent with the thermal preferences of threadfin shad. Mean May-October surface temperatures at Location 507 in the upper reaches of the Keowee River basin ranged from 24.3 to 26.6, significantly lower than those observed downlake at Location 504 (prob>chi-square<0.0001), and more consistent with the thermal preferences of blueback herring.

Purse seine samples were collected in the Little River basin in 2011 and 2012. Blueback herring comprised 81.9% of the purse sample in 2011 and 59.4% in 2012 (Table 3-3). Mean May-October surface temperatures averaged over Locations 500 and 501 in the upper half of the Little River basin ranged from 25.8 to 28.2 C, significantly cooler than the ONS discharge area and warmer than the upper Keowee River basin.

Purse seine samples were collected in November. November surface temperatures at Location 504 near the ONS discharge ranged from 21.5 to 25.2 C, significantly warmer than upstream in the Keowee River basin at Location 507, where November temperatures ranged from 17.0 to 21.0 C; and significantly warmer than average surface temperatures in the upper Little River basin (averaged over Locations 500 and 501), where November temperatures ranged from 17.0 to 20.7 C. Again, this is consistent with the thermal preferences of blueback herring and threadfin shad, in that threadfin shad dominated purse seine samples in the warmer area near the ONS discharge, while blueback herring comprised the majority of the purse seine samples in the upper Keowee and Little River basins (Table 3-3).

Lake level

Lake level characterization – Over the forage fish study period, daily Lake Keowee lake levels ranged from 0.02 to 2.27 meters below full pool, averaging 1.06 meters below full pool, and exhibiting a median of 1.17 meters below full pool. Statistically significant seasonal variation in lake level was detected based on nonparametric analysis of monthly mean lake level data, 1999-2012 (prob>chi-square=0.0039). Lake levels were highest in April and May and lowest in October and November, on average (Figure 3-18).

Lake levels observed over the forage fish period are plotted in Figure 3-19. Lake level varied significantly among years, based on nonparametric analysis of variance of daily lake level data (prob>chi-square<0.0001). Lowest mean annual lake levels were observed in 2001 and 2002, and highest in 2003 and 2004 (Table 3-8). The range over which lake level varied annually was greatest in 2005, 2006, and 2007 (Table 3-8; Figure 3-19).

Forage fish abundance in Lake Keowee is analyzed in relation to lake level observed during the winter (mean, lowest daily, lowest 30-day average lake level observed December-February); during spring forage fish spawning in May and June (mean, range over which lake level varied); and during the period between spring forage fish spawning and fall forage fish sampling in November (mean, lowest daily, lowest 30-day average lake level observed May-October). Lake levels for these periods are documented in Table 3-9 and Figures 3-20 and 3-21.

Effect of winter lake level on spring forage fish abundance – Mean lake levels observed in winter (December-February) ranged from 0.4 to 1.8 meters below full pool (Table 3-9; Figure 3-20). Spearman correlation analysis relating spring forage fish numbers lakewide and spring forage fish densities in basins of Lake Keowee to winter lake level (mean, lowest daily, and lowest 30-day average) detected no significant relationships. Similarly, no significant results were obtained in linear regression analysis of spring forage fish lakewide numbers or forage fish densities in basins of Lake Keowee on mean, lowest daily, or lowest 30-day average winter lake level (Appendix Table 3). Spring forage fish lakewide numbers and densities in basins of Lake Keowee are plotted against mean winter lake levels in Figures 3-22 and 3-23.

Possible combined influences of lake level and operational flows at JPSS and Keowee HS are examined in a later section of this report.

Effect of mean May-June lake level on fall forage fish abundance – Mean lake levels observed during the spring forage fish spawning season (May-June) on Lake Keowee ranged from 0.2 to 1.6 meters below full pool (Table 3-9; Figure 3-21). Fall forage fish numbers lakewide and fall forage fish densities in the Keowee River and Little River basins of Lake Keowee exhibited no relationship to mean lake level observed in May-June in Spearman correlation analysis. Similarly, linear regression analyses of fall forage fish numbers lakewide and fall forage fish densities in basins of Lake Keowee on mean May-June lake levels produced no significant results (Appendix Table 4; Figures 3-24 and 3-25).

Effect of lake level fluctuation during the May-June spawning season – Rapid changes in lake level during the spring spawning season may negatively impact spawning success through exposure of spawning sites, or covering of spawning sites to an unacceptable depth (Moyle and Cech 2000). Fall forage fish abundance on Lake Keowee was analyzed in relation to three measures of lake level fluctuation during the spring spawning season: range over which lake level varied during May-June (difference between minimum and maximum lake level); maximum 3-day decline in lake level observed May-June; and maximum 3-day increase in lake level observed May-June. The magnitude of the range over which lake level varied during May-June exhibited a minimum of 0.3 meters in 2003 and a maximum of 1.2 meters in 2009 (Table 3-9; Figure 3-21).

Fall forage fish lakewide numbers and fall forage fish densities in basins of Lake Keowee are plotted against the range over which lake level varied in May and June in Figures 3-26 and 3-27. Spearman correlation analysis relating fall forage fish numbers lakewide and fall forage fish densities in the Keowee River and Little River basins of Lake Keowee to the range over which lake level varied during the May-June spawning season produced no significant results. Similarly, no significant Spearman correlations were observed between fall forage fish variables and either the maximum 3-day increase or the maximum 3-day decline in May-June lake level.

Fall forage fish lakewide numbers and densities in basins were also subjected to linear regression analysis on the range over which lake level fluctuated during May-June. No significant models were produced in initial regression analysis (Appendix Table 4). Data for 2010 were identified as outlying in the regression of fall forage fish density in the Little River basin on the range over which lake level varied in May-June, as follows:

(4)
logFallDensLit = 3.24867 – 0.24885 RangeMayJunLL
$R^2 = 0.0715$
Pr>F = 0.3553
N = 14
Prob>|t| for intercept < 0.0001
Prob>|t| for range = 0.3553
Data set: 1999-2012, Little River basin
Outlying or highly influential observations: **2010** (studentized residual = -2.731)
where logFallDensLit = log Fall forage fish density in the Little River basin of Lake Keowee, no/ha
RangeMayJunLL = range over which lake level varied in May-June, meters

A repeat of this analysis (Appendix Table 5), excluding the observation for 2010 identified as outlying, produced the following significant model:

(5)
logFallDensLit = 3.45215 – 0.45621 RangeMayJunLL
$R^2 = 0.3865$
Pr>F = 0.0233
N = 13
Prob>|t| for intercept < 0.0001
Prob>|t| for range = 0.0233
Data set: 1999-2012 excluding 2010
Outlying or highly influential observations: (none)
where logFallDensLit = log Fall forage fish density in the Little River basin of Lake Keowee, no/ha
RangeMayJunLL = range over which lake level varied in May-June, meters

Based on this analysis, excluding data for 2010, a significant tendency was detected for fall forage fish density in the Little River basin to decrease with an increase in the range over which lake level varied during the May-June spawning period; in this analysis the overall degree of lake level fluctuation in May-June potentially explained 39% of variance in fall forage fish density in the Little River basin. However, there is no known reason to exclude data for 2010 from this analysis.

Lakewide numbers of forage fish in fall and fall forage fish densities in basins of Lake Keowee were also subjected to linear regression analysis with the maximum 3-day increase and the maximum 3-day decline in lake level observed during May-June spawning. No significant models were produced in these analyses (Appendix Tables 6 and 7). Thus no evidence was detected that rapid increases or declines in lake level influenced fall forage fish abundance on Lake Keowee as observed 1999-2012.

Effect of lake level observed May-October on fall forage fish abundance – Mean lake levels observed during the period between spring spawning and fall forage fish sampling ranged from 0.3 to 1.6 meters below full pool (Table 3-9; Figure 3-20). Fall forage fish numbers lakewide and fall forage fish densities in the Keowee River and Little River basins of Lake Keowee are plotted against mean May-October lake level in Figures 3-28 and 3-29.

Spearman correlation analysis detected no significant relationships between fall forage fish abundance variables (lakewide numbers and densities in basins) and the mean, lowest daily, or lowest 30-day mean lake levels observed May-October, based on data collected 1999-2012. Relationships of fall forage fish abundance variables to May-October lake levels were also investigated with linear regression analysis. No significant models were produced in regressions of fall forage fish lakewide and fall forage fish densities in basins of Lake Keowee on the mean, lowest daily, or lowest 30-day lake levels observed May-October (Appendix Table 8). Thus, no evidence was detected that lake levels observed May-October influenced fall forage fish abundance in Lake Keowee.

Chlorophyll

All chlorophyll concentrations referred to in the following discussion are average chlorophyll concentrations in the top ten meters of the water column. Mean January-February chlorophyll concentrations were used to characterize chlorophyll in winter, as these values did not differ significantly from mean December-February chlorophyll values and missing data for December would have reduced the size of the data set available for analysis. Basinwide mean chlorophyll concentrations referred to below were calculated based on data collected at Locations 500 and 502 (Little River basin) and Locations 504 and 505 (Keowee River basin).

Based on monthly data collected from 1999 through 2012 at Locations 504 and 505 in the Keowee River basin and Locations 500 and 502 in the Little River basin, chlorophyll concentrations averaged 1.89 mg/m^3 in the Keowee River basin and 2.27 mg/m^3 in the Little River basin (Table 3-10). Nonparametric analysis of variance of monthly basinwide chlorophyll data 1999-2012 indicated that chlorophyll concentrations in the Little River basin were significantly higher than in the Keowee River basin (prob>chi-square<0.0001). Additional locations were added to the chlorophyll sampling program in 2011 and 2012. Spatial variation in chlorophyll concentrations on Lake Keowee is illustrated with data from these locations in Figure 3-30.

Significant seasonal variation in chlorophyll concentrations was evident in both basins of Lake Keowee, based on nonparametric analysis of variance comparing basinwide chlorophyll data for individual months observed 1999-2012 (prob>chi-square<0.0001 for Keowee River basin; prob>chi-square=0.0004 for Little River basin). Based on data collected 1999-2012, chlorophyll concentrations in the Keowee River basin tended to peak in late summer, averaging 2.96 mg/m^3 in August, and were lowest in January and February, averaging 1.46 mg/m^3(Figure 3-31). Chlorophyll concentrations in the Little River basin exhibited a somewhat different seasonal pattern, in that two seasonal maxima were observed, in spring and late summer (Figure 3-31). Little River basin chlorophyll concentrations averaged 2.52 mg/m^3 in April and 2.75 mg/m^3 in September. Lowest annual chlorophyll concentrations on average were observed December to February, when chlorophyll concentration averaged 1.96 mg/m^3; and in June, when chlorophyll concentrations averaged 1.86 mg/m^3 (Figure 3-31).

Over the forage fish study period, mean annual chlorophyll concentrations tended to decline from 1999 through 2006, and to increase from 2007 through 2012 (Figure 3-32). Time series analysis indicated that mean annual chlorophyll concentrations exhibited a significant tendency to decline from 1999 to 2006, in both the Keowee and Little River basins (Pr>F=0.0023 and 0.0015 for the Keowee and Little River basins, respectively). The tendency for chlorophyll concentrations to increase from 2007 through 2012 was statistically significant in the Little River basin (Pr>F=0.0215), but not in the Keowee River basin (Pr>F=0.1398).

Relationships of spring forage fish abundance to winter chlorophyll concentrations – Total numbers of forage fish lakewide in spring tended to be higher following winters with higher chlorophyll concentrations (Figure 3-33), suggesting a relationship between food availability in winter and forage fish survival. Pearson correlation analysis detected a significant, positive relationship between mean January-February lakewide chlorophyll concentration and total numbers of forage fish lakewide in spring (r=0.59; P=0.0267; N=14; both variables log-transformed). Linear regression analysis (Appendix Table 9) indicated that mean January-February lakewide chlorophyll concentration potentially explained 35% of variance in spring forage fish numbers:

(6)
logSprFish = 5.83773 + 1.46590 logJanFebLWChlor
$R^2 = 0.3467$
Pr>F = 0.0267
N = 14
Prob>|t| for intercept < 0.0001
Prob>|t| for chlorophyll = 0.0267
Data set: 1999-2013
Outlying or highly influential observations: (none)
where logSprFish= log Total number of forage fish lakewide in spring
logJanFebLWChlor = log Mean lakewide surface (0-10 m) chlorophyll concentration observed January-February, mg/m^3

The tendency for spring forage fish density to be higher following winters with higher chlorophyll concentrations was evident in data for both basins of Lake Keowee individually (Figure 3-34). Linear regression analysis of data from the Keowee River basin (Appendix Table

9) indicated that 42% of variance in spring forage fish density was potentially explained by variation in mean January-February chlorophyll concentrations:

(7)
logSprDensKeo = 2.05979 + 1.64355 logJanFebChl
$R^2 = 0.4210$
Pr>F = 0.0121
N = 14
Prob>|t| for intercept < 0.0001
Prob>|t| for chlorophyll = 0.0121
Data set: 1999-2013, Keowee River basin
Outlying or highly influential observations: (none)
where logSprDensKeo= log Spring forage fish density in the Keowee River basin, no/ha
logJanFebChl = log Mean basinwide surface (0-10 m) chlorophyll concentration in the Keowee River basin observed January-February, mg/m^3

Linear regression analysis of data from the Little River basin (Appendix Table 9) indicated that variation in January-February chlorophyll concentrations potentially explained 31% of variance in spring forage fish density:

(8)
logSprDensLit = 1.87039 + 1.51066 logJanFebChl
$R^2 = 0.3106$
Pr>F = 0.0384
N = 14
Prob>|t| for intercept < 0.0001
Prob>|t| for chlorophyll = 0.0384
Data set: 1999-2013, Little River basin
Outlying or highly influential observations: (none)
where logSprDensLit = log Spring forage fish density in the Little River basin, no/ha
logJanFebChl = log Mean basinwide surface (0-10 m) chlorophyll concentration in the Little River basin observed January-February, mg/m^3

These results suggest that food availability influenced survival of forage fish over the winter in Lake Keowee.

Relationships of fall forage fish abundance to chlorophyll concentration – Lakewide number of forage fish in fall was analyzed in relation to several seasonal measures of lakewide chlorophyll concentration. To examine general relationships between reservoir fertility and fall forage fish numbers in Lake Keowee, correlation and linear regression analyses were performed relating fall forage fish numbers to mean annual chlorophyll concentration. These analyses produced no significant results (Appendix Table 10). Fall forage fish numbers were also subjected to correlation and regression analysis with chlorophyll concentrations measured in May, during the spring peak in chlorophyll concentrations in the Little River basin; and with mean chlorophyll concentrations observed May-June, in order to investigate relationships of fall forage fish abundance to food availability during spawning. Again, no significant relationships were detected (Appendix Table 10). Finally, fall forage fish numbers were analyzed in relation to mean chlorophyll concentrations during the period between spawning and fall forage fish sampling (May-October). No significant results were produced in these analyses (Appendix Table 10).

In addition to analyses of lakewide data, correlation and regression analyses were carried out relating fall forage fish densities in individual basins of Lake Keowee to mean annual, May, mean May-June, and mean May-October basinwide chlorophyll concentrations. Again, no significant relationships were detected in these analyses, for either the Keowee River basin or the Little River basin (Appendix Table 10) (Figure 3-35), suggesting that factors in addition to food availability were influencing fall forage fish abundance.

Comparison of forage fish – chlorophyll relationship in Lake Keowee to Catawba-Wateree reservoirs – Rodriguez (2005) found that variation in spring chlorophyll concentrations could explain 63% of variation in fall densities of pelagic forage fish in data collected at 18 sites on nine reservoirs on the Catawba and Wateree rivers in North and South Carolina. To investigate whether Lake Keowee maintained fall standing stocks of pelagic forage fish similar to those observed on Catawba-Wateree reservoirs of similar fertility, data for Lake Keowee were superimposed on a plot of the Catawba-Wateree regression. Using mean data for the forage fish study period (1999-2012), observations for both the Keowee River basin and the Little River basin of Lake Keowee fell within the 95% confidence limits of the regression (Figure 3-36), indicating that on average over the forage fish study period, Lake Keowee maintained fall standing stocks of pelagic forage fish similar to those of other regional reservoirs of similar fertility. Examination of the most recently collected data from Lake Keowee to date (2011-2012) superimposed on the Catawba-Wateree regression indicated that fall forage fish densities in both the Keowee River basin and the Little River basin fell within the 95% confidence limits associated with the regression (Figure 3-37). Thus, standing stocks of pelagic forage fish in Lake Keowee in fall are consistent with those of other regional reservoirs of similar fertility.

Zooplankton

Davis and Foltz (1991), in a study of food habits of threadfin shad and blueback herring on Lake Jocassee, just upstream of Lake Keowee, found that the diet of blueback herring consisted primarily of larger copepods and cladocerans. The diet of threadfin shad was found to consist of 24 to 32% phytoplankton, with the remainder consisting of smaller zooplankton, including rotifers, copepod nauplii, and smaller copepods and cladocerans, particularly *Bosmina*. Both growth rates and survival of larval clupeids have been observed to be affected by zooplankton abundance during the spawning and growing seasons (Johnson 1970; Welker et al. 1994; Betsill and Van Den Avyle 1997; Michaletz 1997), and larval fish survival may also be influenced by the timing of spawning in relation to the timing of spring peaks in zooplankton abundance (Cushing 1990).

From 1999 through 2012, zooplankton samples were collected quarterly at Location 508 in the Keowee River basin and Location 502 in the Little River basin. In 2012, samples were also collected at Locations 505 and 507 in the Keowee River basin and at Location 500 in the Little River basin. Lakewide zooplankton densities referred to in the following discussion were calculated as the mean of densities at Locations 502 and 508.

Based on data collected at Locations 502 and 508 from 1999 through 2012, total densities of zooplankton on Lake Keowee averaged 41,074 organisms/m^3, consisting on average of 34% copepods, 24% cladocerans, and 44% rotifers (Table 3-11). The copepod community consisted primarily of immature forms (nauplii, cyclopoid and calanoic copepodids) and *Tropocyclops prasinus*. *Bosmina longirostris* dominated the cladoceran community; *Diaphanosoma brachyurum* was relatively abundant during the warmer months, as was *Holopedium amazonicum* in May and *Bosminopsis deitersi* in August. Common genera of rotifers observed on Lake Keowee included *Keratella*, *Ptygura*, *Collotheca*, and *Conochilus*, among others (Table 3-12).

Densities of copepods, cladocerans, and rotifers were highest in August, and lowest in February and November, on average (Figure 3-38). Seasonal variation in zooplankton densities was statistically significant in both basins of Lake Keowee, based on data collected at Locations 502 and 508, 1999-2012.

Mean annual densities of copepods, rotifers, and total zooplankton were significantly higher in the Little River basin than in the Keowee River basin, based on data collected at Locations 502 and 508, 1999-2012 (Table 3-11). However, sampling of additional locations in 2012 indicated that variation in zooplankton densities within basins was substantial, and relative densities of zooplankton among locations varied seasonally (Figure 3-39). Nonparametric analysis of variance comparing densities of major taxa of zooplankton among locations in 2012, utilizing data from different months as replicates, detected no consistent patterns in spatial variation of zooplankton density. Mean annual zooplankton densities observed in 2012 were highest at the most upstream locations in both basins, averaging 75,587 organisms/m^3 at Location 507 in the Keowee River basin and 67,000 organisms/m^3 at Location 500 in the Little River basin. Lowest mean annual densities in 2012 were observed in the lower Keowee River basin at Location 508, averaging 26,832 organisms/m^3 (Table 3-13).

Mean annual total zooplankton densities exhibited a statistically significant general downward trend over the period 1999-2012 in both basins of Lake Keowee, based on time series analysis of data collected at Locations 502 and 508 (Figures 3-40 and 3-41).

In the following discussion of relationships of forage fish abundance to zooplankton abundance, total crustacean zooplankton density was calculated as the sum of copepod and cladoceran densities.

Relationships of spring forage fish abundance to winter zooplankton – Spring forage fish abundance variables were analyzed in relation to zooplankton data collected in February, as zooplankton data were collected quarterly on Lake Keowee. Lakewide numbers of forage fish in spring were positively correlated with February mean lakewide densities of copepods (r_s=0.78; P=0.0017; N=13); cladocerans (r_s=0.64; P=0.0178; N=13); and total crustacean zooplankton

(r_s=0.84; P=0.0003; N=13) in Spearman correlation analysis. No relationship with February rotifer densities was detected.

Significant tendencies for spring forage fish numbers to increase with increasing February densities of copepods, cladocerans, and total crustacean zooplankton were detected in linear regression analysis as well (Appendix Table 11; Figure 3-42). Variation in February densities of total crustacean zooplankton could explain 48% of variance in spring lakewide numbers of forage fish:

(9)
logSprFish = 1.35534 + 1.19369 logFebCrustZoo
R^2 = 0.4849
Pr>F = 0.0082
N = 13
Prob>|t| for intercept = 0.3824
Prob>|t| for zooplankton = 0.0082
Data set: 1999-2012
Outlying or highly influential observations: (none)
where logSprFish = log Spring forage fish numbers lakewide
logFebCrustZoo = log Lakewide density of crustacean zooplankton (sum of copepods and cladocerans) observed in February, organisms/m^3

February copepod and cladoceran densities could individually explain 41% and 36% of variance in spring forage fish numbers, respectively. No relationship was detected between spring forage fish numbers and February rotifer density (Appendix Table 11).

Positive relationships of spring forage fish density and February densities of crustacean zooplankton were evident in data for individual basins of Lake Keowee as well. Spring forage fish density in the Keowee River basin was positively correlated with February densities of copepods (r_s=0.61; P=0.0258; N=13); cladocerans (r_s=0.67; P=0.0115; N=13); and total crustacean zooplankton (r_s=0.78; P=0.0017; N=13) in Spearman correlation analysis. Linear regression analysis of data from the Keowee River basin (Appendix Table 13) indicated that February density of cladocerans could explain 45% of variance in spring forage fish density:

(10)
logSprDensKeo = -1.25355 + 0.96936 logFebClad

R^2 = 0.4531
Pr>F = 0.0117
N = 13
Prob>|t| for intercept = 0.3122
Prob>|t| for cladoceran density = 0.0117
Data set: 1999-2012, Keowee basin
Outlying or highly influential observations: 1999

where logSprDensKeo = log Spring forage fish density in the Keowee River basin, no/ha
logFebClad = log Cladoceran density in February at Location 508 in the Keowee River basin, organisms/m^3

When this regression was repeated, excluding the outlying observation for 1999, variation in February cladoceran density potentially explained 87% of variance in spring forage fish density in the Keowee River basin (R^2=0.8732; Pr>F < 0.0001; N=12) (Appendix Table 14). Spring forage fish density in the Keowee River basin also varied positively with total crustacean density in February (Figure 3-43):

(11)
logSprDensKeo = -2.31141 + 1.15444 logFebCrustZoo

R^2 = 0.4994
Pr>F = 0.0069
N = 13
Prob>|t| for intercept = 0.1263
Prob>|t| for zooplankton = 0.0069
Data set : 1999-2012, Keowee basin
Outlying or highly influential observations: (none)

where logSprDensKeo = log Spring forage fish density in the Keowee River basin, no/ha
logFebCrustZoo = log Density of total crustacean zooplankton in February at Location 508 in the Keowee River basin, organisms/m^3

Spring forage fish density in the Little River basin was positively correlated with February densities of copepods (r_s=0.82; P=0.0005; N=13) and total crustacean zooplankton (r_s=0.70; P=0.0080; N=13) in Spearman correlation analysis. Consistent with these results, linear regression analysis (Appendix Table 13) indicated that 40% of variance in spring forage density in the Little River basin was potentially explained by variation in February copepod density:

(12)
logSprDensLit = -2.00730 + 0.42275 logFebCop
R^2 = 0.3973
Pr>F = 0.0209
N = 13
Prob>|t| for intercept = 0.2315
Prob>|t| for copepod density = 0.0209
Data set: 1999-2012, Little River basin
Outlying or highly influential observations: (none)
where logSprDensLit = log Spring forage fish density in the Little River basin, no/ha
logFebCop = log Copepod density in February at Location 502 in the Little River basin, organisms/m^3

A similar percentage of variance in spring forage fish densities in the Little River basin was explained by variation in February densities of total crustacean zooplankton (Figure 3-43):

(13)
logSprDensLit = -2.04271 + 1.07335 logFebCrustZoo
R^2 = 0.3924
Pr>F = 0.0220
N = 13
Prob>|t| for intercept = 0.2320
Prob>|t| for crustacean zooplankton = 0.0220
Data set: 1999-2012, Little River basin
Outlying or highly influential observations: (none)
where logSprDensLit = log Spring forage fish density in the Little River basin, no/ha
logFebCrustZoo = log Density of total crustacean zooplankton in February at Location 502 in the Little River basin, organisms/m^3

Given the importance of zooplankton in the diet of both blueback herring and threadfin shad, these results suggest that food availability may be an important influence on winter survival of pelagic forage fish in Lake Keowee.

Zooplankton availability during spring forage fish spawning – Cushing (1990) indicated that survival of young-of-the-year forage fish may be influenced by the availability of food during the spawning period. Greater than 96% of fall forage fish in purse seine samples on Lake Keowee were young-of-the-year (Tables 3-4 and 3-5). Fall forage fish lakewide numbers and densities in basins were subjected to Spearman correlation analysis and linear regression analysis in relation to zooplankton densities measured in May, in order to investigate possible relationships between food availability during spawning and survival of young-of-the-year forage fish.

Spearman correlation analysis of fall forage fish lakewide numbers with May densities of copepods, cladocerans, total crustacean zooplankton, rotifers, and total zooplankton yielded no significant results. Analysis of data for the Keowee basin individually detected a significant Spearman correlation between fall forage fish density and rotifer density in May (r_s=0.67; P=0.0122; N=13). Analysis of data for the Little River basin individually produced no significant Spearman correlations.

Relationships of fall forage fish abundance and May zooplankton abundance were further examined with linear regression analysis. Fall forage fish lakewide numbers were unrelated to densities of crustacean zooplankton in May; however, a significant relationship was detected between fall forage fish lakewide numbers and May lakewide rotifer density (Appendix Table 15; Figure 3-44):

(14)
FallFish = 38,309,740 + 11,041,707 logMayLWRot
R^2 = 0.4354
Pr>F = 0.0141
N = 13
Prob>|t| for intercept = 0.0393
Prob>|t| for rotifer density = 0.0141
Data set: 1999-2012
Outlying or highly influential observations: (none)
where FallFish= Total number of forage fish lakewide in fall
logMayLWRot = log Lakewide density of rotifers in May, organisms/m^3

Based on this relationship, rotifer density in May potentially explained 44% of variance in lakewide numbers of forage fish in fall.

Relationships of fall forage fish density and May zooplankton abundance were also examined for each basin of Lake Keowee individually. In data for the Little River basin, no significant relationships were detected in linear regression analysis relating fall forage fish density to May densities of copepods, cladocerans, or rotifers (Appendix Table 16; Figure 3-45). In data for the

Keowee River basin, fall forage fish densities were significantly related to May rotifer density (Appendix Table 16; Figure 3-45):

(15)
FallDensKeo = -4832.69439 + 1426.82994 logMayRot
$R^2 = 0.5823$
Pr>F = 0.0024
N = 13
Prob>|t| for intercept = 0.0089
Prob>|t| for rotifer density = 0.0024
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: 2011 (studentized residual = 2.633)
where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
logMayRot = log Density of rotifers in May in the Keowee River basin, organisms/m^3

This relationship indicates that variation in May rotifer densities potentially explained 58% of variance in fall forage fish density in the Keowee River basin. When the outlying observation for 2011 was excluded from this regression, the percent of variance explained rose to 82% (R^2=0.8162; Pr>F<0.0001; N=12) (Appendix Table 17).

Observations of significant relationships between fall forage fish abundance and May densities of rotifers, particularly in the Keowee River basin where rotifer-loving threadfin shad are known to overwinter, are consistent with the idea that food availability during spawning may have influenced survival of young-of-the-year forage fish.

Zooplankton availability during the growing season – Fall forage fish abundance was analyzed in relation to mean zooplankton densities observed during the growing season (mean of May and August zooplankton data) to investigate possible relationships of food availability during the warmer months and forage fish survival. Spearman correlation analysis and linear regression analysis were carried out relating fall forage fish numbers lakewide and densities in individual basins to mean May-August densities of copepods, cladocerans, total crustacean zooplankton, and rotifers. None of these analyses produced significant results (Appendix Tables 18 and 19). Data for 1999 were identified as highly influential in a linear regression of fall forage fish density in the Little River basin on mean May-August rotifer density (Cook's D=3.737). When this regression was repeated, excluding data for 1999, variation in mean May-August density of rotifers potentially explained 46% of variance in fall forage fish density in the Little River basin (Appendix Table 20). Generally, however, the lack of significant relationships between mean May-August zooplankton abundance and fall forage fish abundance suggests first, that factors in addition to food availability may have significantly influenced fall forage fish abundance in Lake Keowee; and second, that top-down predation pressure on zooplankton may have obscured any relationship between zooplankton and forage fish abundance.

Predation

Littoral density and biomass of potential predators on blueback herring and threadfin shad in Lake Keowee were analyzed in relation to spring and fall forage fish abundance. Density (fish/km) and biomass (kg/km) of predatory species were obtained from spring shoreline electrofishing carried out in 1999, 2002, 2005, 2008, 2010, and 2011.

Based on electrofishing data carried out in three regions of Lake Keowee (upper Keowee River basin, lower Keowee River basin, Little River basin), largemouth bass, spotted bass, and redeye bass constituted the majority of numbers and biomass of species likely to prey on blueback herring and threadfin shad in Lake Keowee (Tables 3-14 and 3-15). Data for these species, as well as data for total black basses, were analyzed in relation to forage fish abundance. Density and biomass of total black basses were calculated as the sums of densities and biomasses of largemouth bass, spotted bass, redeye bass, smallmouth bass, and hybrid black bass.

Spatial variation in predator abundance – Based on electrofishing carried out during the forage fish study period, mean littoral density of largemouth bass was highest in the upper Keowee River basin (Table 3-14; Figure 3-46), averaging 9.7 fish/km, as compared to 5.1 fish/km in the Little River basin and 3.9 fish/km in the lower Keowee River basin. Statistically, largemouth bass density was significantly higher in the upper Keowee River basin than in the lower Keowee River basin, based on nonparametric analysis of variance (prob>chi-square=0.0198). Littoral biomass of largemouth bass averaged 2.58 kg/km in the Little River basin, 2.22 kg/km in the upper Keowee River basin, and 1.54 kg/km in the lower Keowee River basin (Table 3-15; Figure 3-46). Spatial differences in largemouth bass biomass were not statistically significant.

Mean littoral density of spotted bass in the Little River basin averaged 23.9 fish/km, significantly higher than in the upper Keowee River basin (10.3 fish/km) and the lower Keowee River basin (8.5 fish/km). Similarly, biomass of spotted bass averaged 2.97 kg/km in the Little River basin, significantly higher than in the upper Keowee River basin (1.07 kg/km) and the lower Keowee River basin (0.91 kg/km) (Tables 3-14 and 3-15; Figure 3-46). Neither density nor biomass of spotted bass differed significantly between the upper and lower regions of the Keowee River basin.

Mean littoral density of redeye bass averaged 2.3 fish/km in the upper Keowee River basin, 0.9 fish/km in the Little River basin, and 0.6 fish/km in the lower Keowee River basin; biomass averaged 0.43 in the upper Keowee River basin, 0.07 kg/km in the Little River basin, and 0.04 kg/km in the lower Keowee River basin (Tables 3-14 and 3-15). Differences among regions were not statistically significant.

Total littoral density of black basses averaged 30.0 fish/km in the Little River basin and 25.3 fish/km in the upper Keowee River basin. Black bass density was significantly lower in the lower Keowee River basin, averaging 13.1 fish/km. Total black bass biomass averaged 5.62 kg/km in the Little River basin, 3.88 kg/km in the upper Keowee River basin, and 2.48 kg/km in the lower Keowee River basin (Tables 3-14 and 3-15; Figure 3-46). Statistically, total black bass biomass in the Little River basin was significantly higher than in the lower Keowee River basin.

Temporal trends in predator abundance – Based on time series analysis of electrofishing conducted during the forage fish study period (1999-2012), no long-term upward or downward trends in the littoral density or biomass of total black basses, largemouth bass, or spotted bass were detected in any electrofishing region of Lake Keowee. A significant, downward trend was detected in littoral density of redeye bass in the upper Keowee River area ($Pr>F = 0.0374$).

When electrofishing data for 1996 and 1998 were included in time series analysis, thus analyzing trends over the period 1996-2011, littoral density of spotted bass exhibited significant upward temporal trends in all three electrofishing regions of Lake Keowee. Upward trends in spotted bass biomass were significant as well, in the upper Keowee River basin and the Little River basin. In contrast, littoral density and biomass of redeye bass declined significantly over this period in the upper and lower Keowee River basin; no significant trend was detected in the Little River basin. Largemouth bass biomass in the upper Keowee River area exhibited a significant tendency to decline over the period 1996-2011; this tendency was not significant in either the Little River basin or the lower Keowee River basin, nor were any significant temporal trends detected in numbers of largemouth bass. No significant temporal trends in the total numbers or biomass of black basses were detected over this period. Temporal trends in density and biomass of major predators are plotted in Figures 3-47 and 3-48.

Note on methods for assessing relationships of predator abundance to forage fish abundance – For purposes of analyzing predator abundance data in relation to forage fish abundance, electrofishing data for the Keowee River basin were averaged over the upper and lower electrofishing areas to obtain basinwide mean predator abundance data. Lakewide mean predator littoral density and biomass were estimated by averaging basinwide estimates. Data for these analyses were available for the years 1999, 2002, 2005, 2008, 2010, and 2011.

Relationships of spring forage fish abundance to predator abundance – Lakewide mean littoral density (fish/km) and biomass (kg/km) of largemouth bass, spotted bass, and total black basses were subjected to Spearman and Pearson correlation analysis with total numbers of forage fish lakewide in spring. A significant, negative Spearman correlation was detected between lakewide mean littoral density of spotted bass and spring forage fish numbers (r_s= -0.83; P=0.0416; N=6) (Figure 3-49), potentially providing some evidence of predation pressure on forage fish numbers; however, this relationship was not significant in Pearson correlation analysis (r= -0.73; P=0.1006; N=6). Pearson correlation analysis suggested a potentially positive relationship between mean lakewide largemouth bass littoral biomass and spring forage fish numbers, although this relationship approached but did not attain the reference probability for significance (r=0.81; P=0.0530; N=6). Relationships of spring forage fish numbers and littoral abundance of spotted and largemouth bass are plotted in Figure 3-49.

Relationships of spring forage fish densities to littoral predator abundance were also examined for each basin of Lake Keowee. Spring basinwide forage fish densities were subjected to

Spearman and Pearson correlation analysis with basinwide littoral density and biomass of largemouth bass, spotted bass, and total black basses. A significant, positive correlation was detected between log spring forage fish density in the Little River basin and littoral biomass of largemouth bass, in Pearson correlation analysis (r=0.83; P=0.0408; N=6) (Figure 3-50). No other significant relationships were detected in these analyses, potentially due in part to the very small number of observations available for analysis.

Linear regression analyses were carried out relating basinwide spring forage fish density to basinwide predator abundance, using data from both basins in the same analysis to obtain a larger data set. Spring forage fish density was regressed on density and biomass of largemouth bass, spotted bass, and total black basses (Appendix Table 21). One significant model was produced in these analyses (Figure 3-51):

(16)
logSprDens = 1.81285 + 0.20478 LMBkgkm
    R^2=0.3477
    Pr>F = 0.0436
    N = 12
    Prob>|t| for intercept < 0.0001
    Prob>|t| for largemouth bass biomass = 0.0436
    Data set: 1999, 2002, 2005, 2008, 2010, 2011, Keowee River and Little River basins
    Outlying or highly influential observations: (none)
where logSprDens = log Spring basinwide forage fish density, no/ha
    LMBkgkm = basinwide mean littoral biomass of largemouth bass, kg/km

The positive parameter estimate associated with largemouth bass biomass in this analysis suggests that largemouth bass abundance may have been limited by food availability, or that both spring forage fish and largemouth bass were varying along fertility gradients, given the previously described positive relationships between spring forage fish abundance and winter levels of chlorophyll and zooplankton. No evidence of downward predation pressure on spring forage fish was detected in regression analyses.

Relationships of fall forage fish abundance to predator abundance – Total numbers of forage fish lakewide in fall were subjected to Spearman and Pearson correlation analyses with mean lakewide littoral density (fish/km) and biomass (kg/km) of largemouth bass, spotted bass, and total black basses. Mean lakewide littoral densities of basses were calculated by first averaging over the two electrofishing areas of the Keowee River basin, and then averaging over basins.

Fall forage fish lakewide numbers were negatively correlated with littoral density of total black basses in both Spearman (r_s= -0.83; P=0.0416; N=6) and Pearson (r= -0.92; P=0.0095; N=6) correlation analyses. Linear regression analysis of these relationships (Appendix Table 22) indicated that variation in littoral density of total black basses could account for 85% of variance in fall forage fish numbers lakewide (Figure 3-52), in the following regression model:

(17)
FallFish = 17,678,109 – 420,830 LWBLBnumkm
R^2 = 0.8452
Pr>F = 0.0095
N = 6
Prob>|t| for intercept = 0.0016
Prob>|t| for black bass density = 0.0095
Data set: 1999, 2002, 2005, 2008, 2010, 2011, lakewide
Outlying or highly influential observations: (none)
Where FallFish = total number of forage fish lakewide in fall
LWBLBnumkm = lakewide mean littoral density of total black basses, no/km

Though the number of observations in this analysis is small, the strength of the relationship suggests that predation may be an important influence of fall forage fish numbers in Lake Keowee. Regression analysis of fall forage fish lakewide numbers on mean lakewide littoral density of spotted bass yielded the following regression model, which approached but did not meet the reference probability for significance:

(18)
FallFish = 14,000,339 – 400,407 LWSPBnumkm
R^2= 0.6566
Pr>F = 0.0505
N = 6
Prob>|t| for intercept = 0.0057
Prob>|t| for spotted bass density = 0.0505
Data set: 1999, 2002, 2005, 2008, 2010, 2011, lakewide
Outlying or highly influential observations: (none)
where FallFish = total number of forage fish lakewide in fall
LWSPBnumkm = lakewide mean littoral density of spotted bass, no/km

No significant relationships with largemouth bass were detected in these analyses (Appendix Table 22).

Relationships of fall forage fish abundance and predator abundance were examined for each basin of Lake Keowee as well. A significant, negative Spearman correlation was detected between fall forage fish density in the Little River basin and total littoral density of black basses (r_s= -0.94; P=0.0048; N=6), again suggesting that predation pressure may have played a role in regulating fall forage fish density (Figure 3-53). No other significant relationships were detected in these analyses.

Linear regression analyses were carried out relating basinwide fall forage fish densities to basinwide predator abundance, using data from both basins in the same analysis to obtain a larger data set. Fall forage fish density was regressed on density and biomass of largemouth bass, spotted bass, and total black basses (Appendix Table 23). One significant model was produced in these analyses:

(19)
logFallDens = 4.10610 – 0.85820 logBLBnumkm
$R^2 = 0.3422$
Pr>F = 0.0457
N = 12
Prob>|t| for intercept < 0.0001
Prob>|t| for total black basses = 0.0457
Data set: 1999, 2002, 2005, 2008, 2010, 2011, Keowee River and Little River basins
Outlying or highly influential observations: (none)
where logFallDens = log Fall forage fish density in basins of Lake Keowee, no/ha
logBLBnumkm = log Basinwide mean littoral density of total black basses, no/km

This analysis detected a significant tendency for fall forage fish densities to decline with increasing littoral densities of black basses (Figure 3-54), possibly reflecting downward predation pressure. Total black bass density potentially explained 34% of variance in fall forage fish densities in both basins of Lake Keowee.

Relationship of predator abundance to reservoir fertility – Littoral density of total black basses exhibited a significant tendency to increase with increasing chlorophyll concentration. Linear regression analysis relating basinwide mean littoral density of total black basses to mean annual basinwide surface (0-10 m) chlorophyll concentrations, using data from both basins, yielded the following significant regression model:

(20)
logBLBnumkm = 0.74679 + 0.30928 MeanAnnualBasinChlor
$R^2 = 0.6440$
Pr>F = 0.0052
N = 10
Prob>|t| = 0.0028 for intercept
Prob>|t| = 0.0052 for chlorophyll
Data set: 1999, 2005, 2008, 2010, 2011, Keowee River and Little River basins
Outlying or highly influential observations: (none)
where logBLBnumkm = log Mean basinwide littoral density of total black basses, fish/km
MeanAnnualBasinChlor = mean annual basinwide surface (0-10 m) chlorophyll concentration, mg/m^3

This relationship suggests that reservoir fertility potentially explains 64% of variance in mean basinwide littoral densities of total black basses (Figure 3-55). The observation that total black bass numbers were positively correlated with chlorophyll yet negatively correlated with fall forage fish numbers provides some evidence of the downward pressure of predation on forage fish abundance, which may in turn provide some indication of why no relationships were detected between chlorophyll and fall forage fish abundance.

Jocassee Pumped Storage Station Pumping Flow

Jocassee Pumped Storage Station is located at the upstream end of the Keowee River basin of Lake Keowee. During pumping operations at JPSS water is withdrawn from Lake Keowee at a depth of 0 to 13 meters below full pool and pumped into Lake Jocassee. Pumping operations potentially influence forage fish abundance in Lake Keowee through entrainment.

From 1999 through 2012, daily pumping flows at JPSS averaged 132.7 m^3/sec, ranging from a minimum of 0 m^3/sec to a maximum of 448.4 m^3/sec. Monthly mean pumping flows for the forage fish study period are plotted in Figure 3-56. Mean annual pumping flows ranged from 89.8 to 159.5 m^3/sec (Table 3-16; Figure 3-57). No long-term upward or downward linear temporal trends were detected in mean annual pumping flows at JPSS over the forage fish study period, based on time series analysis.

Statistically significant seasonal variation was evident in JPSS pumping flows (prob>chi-square<0.0001 for comparisons among months). Pumping flows were typically highest in July and August and lowest in November and December (Figure 3-58).

Effect of winter JPSS pumping on spring forage fish abundance on Lake Keowee – Spring forage fish abundance on Lake Keowee was analyzed in relation to JPSS pumping flows observed December-February. Spring forage fish lakewide numbers and densities in the Keowee River and Little River basins of Lake Keowee were subjected to correlation and regression analysis with mean, maximum daily, and maximum 30-day average winter pumping flow. Pumping variables were chosen to investigate effects of average winter pumping, short-term high-flow pumping, and sustained high pumping flows. Variation in winter pumping flows is documented in Table 3-16 and Figure 3-59.

Relationships of spring forage fish abundance and winter pumping flows at JPSS are plotted in Figures 3-60 and 3-61. Neither spring forage fish lakewide numbers nor spring forage fish densities in the Keowee River or Little River basin of Lake Keowee were significantly correlated with mean, maximum daily, or maximum 30-day average JPSS pumping flows observed December-February, in Spearman correlation analysis of data collected 1999-2013.

Relationships of spring forage fish to winter JPSS pumping flows were further investigated with linear regression analysis. No significant models were produced in linear regression analysis of spring lakewide forage fish numbers on mean, maximum daily, or maximum 30-day average pumping flows observed December-February, based on data collected 1999-2013. Similarly, no significant relationships were detected between spring forage fish densities in the Keowee River or Little River basins and mean, maximum daily, or maximum 30-day average winter pumping flows at JPSS (Appendix Table 24). Thus, no evidence was detected in data for 1999-2013 that spring forage fish abundance in Lake Keowee was influenced by pumping operations at JPSS.

Previous analysis of these relationships based on data collected 1999-2010 detected significant tendencies for both spring forage fish lakewide numbers and spring forage fish density in the Keowee River basin to decline with increasing mean winter pumping flows (Rodriguez 2011). The larger data set available for analysis in the current report (1999-2013) provides a more robust analysis and therefore a more realistic representation of the relationship of spring forage fish abundance on Lake Keowee to winter pumping flows at JPSS. Analysis of data collected 1999-2013 provided no evidence of significant influence of winter JPSS pumping flows on spring forage fish abundance in Lake Keowee.

Effect of JPSS pumping during spring spawning of forage fish on Lake Keowee – To investigate potential effects of JPSS pumping during the spring spawning season on fall forage fish abundance in Lake Keowee, Spearman correlation analyses were carried out relating fall forage fish lakewide numbers and fall forage fish densities in the Keowee River and Little River basins of Lake Keowee to mean pumping flows at JPSS over the May-June spawning season. No significant correlations were detected in these analyses. In addition, linear regression analysis was carried out, regressing fall forage fish lakewide numbers and fall forage fish basinwide densities on mean May-June pumping flows at JPSS. These analyses did not produce any significant models (Appendix Table 25), and no outlying or highly influential observations were identified. Thus no evidence was detected that pumping at JPSS during the spring forage fish spawning season had any impact on fall forage fish abundance in Lake Keowee.

Effect of May-October JPSS pumping flow on fall forage fish abundance on Lake Keowee – Potential effects of JPSS pumping during the period between spring spawning and fall forage fish sampling on fall forage fish abundance in Lake Keowee were investigated with Spearman correlation analysis and linear regression analysis. Fall forage fish lakewide numbers and forage fish densities in basins of Lake Keowee were analyzed in relation to the mean, maximum daily, and maximum 30-day average pumping flow observed May-October, using data collected from 1999-2012. Analysis of mean May-October pumping was intended to detect general relationships of pumping to forage fish for the season, while analysis of maximum daily May-October pumping flows was intended to detect any impact of short-term, high-flow events.

Analysis of maximum 30-day average May-October pumping flow was intended to detect effects of higher pumping flows sustained for a period of time during the season.

Total numbers of forage fish lakewide in fall and fall forage fish densities in the Keowee River and Little River basins were not significantly correlated with mean or maximum daily May-October measures of JPSS pumping in Spearman correlation analysis. In contrast, fall forage fish density in the Keowee River basin was negatively correlated with maximum 30-day average JPSS pumping flow observed May-October (r_s= -0.71; P=0.0045; N=14). The correlation between fall forage fish lakewide numbers and maximum 30-day average May-October JPSS pumping flow approached, but did not attain, statistical significance (r_s= -0.52; P=0.0562; N=14). Fall forage fish density in the Little River basin was not significantly correlated with maximum 30-day average May-October JPSS pumping flows.

Results obtained in Spearman correlation analysis were reflected in linear regression analysis. Regressions of fall forage fish lakewide numbers and densities in basins exhibited no relationship to mean or maximum daily pumping flows observed May-October (Figures 3-62 and 3-63) (Appendix Table 26). In contrast, both fall forage fish lakewide numbers and fall forage fish densities in the Keowee River basin exhibited significant relationships with the maximum 30-day average pumping flow observed May-October (Appendix Table 26), in the following regressions:

(21)
FallFish = 26,482,038 – 77,886 Max30dayMayOctJocPump
R^2 = 0.3506
Pr>F = 0.0257
N = 14
Prob>|t| for intercept = 0.0026
Prob>|t| for Jocassee pumping = 0.0257
Data set: 1999-2012, lakewide
Outlying or highly influential observations: (none)

where FallFish = total number of forage fish lakewide in Lake Keowee in fall
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec

(22)
FallDensKeo = 3084.97707 – 8.88036 Max30dayMayOctJocPump
R^2 = 0.4355
Pr>F = 0.0102
N = 14
Prob>|t| for intercept = 0.0006
Prob>|t| for Jocassee pumping = 0.0102
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)
where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec

These analyses detected a significant tendency for fall forage fish lakewide numbers and fall forage fish density in the Keowee River basin to be lower when periods of higher sustained pumping flows were observed May-October, quantified as the maximum 30-day average pumping flow. Variation in maximum 30-day average May-October pumping flow potentially explained 35% of variance in fall forage fish lakewide numbers and 44% of variance in fall forage fish density in the Keowee River basin over the years 1999-2012.

Graphical examination of the significant relationships (Figures 3-64 and 3-65) illustrates the non-normal distribution of the independent variable in these analyses. Maximum 30-day average May-October pumping flow was not normally distributed (prob<W=0.0014), exhibiting a negatively-skewed distribution (skewness= -2.350). To ensure that negative skew in the independent variable did not affect the results of these analyses, maximum 30-day May-October pumping flow was power-transformed (cubed), which allowed assumption of a normal distribution for this variable (prob<W=0.0962), and regressions were repeated using the transformed variable (Appendix Table 27). Results of these regressions were quite similar to those detailed above: for the regression of fall lakewide forage fish numbers, R^2=0.3430 and Pr>F=0.0278; for the regression of fall forage fish in the Keowee River basin, R^2=0.4604 and Pr>F=0.0076, indicating that non-normal distribution of the independent variable was not substantially influencing the regression results.

Graphical examination of the significant relationships also suggests that the observation for the year 2000 may have been influential in the regression results. This observation was not statistically identified as highly influential in these regression analyses. However, when the regressions were repeated, excluding data for the year 2000 (Appendix Table 28), results were no longer significant:

(23)
FallFish = 22,978,878 – 63,077 Max30dayMayOctJocPump
$R^2 = 0.0787$
Pr>F = 0.3531
N = 13
Prob>|t| for intercept = 0.1605
Prob>|t| for Jocassee pumping = 0.3531
Data set: 1999-2012 excluding 2000, lakewide
Outlying or highly influential observations: (none)
where FallFish = total number of forage fish lakewide in Lake Keowee in fall
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec

(24)
FallDensKeo = 3507.26307 – 10.66551 Max30dayMayOctJocPump
$R^2 = 0.2123$
Pr>F = 0.1130
N = 13
Prob>|t| for intercept = 0.0344
Prob>|t| for Jocassee pumping = 0.1130
Data set: 1999-2012 excluding 2000, Keowee River basin
Outlying or highly influential observations: (none)
where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec

Although there is no known reason that the observation for 2000 should be excluded from these analyses, the fact that the significance of these regression models depends on the presence of a single observation (data for the year 2000) calls into question the robustness of the relationships and suggests that additional data would be useful to establish whether the detected relationships reflect real processes.

Keowee Hydroelectric Station Generation Flow

Keowee HS generation flow characterization – Over the years 1999-2012, daily mean Keowee Hydro generation flows ranged from 0 to 358 m^3/sec, averaging 19 m^3/sec and exhibiting a median of 0 m^3/sec. Generation flows over the forage fish study period are plotted in Figure 3-

66. With the exception that flows were typically lowest in May, October, and November, strong seasonal patterns were not generally evident in Keowee Hydro generation flow, presumably due at least in part to the dependence of hydro operations on rainfall patterns. No long-term upward or downward linear trends were detected in time series analysis of mean annual Keowee Hydro generation flows; mean generation flows observed December-February; or mean generation flows observed May-October (Table 3-17; Figures 3-67 and 3-68).

Generation at Keowee Hydroelectric Station could potentially influence forage fish abundance on Lake Keowee through flushing of fish during generation (e.g., Walburg 1971; Garvey et al. 2000). Spring forage fish lakewide numbers and forage fish densities in the Keowee River and Little River basins of Lake Keowee were analyzed in relation to mean, maximum daily, and maximum 30-day average generation flows observed in winter (December-February). Fall forage fish lakewide numbers and densities in basins were analyzed in relation to mean generation flows observed during spring forage fish spawning (May-June); and in relation to mean, maximum daily, and maximum 30-day average generation flows observed between spring forage fish spawning and fall forage fish sampling (May-October). Mean seasonal generation flow variables were analyzed to examine general relationships of generation flow to forage fish abundance. Analysis of maximum daily generation flow variables was intended to investigate any influence of short-term, high-flow events, and analysis of maximum 30-day average generation flow was intended to investigate potential impacts of sustained high flows.

Effect of winter Keowee HS generation flow on spring forage fish abundance – Spring forage fish lakewide numbers and densities in the Keowee River and Little River basins of Lake Keowee are plotted against mean winter Keowee HS generation flows in Figures 3-69 and 3-70. Neither spring forage fish lakewide numbers nor spring forage fish density in either basin of Lake Keowee were significantly correlated with mean, maximum daily, or maximum 30-day average generation flows observed December-February in Spearman correlation analysis.

Spring forage fish lakewide numbers and spring forage fish densities in basins of Lake Keowee were subjected to linear regression analysis on mean, maximum daily, and maximum 30-day average generation flows observed December-February. None of these analyses produced significant results, and no outlying or highly influential observations were detected (Appendix Table 29). Thus no evidence was detected that variation in spring forage fish abundance in Lake Keowee was influenced by variation in generation flows at Keowee Hydroelectric Station in winter.

Effect of May-June Keowee HS generation flow on fall forage fish abundance – Fall forage fish lakewide numbers and densities in the Keowee River and Little River basins of Lake Keowee are plotted against mean Keowee HS generation flows observed May-June in Figures 3-70 and 3-71. Potential impacts of Keowee HS generation flow during the spring forage fish spawning period (May-June) on fall forage fish abundance were investigated with Spearman correlation analysis and linear regression analysis. Spearman correlation analysis of fall forage fish lakewide numbers and fall forage fish densities in basins of Lake Keowee detected no relationships with mean or maximum daily generation flows at Keowee HS in May-June, based on data collected 1999-2012. Similarly, no significant models were produced in linear regression analyses of fall forage fish lakewide numbers or fall forage fish densities in basins of Lake Keowee on either mean or maximum daily Keowee Hydro generation flows observed during the May-June forage fish spawning period (Appendix Table 30).

Effect of May-October Keowee HS generation flow on fall forage fish abundance – Potential impacts of Keowee HS generation during the period between spring forage fish spawning and fall forage fish sampling (May-October) were investigated graphically (Figures 3-73 and 3-74), and with Spearman correlation analysis and linear regression analysis. Spearman correlation analysis relating fall forage fish numbers lakewide and fall forage fish densities in the Keowee River and Little River basins of Lake Keowee to mean, maximum daily, and maximum 30-day average Keowee HS generation flows observed May-October detected no significant correlations in data collected 1999-2012. Similarly, linear regression analyses relating fall forage fish lakewide numbers and densities in basins of Lake Keowee to mean, maximum daily, and maximum 30-day average generation flows observed May-October produced no significant regression models (Appendix Table 31). Thus, no evidence was detected that generation flows observed May-October influenced fall forage fish abundance on Lake Keowee.

Responses of Forage Fish Variables to Multiple Predictor Variables

The distribution and abundance of pelagic forage fish on Lake Keowee were undoubtedly influenced by multiple factors, including food availability, predation, and physical factors related to habitat, and potentially operational factors as well. Multiple regression analyses were performed to investigate potential combined influences of environmental and operational factors on pelagic forage fish on Lake Keowee. Spring and fall forage fish total numbers and densities in basins of Lake Keowee were regressed on combinations of variables related to JPSS pumping flow, Keowee HS generation flow, lake level, temperature, food availability as manifested by chlorophyll and zooplankton density, and predation.

Multiple regression analyses were performed to detect potential combined influences of independent variables, in which both independent variables exert an influence on the dependent variable. Multiple regression analyses may provide more realistic representations of the relative importance of independent variables to explaining variance in the dependent variable, as multiple influences on the dependent variable may be taken into account simultaneously. Multiple regression analyses were limited to two independent variables due to the size of the data set (N=14 years). Limiting regressions to two independent variables may lead to specification error, which can occur when an important source of variation in the dependent variable is not included in the regression model, potentially resulting in biased results (Freund et al. 2006).

Multiple regression analyses intended to detect interacting influences of independent variables, in which the influence of a given independent variable changes at different levels of the other independent variable, were not performed. Analysis of interactive influences requires addition of an interaction term to regression models; the number of observations available for analysis did not meet the recommended minimum for multiple regressions with three terms (see Methods).

Spring and fall forage fish variables are analyzed first for combined effects of operational parameters (JPSS pumping and Keowee HS generation); then for combined effects of operational and environmental parameters; and finally for combined effects of environmental parameters. Results for all analyses of spring forage fish data are presented first, followed by results for analyses of fall data.

Spring forage fish in relation to winter JPSS pumping flow and Keowee HS generation flow – To investigate whether winter JPSS pumping and Keowee HS generation may have exerted combined influences on spring forage fish abundance in Lake Keowee, multiple regression analyses were performed relating spring forage fish total lakewide numbers, as well as spring forage fish densities in the Keowee River and Little River basins of Lake Keowee, to combinations of variables for December-February JPSS pumping flow (mean, maximum daily, maximum 30-day average) and Keowee HS generation flow (mean, maximum daily, maximum 30-day average), using data collected 1999-2013. Multiple regression analyses produced no evidence that winter JPSS pumping and Keowee HS generation combined to influence spring forage fish lakewide numbers or densities in basins of Lake Keowee. No significant regression models were produced (Appendix Tables 32 through 34), and no variable for either JPSS pumping or Keowee HS generation flow contributed significantly to explaining variance in spring forage fish lakewide numbers or densities in basins of Lake Keowee.

Spring forage fish in relation to winter JPSS pumping flow and Lake Keowee lake level – Spring forage fish lakewide numbers and densities in basins of Lake Keowee were regressed on combinations of variables for December-February JPSS pumping flow (mean, maximum daily, maximum 30-day average) and December-February Lake Keowee lake level (mean, lowest daily, lowest 30-day average) utilizing data collected 1999-2013, in an attempt to determine whether these parameters may have combined to influence spring forage fish abundance on Lake Keowee. No significant regression models were produced in these analyses (Appendix Tables 35 through 37), consistent with results of linear regression analysis in which neither winter JPSS pumping flow nor winter lake level were observed to significantly influence spring forage fish abundance in Lake Keowee.

Spring forage fish in relation to winter Keowee HS generation flow and lake level – To investigate potential combined effects of winter Keowee HS generation flow and lake level on spring forage fish abundance and distribution in Lake Keowee, multiple regression analyses were carried out relating spring forage fish total lakewide numbers and spring forage fish densities in the Keowee River and Little River basins of Lake Keowee to combinations of variables for winter Keowee HS generation flow (mean, maximum daily, maximum 30-day average) and winter Lake Keowee lake level (mean, lowest daily, lowest 30-day average). No significant models were produced in these analyses, and neither winter Keowee HS generation nor winter lake level were found to contribute significantly to explaining variance in spring forage fish lakewide numbers or densities in basins of Lake Keowee (Appendix Tables 38 through 40). Thus, no evidence was detected that abundance of spring forage fish in Lake Keowee was influenced by combined effects of Keowee HS generation and lake level during the winter.

Spring forage fish in relation to winter JPSS pumping flow and winter temperature – Minimum winter temperatures in the upper reaches of the Keowee River basin (Location 507) averaged 10.6 C over the study period (1999-2013), low enough to potentially affect mobility of threadfin shad (Griffith 1978; Burgess 1980; McLean et al. 1982, 1985) and significantly lower than minimum winter temperatures in the lower Keowee River basin, which averaged 16.0 C (Location 504). To examine whether low winter temperature below the JPSS dam and pumping at JPSS may have combined to influence forage fish abundance in Lake Keowee, multiple regressions were carried out relating total spring forage fish numbers lakewide and forage fish density in the Keowee River basin to combinations of variables for winter JPSS pumping (mean, maximum daily, and maximum 30-day average observed December-February) and winter temperature (minimum winter temperature at Location 507), using data collected 1999-2013. None of these analyses produced significant models, nor were any observations identified as outlying or highly influential (Appendix Table 41). Thus, no evidence was detected that low winter temperatures on Lake Keowee in the vicinity of Jocassee Pumped Storage Station combined with pumping operations to influence spring forage fish abundance on Lake Keowee.

Spring forage fish in relation to winter JPSS pumping flow and winter chlorophyll – To investigate whether spring forage fish abundance in Lake Keowee may have been simultaneously influenced by effects of winter pumping at JPSS and food availability as manifested by winter chlorophyll, multiple regression analyses were performed modeling spring forage fish total lakewide numbers as well as spring forage fish densities in basins of Lake Keowee on combinations of variables for December-February JPSS pumping flow (mean, maximum daily, maximum 30-day average) and mean January-February chlorophyll concentrations.

No significant models were produced in regressions of spring total forage fish numbers lakewide on winter JPSS pumping variables and mean January-February lakewide chlorophyll (Appendix Table 42), although the parameter estimate for chlorophyll was significantly different from zero in one of these analyses, consistent with linear regression analysis in which winter chlorophyll potentially explained 35% of variance in spring forage fish numbers. Thus, no evidence was detected that winter JPSS pumping and chlorophyll exerted combined effects on spring total forage fish numbers on Lake Keowee.

All multiple regression models relating spring forage fish density in the Keowee River basin to winter JPSS pumping flows and winter chlorophyll explained significant variance (Appendix Table 43), with highest R^2 in the following model:

(25)
logSprDensKeo = 2.20328 – 0.00123 MeanDecFebJocPump + 1.50560 logMeanJanFebBasinChlor

$R^2 = 0.4372$
Pr>F = 0.0424
N = 14
Prob>|t| for intercept < 0.0001
Prob>|t| for Jocassee pumping = 0.5848
Prob>|t| for chlorophyll = 0.0342
Data set: 1999-2013, Keowee River basin
Outlying or highly influential observations: (none)

where logSprDensKeo = log Spring forage fish density in Keowee River basin, no/ha
MeanDecFebJocPump = mean JPSS pumping flow observed December-February, m^3/sec
logMeanJanFebBasinChlor = log Mean chlorophyll concentration in the Keowee River basin observed January-February, mg/m^3.

However, the percentage of variance in spring forage fish density explained by this model was 44%, not substantially higher than that explained by chlorophyll alone in linear regression analysis (42%); in addition, the parameter estimate for JPSS pumping flow was not significantly different from zero in any of the significant models (Appendix Table 43). Thus, these models produced no evidence of combined effects of winter JPSS pumping and winter chlorophyll on spring forage fish density.

No significant models were produced in multiple regression analysis of data from the Little River basin (Appendix Table 43), although again, the parameter estimate for chlorophyll was significantly different from zero in one of these analyses, consistent with the significant relationship detected between winter chlorophyll and spring forage fish density in the Little River basin in linear regression analysis.

Spring forage fish in relation to winter Keowee HS generation flow and winter chlorophyll – The possibility that winter Keowee HS generation flow and winter chlorophyll exerted simultaneous influences on spring forage fish in Lake Keowee was examined through multiple regression analysis of spring total forage fish numbers lakewide, as well as spring forage fish densities in zones, on combinations of variables for December-February Keowee HS generation flow (mean, maximum daily, maximum 30-day average) and mean January-February chlorophyll.

No significant models were produced in regressions of total spring forage fish lakewide numbers on winter Keowee HS generation flow and winter lakewide chlorophyll. Again, consistent with linear regression analyses, parameter estimates for chlorophyll in these models were significantly different from zero, but those for Keowee HS generation flow were not and the models as a whole did not explain significant variance in spring forage fish numbers (Appendix Table 44).

Regressions of spring forage fish density in the Keowee River basin on winter Keowee HS generation flow and winter chlorophyll produced three significant models (Appendix Table 45).

The model explaining the highest percentage of variance in spring forage fish density was the following:

(26)
logSprDensKeo = 1.22015 + 0.37140 logMaxDailyDecFebKeoGen + 1.63653 logMeanJanFebChlor

R^2 = 0.4459
Pr>F = 0.0389
N = 14
Prob>|t| for intercept = 0.3308
Prob>|t| for Keowee generation = 0.4964
Prob>|t| for chlorophyll = 0.0150
Data set: 1999-2013, Keowee River basin
Outlying or highly influential observations: (none)

where logSprDensKeo = log Spring forage fish density in the Keowee River basin, no/ha

logMaxDailyDecFebKeoGen = log Maximum daily Keowee HS generation flow observed December-February, m^3/sec
logMeanJanFebChlor = log Mean chlorophyll concentration observed January-February in the Keowee River basin, mg/m^3

Once again, however, the model explained 45% of variance in spring forage fish density in the Keowee River basin, not substantially higher than that explained by chlorophyll alone in linear regression analysis (42%). In addition, the parameter estimate for winter Keowee HS generation flow was not significantly different from zero, indicating that this variable did not contribute significantly to explaining variance in spring forage fish density in the Keowee River basin.

Multiple regression analysis of data from the Little River basin yielded no significant models (Appendix Table 45). Again, however, the parameter estimates for chlorophyll were significantly different from zero in all of these analyses. This observation is consistent with linear regression results which indicated that variation in winter chlorophyll in the Little River basin could account for 31% of variance in spring forage fish density. Thus, multiple regression analyses produced no evidence of combined influences of winter Keowee HS generation flow and chlorophyll on spring forage fish abundance in Lake Keowee.

Spring forage fish in relation to winter JPSS pumping and winter zooplankton – The potential that food availability and JPSS pumping in winter may have exerted simultaneous influences on spring forage fish abundance in Lake Keowee was further examined through multiple regression analyses of spring forage fish variables on variables for winter JPSS pumping flows and winter zooplankton densities.

The total number of forage fish lakewide in spring on Lake Keowee was regressed on combinations of variables for December-February JPSS pumping flows (mean, maximum daily, maximum 30-day average) and February lakewide densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton in Lake Keowee (Appendix Table 46). These analyses produced three regression models which explained significant variance in spring forage fish numbers; in all of these models the independent zooplankton variable was total crustacean zooplankton density. The following model exhibited the highest R^2 value:

(27)
logSprFish = 2.00438 – 0.00167 MeanDecFebJocPump + 1.07309 logFebLWCrustZoo
R^2 = 0.5189
Pr>F = 0.0258
N = 13
Prob>|t| for intercept = 0.2644
Prob>|t| for Jocassee pumping = 0.4196
Prob>|t| for zooplankton = 0.0236
Data set: 1999-2012, lakewide
Outlying or highly influential observations: (none)
where logSprFish = log Total number of forage fish lakewide in spring
MeanDecFebJocPump = mean JPSS pumping flow observed December-February, m^3/sec
logFebLWCrustZoo = log Lakewide densities of total crustacean zooplankton observed in February, organisms/m^3

This model potentially explained 52% of variance in spring forage fish numbers on Lake Keowee, not substantially higher than that explained by February densities of crustacean zooplankton alone (48% in linear regression analysis). In addition, in none of these regression models was the parameter estimate associated with JPSS pumping flow significantly different from zero (Appendix Table 46). Thus, no evidence was detected that total spring forage fish numbers on Lake Keowee were simultaneously influenced by JPSS pumping flows and food availability as manifested by zooplankton density.

Similar results were obtained in multiple regression analyses of spring forage fish density in the Keowee River basin. Three regression models explained significant variance in spring forage fish density; all of these models contained a term for February density of crustacean zooplankton (Appendix Table 48). The following model exhibited the highest R^2 value:

(28)
logSprDensKeo = -1.82915 – 0.00147 MeanDecFebJocPump + 1.07038 logFebCrustZoo
R^2 = 0.5244
Pr>F = 0.0243
N = 13
Prob>|t| for intercept = 0.2726
Prob>|t| for Jocassee pumping = 0.4847
Prob>|t| for zooplankton = 0.0170
Dataset: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)
where logSprDensKeo = log Spring forage fish density in the Keowee River basin, no/ha

MeanDecFebJocPump = mean JPSS pumping flows observed December-February, m^3/sec
logFebCrustZoo = log February densities of total crustacean zooplankton in the Keowee River basin, organisms/m^3

This model potentially explained 52% of variance in spring forage fish density in the Keowee River basin, again not substantially higher than explained by February crustacean zooplankton densities alone in linear regression analysis (50%). Once again, in none of the multiple regression models was the parameter estimate associated with JPSS pumping flows significantly different from zero, indicating that winter pumping variables did not contribute to explaining significant variance in spring forage fish density in the Keowee River basin.

Multiple regression analyses modeling spring forage fish density in the Little River basin on combinations of variables for winter JPSS pumping flow and February densities of crustacean zooplankton, rotifers, or total zooplankton did not produce any significant regression models (Appendix Table 50). Parameter estimates associated with crustacean zooplankton density in the Little River basin were significantly different from zero in two of the regression models, again consistent with the fact that crustacean zooplankton densities in February potentially explained 39% of variance in spring forage fish density in the Little River basin, based on linear regression analysis. Thus, multiple regression analyses of spring forage fish abundance variables on winter JPSS pumping variables and winter zooplankton densities provided no evidence that spring forage fish abundance in the Little River Basin of Lake Keowee were simultaneously, significantly influenced by both Jocassee pumping and food availability.

Spring forage fish in relation to winter Keowee HS generation and winter zooplankton – To investigate the possibility that spring forage fish abundance on Lake Keowee was influenced by both winter Keowee HS generation flow and winter food availability as manifested by zooplankton, total spring forage fish numbers lakewide as well as spring forage fish densities in the Keowee River and Little River basins of Lake Keowee were regressed on combinations of variables for December-February Keowee HS generation flows (mean, maximum daily, maximum 30-day average) and February zooplankton densities (total crustacean zooplankton, rotifers, and total zooplankton).

Multiple regressions of total numbers of forage fish lakewide in spring on winter Keowee HS generation flows and February zooplankton densities produced three significant regression models, all of which contained a term for total crustacean zooplankton (Appendix Table 51). The following model exhibited the highest R^2 value:

(29)
logSprFish = 0.53027 + 0.17686 logMeanDecFebKeoGen + 1.34630 logFebLWCrustZoo

$R^2 = 0.5081$
Pr>F = 0.0288
N = 13
Prob>|t| for intercept = 0.7904
Prob>|t| for Keowee generation = 0.5076
Prob>|t| for zooplankton = 0.0121
Data set: 1999-2012, lakewide
Outlying or highly influential observations: (none)

where logSprFish = log Total number of forage fish lakewide in spring
logMeanDecFebKeoGen = log Mean Keowee HS generation flow observed December-February, m^3/sec
logFebLWCrustZoo = log Lakewide densities of total crustacean zooplankton observed in February, organisms/m^3

This model did not explain substantially more variance in spring forage fish numbers (51%) than was explained by February densities of crustacean zooplankton alone in linear regression analysis (48%). In addition, the parameter estimates associated with winter Keowee generation flow were not significantly different from zero in any of the regression models, indicating that this variable did not contribute significantly to explaining variance in spring forage fish numbers in these models.

When spring forage fish density in the Keowee River basin was regressed on winter Keowee HS generation flows and February zooplankton densities in the Keowee River basin, again, three significant models were produced (Appendix Table 53), all of which contained a term for total crustacean zooplankton. The following model exhibited the highest R^2:

(30)
logSprDensKeo = -5.03194 + 0.56208 logMeanDecFebKeoGen + 1.66481 logFebCrustZoo

$R^2 = 0.6895$
Pr>F = 0.0029
N = 13
Prob>|t| for intercept = 0.0102

Prob>|t| for Keowee generation = 0.0328
Prob>|t| for zooplankton = 0.0008
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)

where logSprDensKeo = log Spring forage fish density in the Keowee River basin, no/ha
logMeanDecFebKeoGen = log Mean Keowee HS generation flow observed December-February, m^3/sec
logFebCrustZoo = log Density of total crustacean zooplankton (sum of copepod and cladoceran densities), organisms/m^3

In this model, influences of mean winter Keowee HS generation flow and February densities of crustacean zooplankton combined to explain 69% of variance in spring forage fish density in the Keowee River basin, substantially more than the 50% of variance explained by February crustacean density alone in linear regression analysis. Both Keowee generation flow and food availability as manifested in crustacean zooplankton density contributed significantly to explaining variance in spring forage fish density in the Keowee River basin, based on the fact that parameter estimates for both variables were significantly different from zero. The parameter estimates for both independent variables were positive, indicating that spring forage fish density in the Keowee River basin was higher following winters with higher Keowee HS generation flows and higher densities of crustacean zooplankton. Thus, no negative impact of winter Keowee HS generation flow on spring forage fish density was detected in these analyses.

No significant models were produced in multiple regression analysis of spring forage fish density in the Little River basin on winter Keowee HS generation flow and February zooplankton densities (Appendix Table 55).

Spring forage fish in relation to winter chlorophyll and predation – To investigate the relative importance of winter food availability as manifested by chlorophyll and possible top-down pressures of predation on spring forage fish abundance in Lake Keowee, multiple regression analyses were carried out relating spring forage fish densities in the Keowee River and Little River basins of Lake Keowee to mean basinwide winter (January-February) chlorophyll concentrations and mean basinwide abundance of predators. Predator abundance was quantified as total littoral density (no/km) and biomass (kg/km) of black basses, as measured in spring electrofishing. Because electrofishing data were available for only six years, these analyses were carried out using data from both basins in the same analysis in order to obtain sufficient observations for multiple regression analysis. Due to the small number of electrofishing observations (N=6), it was not possible to analyze total numbers of forage fish lakewide in relation to chlorophyll and predation, as the recommended sample size for a multiple regression analysis with two independent variables is 10 (see Methods).

Multiple regression analyses of spring forage fish density on chlorophyll and black bass density, as well as on chlorophyll and black bass biomass, produced significant models (Appendix Table 56). The following model exhibited the highest R^2:

(31)
logSprDens = 2.62012 + 1.85503 logJanFebBasinChlor – 0.60390 logBLBnumkm
$R^2 = 0.5948$
Pr>F = 0.0172
N = 12
Prob>|t| for intercept = 0.0023
Prob>|t| for chlorophyll = 0.0074
Prob>|t| for black bass = 0.2118
Data set: 1999, 2002, 2005, 2008, 2010, 2011, Keowee River and Little River basins
Outlying or highly influential observations: (none)

where logSprDens = log Spring forage fish density, no/ha
logJanFebBasinChlor = log Basinwide chlorophyll concentration observed January-February, mg/m^3
BLBnumkm = log Littoral density of total black basses, no/km, in spring shoreline electrofishing

This model potentially explained 59% of variance in spring forage fish densities in the Keowee River and Little River basins of Lake Keowee. While the parameter estimate associated with chlorophyll was significantly different from zero, that for black bass density was not, suggesting that most of the variance explained in this model was due to variation in winter chlorophyll concentrations. Similar results were obtained in the regression of spring forage fish density on chlorophyll (prob>|t|=0.0133) and total black bass biomass (prob>|t|=0.6743) (Appendix Table 56).

Linear regression analysis of spring forage fish densities in both basins of Lake Keowee on basinwide winter chlorophyll concentrations, limiting data to years with electrofishing data as in Regression (x), indicated that variation in winter chlorophyll concentrations alone could explain

51% of variance in spring forage fish densities (R^2=0.5134; Pr>F = 0.0087; N=12). Thus, an apparent response to food availability was detected, but statistically significant downward predation pressure on spring forage fish abundance was not detected in these analyses.

Spring forage fish in relation to winter zooplankton and predation – Potential simultaneous influences of food availability and predation pressure in winter on spring forage fish densities were also investigated in multiple regression analyses relating spring forage fish densities in the Keowee River and Little River basins of Lake Keowee to winter zooplankton densities and spring littoral abundance of black basses. Using data from both basins collected in 1999, 2002, 2005, 2008, 2010, and 2011, spring forage fish density was regressed on combinations of variables for basin zooplankton densities measured in February (total crustacean zooplankton, rotifers, total zooplankton) and spring basinwide littoral density (no/km) and biomass (kg/km) of total black basses as measured in electrofishing. These regressions produced no models which explained significant variance in spring forage fish basinwide densities in Lake Keowee (Appendix Table 57). In this limited data set, neither February zooplankton densities nor spring littoral total densities of black basses contributed significantly to explaining variance in spring forage fish density (as described previously, February zooplankton densities did explain significant variance in spring forage fish abundance in linear regression analysis of data from all years, 1999-2012). Thus, no evidence was detected in this series of multiple regression analyses that spring forage fish abundance was influenced by top-down predation pressure in combination with influences of food availability in winter. Lack of significant results may have been due in part to the small number of observations for predator data.

Fall forage fish in relation to May-October JPSS pumping flow and Keowee HS generation flow – To examine whether May-October pumping at JPSS and generation at Keowee HS may have exerted simultaneous influences on fall forage fish abundance in Lake Keowee, multiple regression analyses were performed relating total numbers of forage fish lakewide in fall on combinations of variables for May-October JPSS pumping flow (mean, maximum daily, maximum 30-day average) and May-October Keowee HS generation flow (mean, maximum daily, maximum 30-day average). While parameter estimates for maximum 30-day average JPSS May-October pumping flow were significantly different from zero in analyses containing this independent variable, none of these models were statistically significant overall (Appendix Table 58). Thus, no evidence was detected that operations at JPSS and Keowee HS combined to influence fall forage fish numbers in Lake Keowee, based on data collected 1999-2012.

Multiple regression analyses were also performed for each basin of Lake Keowee, relating fall forage fish density to combinations of variables for May-October JPSS pumping flow and Keowee HS generation flow, as detailed above. Three significant models were produced in analyses of data for the Keowee River basin, all of which contained a term for maximum 30-day mean JPSS pumping flow observed May-October (Appendix Table 59). The following model exhibited the highest R^2 value:

(32)
FallDensKeo = 2877.82971 – 9.05549 Max30dayMayOctJocPump + 6.16329 Max30dayMayOctKeoGen

$R^2 = 0.4955$
Pr>F = 0.0232
N = 14
Prob>|t| for intercept = 0.0015
Prob>|t| for Jocassee pumping = 0.0094
Prob>|t| for Keowee generation = 0.2770
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day mean pumping flow at Jocassee Pumped Storage Station observed May-October, m^3/sec
Max30dayMayOctKeoGen = maximum 30-day mean generation flow at Keowee Hydroelectric Station observed May-October, m^3/sec

This model potentially explained 50% of variance in fall forage fish density in the Keowee River basin, not substantially more than the 44% of variance explained by variation in maximum 30-day mean Jocassee pumping flow alone in linear regression analysis. The parameter estimates for Keowee generation flow in these models were not significantly different from zero, indicating that the significance of these models was due to the contribution of JPSS pumping flow to explaining variance in fall forage fish density. Thus, no evidence of combined influences of JPSS pumping and Keowee HS generation on fall forage fish density in the Keowee River basin was detected in these analyses.

Multiple regression analyses of fall forage fish density in the Little River basin on combinations of variables for May-October JPSS pumping flow and Keowee HS generation flow produced no significant results (Appendix Table 60).

Fall forage fish in relation to May-October JPSS pumping flow and Lake Keowee lake level – To investigate potential combined influences of May-October JPSS pumping flow and Lake Keowee lake level on fall forage fish abundance in Lake Keowee, multiple regression analyses were carried out relating total numbers of forage fish in Lake Keowee in fall to combinations of variables for May-October JPSS pumping flow (mean, maximum daily, maximum 30-day average) and May-October Lake Keowee lake level (mean, lowest daily, lowest 30-day average). Parameter estimates for maximum 30-day mean JPSS pumping flow observed May-October were significantly different from zero in three regressions, consistent with linear regression analyses where variation in this parameter potentially explained 35% of variance in fall forage fish lakewide numbers. However, none of these regressions produced models significant at the reference probability (Appendix Table 61); thus, no evidence was detected that combined effects of May-October JPSS pumping flow and lake level explained significant variance in total forage fish numbers in fall.

Multiple regression analyses were also performed relating fall forage fish density in each basin of Lake Keowee to combinations of variables for May-October JPSS pumping flow and Lake Keowee lake level. Analysis of data for the Keowee River basin produced three significant models, all of which included a term for maximum 30-day mean May-October JPSS pumping flow (Appendix Table 62). The highest R^2 value was produced by the following model:

(33)
FallDensKeo = 2667.37626 – 9.56580 Max30dayMayOctJocPump + 386.70999 Max30dayMayOctLL

$R^2 = 0.5264$
Pr>F = 0.0164
N = 14
Prob>|t| for intercept = 0.0029
Prob>|t| for Jocassee pumping = 0.0062
Prob>|t| for lake level = 0.1742
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day average pumping flow observed May-October at Jocassee Pumped Storage Station, m^3/sec
Max30dayMayOctLL = lowest 30-day average Lake Keowee lake level observed May-October, meters below full pool

This model potentially explained 53% of variance in fall forage fish density in the Keowee River basin, as compared to 44% of variance explained by the JPSS pumping variable alone in linear regression analysis. Again, however, only the parameter estimate for JPSS pumping flow was significantly different from zero in Regression (x) above, thus providing no evidence that JPSS pumping flow and Lake Keowee lake level exerted significant, simultaneous influences on fall forage fish density in the Keowee River basin.

Multiple regression analyses of fall forage fish density in the Little River basin on combinations of variables for May-October JPSS pumping flows and May-October Lake Keowee lake levels produced no significant results (Appendix Table 63).

Fall forage fish in relation to May-October Keowee HS generation flow and Lake Keowee lake level – Multiple regression analysis was employed to examine the possibility that Keowee Hydroelectric Station generation flow and Lake Keowee lake level exerted combined influences on fall forage fish abundance in Lake Keowee. Total numbers of forage fish lakewide in fall were regressed on combinations of variables for May-October Keowee HS generation flow (mean, maximum daily, maximum 30-day average) and variables for May-October Lake Keowee lake level (mean, lowest daily, lowest 30-day average). None of the resulting models explained significant variance in fall forage fish lakewide numbers (Appendix Table 64). Multiple regressions of fall forage fish density in the Keowee River and Little River basins were carried out as well, regressing fall forage fish density on combinations of variables for May-October Keowee HS generation flow and lake level. Again, none of the resulting models were statistically significant (Appendix Tables 65 and 66). Thus, no evidence was detected that May-October Keowee HS generation flow and May-October Lake Keowee lake level exerted combined effects on fall forage fish densities in Lake Keowee.

Fall forage fish in relation to May-October JPSS pumping flow and maximum summer temperature – As described previously, fall forage fish densities in the Keowee River basin were negatively correlated with maximum summer surface temperatures observed in the middle Keowee River basin (Locations 505 and 506), and fall forage fish densities in the Little River basin were negatively correlated with maximum summer surface temperatures in the Little River basin, potentially reflecting the inverse relationship between summer surface maximum temperature and available preferred habitat for blueback herring in late summer, documented earlier. To investigate possible combined effects of May-October JPSS pumping and maximum summer surface temperature, multiple regression analyses were carried out relating fall forage fish densities in the Keowee River and Little River basins of Lake Keowee to combinations of variables for May-October JPSS pumping flows (mean, maximum daily, maximum 30-day average) and maximum summer surface temperature. Maximum summer surface temperature was that observed in the middle Keowee River basin (mean of Locations 505 and 506) for analyses of Keowee River basin forage fish; and mean basinwide summer surface temperature (mean of Locations 500, 501, 502) for analyses of Little River basin forage fish. Lakewide forage fish numbers in fall were analyzed in relation to both summer maximum temperature in the middle area of the Keowee River basin, and summer maximum temperature in the Little River basin, potentially most reflective of meteorological conditions.

One significant model was produced in multiple regressions of total fall forage fish numbers lakewide on variables for May-October JPSS pumping flow and summer maximum surface temperature (Appendix Table 67), as follows:

(34)
FallFish = 125,039,005 – 62,901 Max30dayMayOctJocPump – 3,360,287 LitMaxTemp
$R^2 = 0.5307$
Pr>F = 0.0156
N = 14
Prob>|t| for intercept = 0.0254
Prob>|t| for Jocassee pumping = 0.0470
Prob>|t| for Little basin maximum temperature = 0.0645
Data set: 1999-2012
Outlying or highly influential observations: (none)
where FallFish = total number of forage fish lakewide in fall

Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec
LitMaxTemp = mean summer surface (0-5 m) maximum temperature observed in the Little River basin, C, calculated as the average of maximum summer surface temperatures observed at Locations 500, 501, and 502

This model potentially explained 53% of variance in fall forage fish lakewide numbers, substantially more than explained by the JPSS pumping variable alone (35%) or the temperature variable alone (32%) in linear regression analysis. Based on significance probabilities associated with parameter estimates (prob>|t|), the JPSS pumping variable contributed significantly to explaining variance in fall forage fish numbers, while the significance probability for the temperature parameter estimate approached, but did not attain, the reference probability for significance.

All multiple regression analyses relating fall forage fish density in the Keowee River basin to measures of May-October JPSS pumping flow and summer surface maximum temperature in the middle Keowee River basin produced models which explained significant variance (Appendix Table 67). In the first two of these models (below), the temperature term contributed significantly to explaining variance in fall forage fish density while the pumping variable did not:

(35)
FallDensKeo = 12,988 – 2.52541 MeanMayOctJocPump – 366.61551 KeoMiddleMaxTemp
R^2 = 0.4256
Pr>F = 0.0474
N = 14
Prob>|t| for intercept = 0.0201
Prob>|t| for Jocassee pumping = 0.5435
Prob>|t| for maximum temperature = 0.0422
Data set: 1999-2012, Keowee basin
Outlying or highly influential observations: (none)
where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
MeanMayOctJocPump = mean JPSS pumping flow observed May-October, m^3/sec
KeoMiddleMaxTemp = summer surface maximum temperature observed in the middle Keowee River basin, C, calculated as the average of maximum summer surface temperatures observed at Locations 505 and 506

(36)
FallDensKeo = 13,329 – 2.45034 MaxDailyMayOctJocPump – 363.52090 KeoMiddleMaxTemp
R^2 = 0.4468
Pr>F = 0.0385

N = 14
Prob>|t| for intercept = 0.0135
Prob>|t| for Jocassee pumping = 0.3822
Prob>|t| for maximum temperature = 0.0349
Data set: 1999-2012, Keowee basin
Outlying or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
MaxDailyMayOctJocPump = maximum daily mean JPSS pumping flow observed May-October, m^3/sec
KeoMiddleMaxTemp = summer surface maximum temperature observed in the middle Keowee River basin, C, calculated as the average of maximum summer surface temperatures observed at Locations 505 and 506

These models did not produce substantially higher R^2 values than that produced in linear regression analysis of fall forage fish density in the Keowee River basin on the temperature variable alone (R^2=0.41), and the parameter estimate for JPSS pumping in these analyses did not differ significantly from zero. Thus, these models did not detect combined effects.

The third model relating fall forage fish density in the Keowee River basin to JPSS pumping flow and maximum summer surface temperature explained 59% of variance, more than explained by either independent variable alone, as follows:

(37)
FallDensKeo = 11,251 – 6.40157 Max30dayMayOctJocPump – 278.14919 KeoMiddleMaxTemp
R^2 = 0.5909
Pr>F = 0.0073
N = 14
Prob>|t| for intercept = 0.0177
Prob>|t| for Jocassee pumping = 0.0471
Prob>|t| for maximum temperature = 0.0657
Data set: 1999-2012, Keowee basin
Outlying or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec
KeoMiddleMaxTemp = summer surface maximum temperature observed in the middle Keowee River basin, C, calculated as the average of maximum summer surface temperatures observed at Locations 505 and 506

This model could account for 59% of variance in fall forage fish density in the Keowee River basin, somewhat higher than the percents of variance explained by either the JPSS pumping variable alone (44%) or the maximum summer surface temperature variable alone (41%). Thus, this model provides some evidence that high pumping flows observed May-October and high summer temperatures exerted simultaneous, significant effects on fall forage fish density in the Keowee River basin. Too few observations were available to assess any interactive effects of these variables (see Methods).

Multiple regressions relating fall forage fish density in the Little River basin to combinations of variables for May-October JPSS pumping flow and maximum summer surface temperature in the Little River basin did not produce any significant models (Appendix Table 67).

Fall forage fish in relation to May-October JPSS pumping flow and chlorophyll – Fall forage fish lakewide numbers and densities in basins were regressed on combinations of variables for May-October JPSS pumping flows (mean, maximum daily, maximum 30-day average) and chlorophyll (May concentrations and mean of May through October concentrations), in an attempt to model combined influences of food availability and JPSS pumping on fall forage fish in Lake Keowee. Chlorophyll concentrations measured in May were intended to characterize food availability during spring spawning, and mean May-October chlorophyll concentrations were intended to characterize food availability during the period between spring spawning and fall sampling.

Multiple regressions of total numbers of forage fish lakewide in fall on May-October JPSS pumping flows and May or May through October mean lakewide chlorophyll concentrations produced no significant models, thus detecting no combined effects of food availability and JPSS pumping on fall forage fish lakewide numbers (Appendix Table 68).

Regressions of fall forage fish density in the Keowee River basin produced two significant models, both of which contained a term for maximum 30-day average JPSS pumping flow observed May-October (Appendix Table 70). The following model exhibited the highest R^2 value:

(38)
FallDensKeo = 3798.49812 – 9.86530 Max30dayMayOctJocPump – 220.84285 MeanMayOctChlor

$R^2 = 0.4667$
Pr>F = 0.0315
N = 14
Prob>|t| for intercept = 0.0060
Prob>|t| for Jocassee pumping = 0.0105
Prob>|t| for chlorophyll = 0.4395
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m3/sec
MeanMayOctChlor = mean surface (0-10 m) chlorophyll concentration May through October, mg/m^3

This model potentially explained 47% of variance in fall forage fish density in the Keowee River basin, not substantially more than was explained by the pumping term alone in linear regression analysis (44%). In addition, the parameter estimate for chlorophyll was not significantly different from zero. Thus, these analyses did not detect combined responses of fall forage fish in the Keowee River basin to both food availability and pumping.

Multiple regressions of fall forage fish density in the Little River basin on combinations of variables for May-October JPSS pumping flow and basinwide chlorophyll concentration did not produce any significant models (Appendix Table 72), again detecting no combined effects of pumping and food availability as manifested by chlorophyll.

Fall forage fish in relation to May-October Keowee HS generation flow and chlorophyll – Fall forage fish variables were subjected to multiple regression analysis on variables for May-October Keowee HS generation flow and chlorophyll, in an attempt to model combined or counteracting influences of Keowee HS generation and food availability as manifested by chlorophyll.

Multiple regressions of total numbers of forage fish lakewide in fall on combinations of variables for Keowee HS generation flow observed May-October (mean, maximum daily, maximum 30-day average) and lakewide chlorophyll concentrations (May and mean May-October concentrations) produced no significant models (Appendix Table 73) and parameter estimates were not significantly different from zero for any independent variable. Similarly, no significant models were produced in multiple regression analysis of fall forage fish density in the Keowee River or Little River basins on May-October Keowee HS generation flows and basinwide chlorophyll concentrations in May or averaged over May-October (Appendix Tables 74 and 75). Thus, no evidence was detected of simultaneous influences of Keowee HS generation and food availability as manifested by chlorophyll on fall forage fish abundance in Lake Keowee.

Fall forage fish in relation to May-October JPSS pumping flow and zooplankton – Multiple regression analysis was employed to investigate responses of fall forage fish lakewide numbers and densities in basins of Lake Keowee to combined effects of May-October JPSS pumping flows and food availability as manifested by zooplankton density. Fall forage fish variables were regressed on combinations of variables for May-October JPSS pumping flows (mean, maximum daily, maximum 30-day average) and zooplankton densities observed in May during forage fish spawning, and averaged over May and August. Zooplankton variables analyzed in relation to fall forage fish and Jocassee May-October pumping flows include densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton.

Three significant models were produced in regression analyses of total fall forage fish numbers on May-October JPSS pumping flows and zooplankton densities observed in May during spring spawning. All of these models contained a term for May densities of rotifers (Appendix Table 77). Of these, the model which produced the highest R^2 was as follows:

(39)
FallFish = -53,991,757 + 34,335 MeanMayOctJocPump + 13,382,663 logMayLWRot
$R^2 = 0.4754$
Pr>F = 0.0397
N = 13
Prob>|t| for intercept = 0.0515
Prob>|t| for Jocassee pumping = 0.4029
Prob>|t| for rotifers = 0.0169
Data set: 1999-2012, lakewide
Outlying or highly influential observations: (none)
where FallFish = total number of forage fish lakewide in fall
MeanMayOctJocPump = mean JPSS pumping flow observed May-October, m^3/sec
logMayLWRot = log Lakewide densities of rotifers observed in May, organisms/m^3

This model potentially explained 48% of variance in fall forage fish numbers, not substantially more than was explained by May rotifer density alone in linear regression analysis (44%). The parameter estimate for JPSS pumping flow was not significantly different from zero in this model, indicating that this variable did not contribute to explaining variance beyond that explained by May rotifer density alone.

Regressions of Keowee basin fall forage fish density on May-October JPSS pumping flows and May zooplankton densities produced six models which explained significant variance (Appendix Table 78). Three of these models contained a term for May rotifer density, which, based on significance probabilities associated with parameter estimates, was the only term with a parameter estimate significantly different from zero. Of these three models, the following model exhibited the highest R^2:

(40)
FallDensKeo = -2452.05628 – 3.98278 Max30dayMayOctJocPump + 1071.56345 logMayRot
$R^2 = 0.6592$
Pr>F = 0.0046
N = 13
Prob>|t| for intercept = 0.2793
Prob>|t| for Jocassee pumping = 0.1637
Prob>|t| for rotifers = 0.0283
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)
where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec

logMayRot = log Rotifer density measured in May at Location 508, organisms/m^3

This model potentially explained 66% of variance in fall forage fish density in the Keowee River basin. Linear regression analysis indicated that May density of rotifers alone could account for 58% of variance in fall forage fish density in the Keowee River basin. This observation, in conjunction with the fact that the parameter estimate for JPSS pumping was not significantly different from zero, suggests that variation in May rotifer densities was primarily responsible for explaining variance in fall forage fish density in the Keowee River basin in this analysis.

In two of the additional three models which produced significant results, the zooplankton variable was May densities of total zooplankton. In these models, neither of the parameter estimates was significantly different from zero (Appendix Table 78). Although these models as a whole explained significant variance in fall forage fish density in the Keowee River basin, the amount of variance explained (48-52%) was less than that explained by models which included a term for rotifer density (62-66%). The significance of these two models is most likely attributable to the significant correlation between May rotifer density and May total zooplankton density in the Keowee River basin (r=0.88; P<0.0001; N=13).

The final significant regression model produced in regressions of fall forage fish density in the Keowee River basin on May-October JPSS pumping flows and May zooplankton was the following:

(41)
FallDensKeo = 3431.11985 – 8.72036 Max30dayMayOctJocPump – 0.01686 MayCrustZoo
R^2 = 0.4716
Pr>F = 0.0412
N = 13
Prob>|t| for intercept = 0.0035
Prob>|t| for Jocassee pumping = 0.0140
Prob>|t| for crustacean zooplankton = 0.4291
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec
MayCrustZoo = total crustacean zooplankton density in May in the Keowee River basin (Location 508), organisms/m^3

This regression model potentially explained 47% of variance in fall forage fish density in the Keowee River basin, not substantially more than was explained by maximum 30-day average JPSS pumping flow alone in linear regression analysis (46%). In addition the parameter estimate for crustacean zooplankton was not significantly different from zero, indicating that the variance in fall forage fish density explained by this model was due to variation in JPSS pumping flows alone.

Multiple regressions of fall forage fish density in the Little River basin on combinations of variables for May-October JPSS pumping flows and May zooplankton densities in the Little River basin produced no significant models (Appendix Table 79). Thus, combinations of JPSS pumping flows and zooplankton densities during spawning in this basin did not explain significant variance in fall forage fish density in the Little River basin.

No significant models were produced in multiple regression analyses of total numbers of forage fish lakewide in fall on May-October JPSS pumping flows and mean May-August densities of total crustacean zooplankton, rotifers, or total zooplankton (Appendix Table 80).

Four significant models were produced in regressions of fall forage fish density in the Keowee River basin on May-October JPSS pumping flows and mean May-August zooplankton densities measured at Location 508 in the Keowee River basin (Appendix Table 81). Three of these models included a term for maximum 30-day average May-October JPSS pumping flow. Of these three, models containing rotifer density or total zooplankton density as the second independent variable did not explain substantially more variance in fall forage fish density in the Keowee River basin than was explained by maximum 30-day average May-October JPSS pumping alone in linear regression analysis (51% and 50%, as compared to 44% for the pumping variable alone). In addition, the parameter estimates associated with rotifer density and total zooplankton density were not significantly different from zero, suggesting that the zooplankton variables did not account for significant variance in fall forage fish densities in these models (Appendix Table 81). The third model containing a term for maximum 30-day average May-

October JPSS pumping flow could potentially account for 66% of variance in fall forage fish density in the Keowee River basin, as follows:

(42)
FallDensKeo = 4011.74467 – 9.81913 Max30dayMayOctJocPump – 0.02762 MayAugCrustZoo
R^2 = 0.6565
Pr>F = 0.0082
N = 12
Prob>|t| for intercept = 0.0004
Prob>|t| for Jocassee pumping = 0.0028
Prob>|t| for zooplankton = 0.0662
Data set: 1999-2012, Keowee River basin
Outyling or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
Max30dayMayOctJocPump = maximum 30-day average JPSS pumping flow observed May-October, m^3/sec
MayAugCrustZoo = mean of May and August densities of total crustacean zooplankton (sum of copepods and cladocerans) at Location 508 in the Keowee River basin, organisms/m^3

The R^2 value of 0.66 associated with this model was substantially higher than that observed in linear regression analysis of fall forage fish density on maximum 30-day average May-October JPSS pumping flow alone (R^2=0.44), suggesting that both independent variables contributed to explaining variance in fall forage fish density in the Keowee River basin. The parameter estimate for the pumping variable is significantly different from zero, and the significance probability for the crustacean zooplankton variables approached, but did not meet, the reference probability. Unlike relationships detected between crustacean zooplankton in winter and spring forage fish, the sign of the parameter estimate associated with crustacean zooplankton in this model is negative, possibly suggesting downward predation pressure on zooplankton. This is problematic, as it would tend to indicate that zooplankton is exhibiting a response to predation pressure from forage fish, rather than influencing forage fish abundance. Similar tendencies were observed in the fourth significant regression model relating fall forage fish densities in the Keowee River basin to May-October JPSS pumping flows and zooplankton:

(43)
FallDensKeo = 4518.38235 – 7.35202 MaxDailyMayOctJocPump – 0.03187 MayAugCrustZoo
R^2 = 0.4935
Pr>F = 0.0468
N = 12

Prob>|t| for intercept = 0.0037
Prob>|t| for Jocassee pumping = 0.0181
Prob>|t| for zooplankton = 0.0926
Data set: 1999-2012, Keowee River basin
Outlying or highly influential observations: (none)

where FallDensKeo = fall forage fish density in the Keowee River basin, no/ha
MaxDailymayOctJocPump = maximum daily JPSS pumping flow observed May-October, m3/sec
MayAugCrustZoo = mean of May and August densities of total crustacean zooplankton (sum of copepods and cladocerans) at Location 508 in the Keowee River basin, organisms/m^3

No significant models were produced in multiple regression analyses of fall forage fish density in the Little River basin on combinations of variables for May-October JPSS pumping flows (mean, maximum daily, maximum 30-day average) and mean zooplankton densities observed at Location 502 in the Little River basin in May and August (Appendix Table 82).

Fall forage fish in relation to May-October Keowee HS generation flow and zooplankton – To investigate whether combined effects of May-October Keowee HS generation flow and food availability as manifested by zooplankton may have influenced fall forage fish abundance in Lake Keowee, multiple regression analyses were carried out relating total numbers of forage fish in fall and fall forage fish densities in basins of Lake Keowee to combinations of variables for May-October Keowee HS generation flow (mean, maximum daily, maximum 30-day average) and mean zooplankton densities observed in May and August (total crustacean zooplankton, rotifers, total zooplankton). None of these analyses produced models which explained significant variance in fall forage fish lakewide numbers or densities in basins of Lake Keowee (Appendix Tables 83 through 85).

Relationships of fall forage fish to chlorophyll and predation – To investigate whether food availability as manifested by chlorophyll and top-down pressures of predation could combine to explain significant variance in fall forage fish abundance in Lake Keowee, fall forage fish densities in basins of Lake Keowee were subjected to multiple correlation analysis with variables chosen to characterize chlorophyll concentrations during spawning (May, May-June mean) and over the growing season (May-October mean) and variables for littoral density (no/km) and biomass (kg/km) of black basses, primary predators on forage fish in Lake Keowee.

Electrofishing data were only available for six years of the forage fish study period, requiring that data for both basins be utilized in each of these analyses. No significant regression models were produced in these analyses (Appendix Table 86).

Relationships of fall forage fish to zooplankton and predation – Multiple regression analyses were carried out to examine the possibility that food availability as manifested by zooplankton densities and top-down pressures of predation could combine to explain significant variance in fall forage fish densities in Lake Keowee. Fall forage fish densities in both basins were regressed on combinations of variables for zooplankton and for littoral density and biomass of black basses measured in spring electrofishing. Zooplankton taxa analyzed included densities of total crustacean zooplankton (sum of copepods and cladocerans), rotifers, and total zooplankton, measured during the spawning season (May) and the growing season (mean of May and August data). Mean annual zooplankton data were also analyzed, in an attempt to detect relationships to general trends in reservoir productivity. Data from both basins were analyzed together to obtain sufficient observations for multiple regression analysis, as electrofishing data were available for only six years. None of these analyses produced significant results (Appendix Table 87), potentially due in part to the small number of observations available for analysis.

SUMMARY

From spring 1999 through spring 2013, lakewide pelagic forage fish densities on Lake Keowee averaged 272 fish/ha in spring and 1,251 fish/ha in fall. Total numbers of forage fish on Lake Keowee varied substantially among years. Total number of forage fish lakewide in spring ranged from 399,809 in 2010 to 6,154,803 in 2001; fall forage fish numbers ranged from 2,080,344 in 2010 to 16,936,544 in 2000. Both spring and fall forage fish numbers exhibited statistically significant tendencies to decline from 1999 through 2012, although spring forage fish densities stabilized and no significant decline was detected 2002-2013. Lowest forage fish numbers of the study period were observed in 2010. Fall forage fish numbers in 2011 and 2012 and spring forage fish numbers in 2011, 2012, and 2013 increased over those observed in 2010.

Seasonally, forage fish numbers were significantly higher in fall than in spring. Spatially, forage fish densities did not differ significantly between the Keowee River and Little River basins of

Lake Keowee. Forage fish density in the Keowee River basin averaged 295 fish/ha in spring and 1,073 fish/ha in fall, as compared to 253 fish/ha in spring and 1,394 fish/ha in fall in the Little River basin.

The pelagic forage fish community of Lake Keowee consisted of threadfin shad and blueback herring. The relative abundance of these species varied spatially. Threadfin shad accounted for 87% of pelagic forage fish in the lower Keowee River basin near the Oconee Nuclear Station discharge, on average, while blueback herring accounted for 82% of pelagic forage fish in the upper Keowee River basin near Fall Creek Landing, on average. Blueback herring accounted for 59 to 82% of pelagic forage fish in the Little River basin, based on purse seine samples collected in 2011 and 2012. No significant long-term trends in community composition were detected at either location in the Keowee River basin. In terms of age structure, fall populations of both blueback herring and threadfin shad consisted of greater than 95% young-of-the-year fish, on average.

Relationships of spring forage fish abundance to environmental and operational parameters – Spring forage fish total numbers lakewide and densities in basins of Lake Keowee were analyzed in relation to temperature, lake level, food availability (chlorophyll, zooplankton); predation; winter pumping flows at JPSS; and winter generation flows at Keowee HS.

Threadfin shad and blueback herring exhibit markedly different thermal preferences. Threadfin shad are susceptible to impaired mobility at temperatures below about 14 C and may be subject to die-offs at temperatures below 9-12 C (Griffith 1978; Burgess 1980; McLean et al. 1982, 1985; Etnier and Starnes 1993). In contrast, blueback herring tolerate temperatures as low as 2 C (Lee et al. 1980; Page and Burr 1991). Winter temperatures on Lake Keowee exhibited substantial spatial variation during the winter due in part to the presence of the thermal discharge at Oconee Nuclear Station. Over the study period, minimum winter temperatures ranged from 8.0 to 14.0 at locations on the Little River basin, and from 9.0 to 18.5 at locations on the Keowee River basin. Minimum winter temperatures never fell below 13.3 in the vicinity of the thermal discharge at ONS, presumably providing a thermal refuge for threadfin shad. Linear regression analysis detected no relationships between minimum winter temperature and spring forage fish numbers lakewide or spring forage fish densities in either basin of Lake Keowee. The possibility that low winter temperature observed in the upper reaches of the Keowee River basin and pumping at JPSS combined to influence spring forage fish abundance in Lake Keowee was examined with multiple regression analysis. No evidence of combined effects was detected.

Mean winter lake levels on Lake Keowee ranged from 0.4 to 1.8 meters below full pool. No relationships were detected between winter lake level and spring forage fish abundance in Lake Keowee. Multiple regression analyses were carried out to investigate the possibility that low lake levels in conjunction with winter JPSS pumping or Keowee HS generation may have influenced spring forage fish numbers lakewide or densities in basins of Lake Keowee. No evidence of combined effects of lake level and winter operations at JPSS or Keowee HS was detected.

Spring forage fish abundance on Lake Keowee was analyzed in relation to winter chlorophyll as an indicator of food availability. Significant, positive relationships were detected between mean January-February surface (0-10 m mean) chlorophyll concentrations and spring forage fish abundance. Variation in lakewide winter chlorophyll concentration potentially explained 35% of variance in total numbers of forage fish lakewide in spring. Similarly, variation in winter chlorophyll concentrations in the Keowee River basin could account for 42% of variance in spring forage fish basin densities; variation in winter chlorophyll concentrations in the Little River basin could explain 31% of variance in spring forage fish densities in that basin. These results suggest that food availability was a significant influence on winter survival of pelagic forage fish.

Zooplankton comprise the majority of the diet of both threadfin shad and blueback herring, with blueback herring consuming primarily larger copepods and cladocerans, and threadfin shad consuming rotifers, copepod nauplii, and smaller copepods and cladocerans, as well as phytoplankton (Davis and Foltz 1991). In the current study, linear regression analysis detected significant, positive relationships between winter densities of crustacean zooplankton (copepods and cladocerans) and spring forage fish abundance in Lake Keowee. Variation in densities of total crustacean zooplankton in February could explain 49% of variance in spring forage fish numbers lakewide. Variation in cladoceran density in February could account for 45% of variance in spring forage fish density in the Keowee River basin, while variation in copepod density in February could account for 40% of variance in spring forage fish density in the Little River basin. These results provide evidence that food availability was an important factor influencing abundance of pelagic forage fish in spring on Lake Keowee.

Based on spring shoreline electrofishing, largemouth bass and spotted bass were the most abundant of species likely to prey on blueback herring and threadfin shad on Lake Keowee. Spring forage fish densities in the Keowee River and Little River basins of Lake Keowee were analyzed in relation to littoral density and biomass of largemouth bass, spotted bass, and total black basses. Spring forage fish basin densities were found to be positively correlated with the littoral biomass of largemouth bass, suggesting that abundance of both spring forage fish and largemouth bass varied along a fertility gradient. No evidence of downward predation pressure on spring forage fish was detected.

Pumping operations at Jocassee Pumped Storage Station may influence forage fish in Lake Keowee through entrainment. Linear regression analysis was employed to investigate possible effects of JPSS pumping flow during the winter on the abundance of forage fish in Lake Keowee in spring. Total numbers of forage fish lakewide in spring, as well as spring forage fish densities in basins of Lake Keowee, were regressed on mean, maximum daily, and maximum 30-day average JPSS pumping flow observed December-February. Pumping variables were intended to quantify mean pumping during the winter; short-term high-flow events; and periods of sustained high pumping flows. No significant relationships were detected between any measure of JPSS winter pumping flow and spring total forage fish numbers lakewide or spring forage fish densities in basins of Lake Keowee.

Generation operations at Keowee Hydroelectric Station could potentially influence forage fish in Lake Keowee through flushing of fish. Potential impacts of winter Keowee HS generation on spring forage fish abundance in Lake Keowee were investigated through linear regression analysis of spring forage fish lakewide numbers, as well as spring forage fish densities in basins, on the mean, maximum daily, and maximum 30-day average Keowee HS generation flows observed during the winter. These analyses produced no evidence that generation at Keowee HS during the winter influenced spring forage fish abundance in Lake Keowee.

Multiple regression analyses were carried out relating spring forage fish lakewide numbers and spring forage fish densities in the Keowee River and Little River basins to combinations of variables for JPSS pumping flow, Keowee HS generation flow, lake level, temperature, chlorophyll, zooplankton, and predation. These analyses were intended to model the response of spring forage fish abundance variables to more than one independent variable, potentially detecting simultaneous influences of more than one parameter. Multiple regressions were limited to two independent variables due to the size of the data set. With one exception, none of these analyses produced models in which more than one variable contributed significantly to explaining variance in spring forage fish abundance. The exception was a model in which February density of total crustacean zooplankton and mean winter Keowee HS generation flow combined to explain 69% of variance in spring forage fish density in the Keowee River basin; however, the parameter estimates for both independent variables were positive in this analysis, indicating that higher Keowee generation flows had a positive impact on spring forage fish density. No negative impacts were detected.

Relationships of fall forage fish abundance to environmental and operational parameters – Fall forage fish total numbers lakewide and densities in basins of Lake Keowee were analyzed in relation to summer temperature and oxygen; lake level; chlorophyll; zooplankton; predation; JPSS pumping flow; and Keowee HS generation flow. Generally, fall forage fish abundance variables were analyzed in relation to conditions encountered during the spring forage fish spawning season (May-June), and during the period between spring spawning and fall forage fish sampling (May-October).

As in winter, thermal preferences of threadfin shad and blueback herring differ during the summer as well. Threadfin shad congregate in warm surface waters where temperatures exceed 30 C (Schael et al. 1995), while blueback herring tend to avoid temperatures above 25 C, preferring habitat with temperatures between 13 and 24 C where oxygen concentrations exceed 3 mg/L (Dennerline and Degan 1999; Goodrich 2002). Over the study period, maximum summer surface (0-5 m mean) temperatures ranged from 29.3 to 31.6 C at locations in the Little River basin and from 27.0 to 33.7 C at locations in the Keowee River basin. Substantial spatial variation was evident in summer maximum temperatures in the Keowee River basin due to the presence of the Oconee NS thermal discharge; fall forage fish abundance was analyzed in relation to maximum summer surface temperatures observed in the Little River basin, and in the lower, middle, and upper Keowee River basins separately. Fall forage fish density in the Little River basin exhibited a significant tendency to decline with increasing summer surface maximum temperatures; maximum temperature potentially explained 32% of variance in fall forage fish density in the Little River basin. This may reflect a tendency for blueback herring to seek cooler, well-oxygenated habitat in late summer, as examination of temperature and oxygen profiles indicated that preferred habitat for blueback herring frequently was not present in the Little River basin in late summer. However, fall forage fish density in the Keowee River basin was also observed to decline with maximum summer surface temperature as measured in the middle Keowee River basin; maximum temperature could potentially account for 41% of variance in fall forage fish density. Again, examination of temperature and oxygen profiles in the Keowee River basin indicated that preferred blueback herring habitat was restricted or not present in late summer in the Keowee River basin in some years. Regarding temperatures during the spring spawning season, although some authors have noted a relationship between temperature during spawning and forage fish survival, no evidence was detected in data for Lake Keowee that temperature during the May-June spawning period was related to fall forage fish abundance. Correlation analysis did, however, produce some evidence that growth rates of blueback herring as manifested in length at fall sampling were positively related to temperature during spawning. In addition, temperature may have played a role in the differential distribution of forage fish species. As previously described, the forage fish community in the vicinity of the ONS thermal discharge was dominated by threadfin shad, while that in the cooler waters of the upper Keowee River basin was dominated by blueback herring, consistent with the thermal preferences of these species.

Total numbers of forage fish in fall and fall forage fish densities in basins of Lake Keowee were analyzed in relation to mean lake level observed during spring forage fish spawning in May-June, and in relation to mean, lowest daily, and lowest 30-day average lake level observed between spring spawning and fall forage fish sampling (May-October). No significant relationships between lake level and fall forage fish abundance were detected in these analyses. In addition, multiple regression analyses were carried out to determine if lake level and either JPSS pumping flows or Keowee HS generation flows observed May-October exerted combined influences to affect fall forage fish densities in Lake Keowee. None of these models provided any evidence that lake level contributed significantly to explaining variance in fall forage fish abundance variables in Lake Keowee.

Fluctuation in lake level during the spring forage fish spawning season (May-June) was also investigated in relation to fall forage fish abundance on Lake Keowee, as spawning sites may be exposed or covered to an unacceptable depth by rapid changes in lake level. Fall forage fish total lakewide numbers and densities in basins were analyzed in relation to three measures of lake level variability observed May-June: range over which lake level varied during the season (maximum minus minimum lake level); maximum 3-day decline in lake level; and maximum 3-day increase in lake level. Based on data collected in years 1999-2012, no significant relationships were detected between fall forage fish abundance variables and any measure of lake level variability during the May-June spawning season.

Fall forage fish total lakewide numbers and densities in basins of Lake Keowee were analyzed in relation to several measures of lakewide and basinwide surface (0-10 m mean) chlorophyll concentration as an indicator of food availability. Mean annual chlorophyll concentration was utilized as a general measure of fertility. Mean chlorophyll concentrations observed during the May-June forage fish spawning season were analyzed in an attempt to detect any relationships of food availability during spawning on forage fish survival; because the spring peak in chlorophyll observed in the Little River basin was generally over by June, May chlorophyll concentrations were analyzed as well. Mean chlorophyll concentrations observed during the growing season (May-October) was also analyzed in relation to fall forage fish abundance variables. None of these analyses produced significant results, potentially indicating that factors in addition to food availability were significantly influencing fall forage fish abundance on Lake Keowee.

In a study of reservoirs on the Catawba and Wateree Rivers in North and South Carolina, regression analysis indicated that variation in spring chlorophyll concentrations could account for 63% of variance in fall forage fish densities (Rodriguez 2005). To determine whether Lake Keowee maintained fall forage fish populations similar to those of other regional reservoirs of similar fertility, average spring chlorophyll and fall forage fish densities for the Keowee River and Little River basins of Lake Keowee were superimposed on a plot of the Catawba-Wateree regression. These observations fell within the 95% confidence limits associated with the regression, indicating that over the forage fish study period, Lake Keowee maintained standing stocks of pelagic forage fish similar to those of other regional reservoirs of similar fertility.

As noted previously, zooplankton represent a major component of the diet of both threadfin shad and blueback herring. Survival of young-of-the-year forage fish is potentially influenced by food availability during the spawning period. To investigate whether fall forage fish abundance in Lake Keowee may have been influenced by zooplankton abundance during spawning, fall forage fish lakewide numbers and densities in basins were analyzed in relation to zooplankton densities (total crustacean zooplankton, rotifers, total zooplankton) in May. A significant tendency was detected for fall forage fish densities to increase with increasing densities of rotifers in May; May rotifer densities could potentially explain 44% of variance in fall forage fish lakewide numbers, based on linear regression analysis. Similarly, fall forage fish density in the Keowee River basin tended to increase with increasing densities of rotifers in May, with rotifer density accounting for 58% of variance in fall forage fish density. The preference of threadfin shad for rotifers, the overwintering of threadfin shad in the Keowee Rvier Basin near ONS, and the significance of the fall forage fish density to May rotifer density relationship is compelling. No relationship was detected in data for the Little River basin. Fall forage fish abundance variables were also analyzed in relation to zooplankton abundance during the period between spring spawning and fall sampling (mean of May and August zooplankton data). No significant relationships were detected between fall forage fish lakewide numbers or densities in basins of Lake Keowee and mean zooplankton densities measured in May and August, suggesting that factors in addition to food availability may have influenced fall forage fish density. In addition, positive relationships of zooplankton densities to fall forage fish abundance may have been obscured by forage fish predation pressure on zooplankton.

To investigate the potential influence of downward predation pressure on fall forage fish in Lake Keowee, fall forage fish lakewide numbers and densities in basins of Lake Keowee were regressed on littoral density and biomass of largemouth bass, spotted bass, and total black basses measured in spring shoreline electrofishing. Linear regression analysis detected a significant tendency for total fall forage fish numbers lakewide to decline with increasing lakewide mean littoral density of black basses; variation in mean lakewide littoral density of black basses potentially explained 85% of variance in fall forage fish numbers lakewide. Though the number of observations was small (N=6), the strength of the relationship suggests that predation was an important influence on fall forage fish numbers. Linear regression analysis also detected a significant tendency for littoral density of black basses to increase with increasing mean annual chlorophyll concentration, indicating that density of black basses was varying along a fertility gradient. In light of this, the fact that no relationship was detected between fall forage fish and chlorophyll may provide further evidence of the importance of top-down predation pressure in regulating fall forage fish abundance on Lake Keowee.

Pumping operations at JPSS have the potential to influence fall forage fish abundance on Lake Keowee through entrainment. Fall forage fish lakewide numbers and densities in basins were analyzed in relation to mean, maximum daily, and maximum 30-day average JPSS pumping flow observed during the period between spring forage fish spawning and fall sampling. Pumping variables were intended to quantify mean conditions, short-term high-flow events, and sustained periods of high flow. Both total numbers of forage fish lakewide in fall and fall forage fish density in the Keowee River basin exhibited significant tendencies to decline as maximum 30-day average pumping flow observed May-October increased. This variable could explain 35% of variance in total fall forage fish numbers lakewide on Lake Keowee, and 44% of variance in fall forage fish density in the Keowee River basin. The significance of both of these relationships, however, was dependent on the inclusion of data for one observation, for the year 2000. When data for the year 2000 were excluded from these analyses, the relationships were no longer close to significant, suggesting that these relationships were not robust. Additional data would be useful to determine whether these relationships reflect real processes. No relationships were detected between mean or maximum daily JPSS pumping flows observed May-October and any measure of fall forage fish abundance on Lake Keowee. Relationships of fall forage fish abundance were also investigated in relation to mean pumping flows at JPSS during the forage fish spawning season. No significant relationships were detected in these analyses.

Generating operations at Keowee HS have the potential to affect fall forage fish abundance in Lake Keowee through flushing of fish. Fall forage fish lakewide numbers and densities in zones were analyzed in relation to mean Keowee generation flows observed during spring forage fish spawning (May-June); and in relation to mean, maximum daily, and maximum 30-day average Keowee generation flows observed during the period between spring spawning and fall sampling (May-October). No relationships between any measure of Keowee HS generation flow and any measure of fall forage fish abundance on Lake Keowee were detected in correlation or linear regression analysis.

Multiple regression analyses were carried out relating fall forage fish lakewide numbers and fall forage fish densities in the Keowee River and Little River basins of Lake Keowee to combinations of variables for JPSS pumping flow, Keowee HS generation flow, lake level, temperature, chlorophyll, zooplankton, and predation. These analyses were intended to model the response of spring forage fish abundance variables to more than one independent variable, potentially detecting simultaneous influences of more than one parameter. Multiple regressions were limited to two independent variables without interaction due to the size of the data set. Generally, where models explaining significant variance in fall forage fish abundance variables were produced in multiple regression analysis, only one of the two independent variables contributed significantly to explaining variance in the dependent variable, thus providing little additional information beyond that obtained in linear regression analysis.

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Table 3-1. Morphometric characteristics of Lake Keowee, South Carolina (modified from Barwick et al. 2007).

Characteristics	Lake Keowee	Keowee River basin	Little River basin
Surface area, m^2	7.429×10^7	3.27×10^7	4.16×10^7
Volume, m^3	1.178×10^9	5.174×10^8	6.61×10^8
Mean depth, m	15.85	15.82	15.89
Maximum depth, m	42.9	42.9	40.3
Shoreline length, km	624.30	274.76	349.54
Shoreline development ratio[a]	20.43	13.6	15.3
Watershed area, km^2	1137.0[b]	712.1[b]	424.9

[a] Shoreline Development Ratio: length of shoreline divided by circumference of a circle with area equal to lake area

[b] Includes watershed of Lake Jocassee

Table 3-2. Total numbers of pelagic forage fish in Lake Keowee and densities of forage fish in the Keowee River basin and Little River basin of Lake Keowee in spring and fall, based on hydroacoustics sampling, spring 1999 -spring 2013.

	Spring	**Spring forage fish density, no/ha**		**Fall**	**Fall forage fish density, no/ha**	
Year	**Total fish**	**Keowee basin**	**Little basin**	**Total Fish**	**Keowee basin**	**Little basin**
1999	5,870,503	1057	652	6,404,049	1196	677
2000	-	-	-	16,936,544	1889	2807
2001	6,154,803	951	809	16,767,013	1593	3000
2002	1,604,306	160	281	11,455,066	1074	2061
2003	1,300,685	132	226	10,173,292	1126	1693
2004	1,001,416	148	137	10,217,527	1382	1500
2005	1,651,596	234	234	11,108,026	1556	1588
2006	1,777,632	280	230	7,064,120	1032	976
2007	1,289,760	220	153	4,711,497	593	727
2008	1,139,831	216	118	5,693,165	751	851
2009	569,752	128	43	6,460,819	1056	803
2010	399,809	75	42	2,080,344	304	287
2011	877,868	75	164	7,220,721	611	1351
2012	1,112,738	159	157	7,348,859	852	1192
2013	2,122,612	299	302	-	-	-
Mean	1,919,522	295	253	8,831,503	1,073	1,394
Median	1,295,223	188	195	7,284,790	1,065	1,272
Minimum	399,809	75	42	2,080,344	304	287
Maximum	6,154,803	1,057	809	16,936,544	1,889	3,000

Table 3-3. Percent which blueback herring and threadfin shad constituted of fall purse seine samples collected at two locations on the Keowee River basin and one location on the Little River basin of Lake Keowee, 1999-2012. Gizzard shad were present in hauls in the Lower Keowee River basin in 2009 but comprised less than 1% of fish collected. Samples in the Lower Keowee River basin were collected in the Oconee Nuclear Station discharge area; samples in the Upper Keowee River basin were collected in the Fall Creek Landing area; samples in the Upper Little River basin were collected in the Cane Creek area.

	Lower Keowee basin		**Upper Keowee basin**		**Upper Little basin**	
Year	**Blueback herring %**	**Threadfin shad %**	**Blueback herring %**	**Threadfin shad %**	**Blueback herring %**	**Threadfin shad %**
1999	0.2	99.8	-	-	-	-
2000	1.8	98.2	-	-	-	-
2001	0.0	100.0	-	-	-	-
2002	0.6	99.4	-	-	-	-
2003	-	-	94.2	5.8	-	-
2004	-	-	78.9	21.1	-	-
2005	-	-	67.9	32.1	-	-
2006	-	-	63.2	36.8	-	-
2007	11.0	89.0	75.9	24.2	-	-
2008	7.6	92.4	60.6	39.5	-	-
2009	4.6	94.8	82.4	17.6	-	-
2010	54.7	45.3	97.7	2.3	-	-
2011	45.7	54.3	98.7	1.3	81.9	18.1
2012	4.3	95.7	96.6	3.4	59.4	40.6
Mean	**13.1**	**86.9**	**81.6**	**18.4**	**70.6**	**29.4**
Median	4.5	95.3	80.7	19.3	-	-
Minimum	0.0	45.3	60.6	1.3	59.4	18.1
Maximum	54.7	100.0	98.7	39.5	81.9	40.6

Table 3-4. Median lengths of young-of-the-year blueback herring and percent which YOY blueback herring constituted of the total population, based on fall purse seine samples in three areas of Lake Keowee. Missing data indicate that zone was not sampled, or that too few fish were collected to characterize age and growth.

	BLUEBACK HERRING					
	Median length YOY fish, mm			Percent YOY of total population		
Year	**Lower Keowee River basin**	**Upper Keowee River basin**	**Upper Little River basin**	**Lower Keowee River basin**	**Upper Keowee River basin**	**Upper Little River basin**
1999	-	-	-	-	-	-
2000	-	-	-	-	-	-
2001	-	-	-	-	-	-
2002	-	-	-	-	-	-
2003	-	70	-	-	98.7	-
2004	-	76	-	-	94.6	-
2005	-	64	-	-	100.0	-
2006	-	70	-	-	98.4	-
2007	62	72	-	94.6	100.0	-
2008	65	68.5	-	92.1	98.1	-
2009	61.5	71	-	100.0	100.0	-
2010	75	80	-	89.3	90.5	-
2011	64	74	69	100.0	99.6	96.1
2012	63.5	78	75	100.0	98.5	96.4
Mean	**65.2**	**72.4**	**72.0**	**96.0**	**97.8**	**96.3**
Minimum	61.5	64	69	89.3	90.5	96.1
Maximum	75	80	75	100.0	100.0	96.4

Table 3-5. Median lengths of young-of-the-year threadfin shad and percent which YOY threadfin shad constituted of the total population, based on fall purse seine samples in three areas of Lake Keowee. Missing data indicate that zone was not sampled, or that too few fish were collected to characterize age and growth.

	THREADFIN SHAD					
	Median length YOY fish, mm			**Percent YOY of total population**		
Year	**Lower Keowee River basin**	**Upper Keowee River basin**	**Upper Little River basin**	**Lower Keowee River basin**	**Upper Keowee River basin**	**Upper Little River basin**
1999	56	-	-	99.2	-	-
2000	55	-	-	95.5	-	-
2001	51	-	-	99.0	-	-
2002	57	-	-	92.1	-	-
2003	-	53.5	-	-	100.0	-
2004	-	60	-	-	97.7	-
2005	-	49	-	-	98.6	-
2006	-	59	-	-	100.0	-
2007	54	55	-	98.7	94.1	-
2008	55	57	-	97.0	100.0	-
2009	57	55	-	95.2	98.1	-
2010	75	79	-	100.0	100.0	-
2011	57	-	55	100.0	-	100.0
2012	70	-	65	100.0	-	100.0
Mean	**58.7**	**58.4**	**60.0**	**97.6**	**98.6**	**100.0**
Minimum	51	49	55	92.1	94.1	100.0
Maximum	75	79	65	100.0	100.0	100.0

Table 3-6. Minimum annual surface (0-5 m mean) temperature at locations on Lake Keowee, 1999-2013.

	Minimum winter temperature, C							
Year	**Loc500**	**Loc501**	**Loc502**	**Loc508**	**Loc504**	**Loc505**	**Loc506**	**Loc507**
1999	11.0	11.3	13.7	17.1	16.5	15.4	14.6	11.2
2000	11.3	11.5	12.8	15.2	16.1	14.5	13.9	11.5
2001	9.0	10.1	11.3	13.4	14.5	13.5	13.0	10.8
2002	11.3	11.8	13.9	-	-	16.2	15.1	12.6
2003	9.2	9.4	11.3	14.8	15.9	13.8	13.0	9.6
2004	-	-	-	-	-	-	-	-
2005	11.7	12.0	13.2	15.6	15.9	15.0	-	-
2006	10.7	11.3	12.8	16.4	17.7	15.3	-	11.1
2007	9.4	10.0	11.6	13.3	13.9	12.4	12.3	11.0
2008	-	-	13.0	16.4	17.0	15.2	-	-
2009	9.9	10.4	12.5	15.5	15.8	14.3	13.6	10.2
2010	8.0	8.2	9.9	14.6	14.3	12.2	11.3	9.0
2011	9.6	9.9	11.2	15.0	-	12.9	12.0	9.3
2012	11.9	12.3	14.0	17.3	18.5	16.2	15.2	10.5
2013	10.9	11.3	12.9	15.7	-	14.8	-	-
Mean	**10.3**	**10.7**	**12.5**	**15.4**	**16.0**	**14.4**	**13.4**	**10.6**
Median	10.7	11.3	12.8	15.5	15.9	14.7	13.3	10.8
Minimum	**8.0**	**8.2**	**9.9**	**13.3**	**13.9**	**12.2**	**11.3**	**9.0**
Maximum	11.9	12.3	14.0	17.3	18.5	16.2	15.2	12.6

Table 3-7. Maximum annual surface (0-5 m mean) temperature at locations on Lake Keowee, 1999-2013.

	Maximum summer temperature, C							
Year	**Loc500**	**Loc501**	**Loc502**	**Loc508**	**Loc504**	**Loc505**	**Loc506**	**Loc507**
1999	31.0	31.2	30.9	31.6	31.8	31.0	30.9	28.2
2000	29.9	29.8	29.9	32.6	32.3	31.0	30.6	29.1
2001	29.6	29.9	30.4	32.8	32.3	31.6	31.4	29.2
2002	30.1	30.2	30.9	33.7	33.4	32.3	31.8	29.4
2003	29.4	29.3	29.6	31.4	30.9	30.6	30.5	28.2
2004	29.7	29.8	29.5	31.5	31.4	30.4	29.7	27.0
2005	30.8	30.5	30.2	31.7	31.2	31.0	-	30.1
2006	29.8	29.8	30.5	32.9	32.4	31.2	30.8	27.6
2007	31.2	31.2	31.6	33.0	32.6	32.4	32.3	28.0
2008	29.5	29.8	30.7	-	33.6	32.1	-	-
2009	29.9	30.1	30.7	32.7	32.4	32.1	31.7	27.2
2010	30.8	31.2	30.8	33.1	32.9	32.2	31.9	29.2
2011	31.1	30.8	31.0	32.9	32.1	32.0	31.6	27.2
2012	30.4	30.4	30.4	33.5	32.9	31.5	31.1	28.4
Mean	**30.2**	**30.3**	**30.5**	**32.6**	**32.3**	**31.5**	**31.2**	**28.4**
Median	30.0	30.1	30.6	32.8	32.3	31.6	31.3	28.2
Minimum	29.4	29.3	29.5	31.4	30.9	30.4	29.7	27.0
Maximum	31.2	31.2	31.6	33.7	33.6	32.4	32.3	30.1

Table 3-8. Annual summary statistics for daily lake level on Lake Keowee, 1999-2012. Range is maximum minus minimum daily lake level.

	Lake level, meters below full pool				
Year	**Mean**	**Median**	**Minimum**	**Maximum**	**Range, m**
1999	0.765	0.631	0.119	1.506	1.387
2000	1.352	1.341	0.244	1.908	1.664
2001	1.666	1.707	1.189	1.981	0.792
2002	1.635	1.646	1.158	1.868	0.710
2003	0.562	0.418	0.030	1.829	1.799
2004	0.564	0.506	0.119	1.646	1.527
2005	0.748	0.515	0.024	2.234	2.210
2006	1.005	0.893	0.158	2.268	2.110
2007	1.007	0.936	0.131	2.246	2.115
2008	1.388	1.353	0.756	2.234	1.478
2009	1.109	1.207	0.186	1.573	1.387
2010	0.700	0.448	0.107	1.618	1.511
2011	1.033	1.106	0.308	1.530	1.222
2012	1.251	1.262	0.707	1.564	0.857
Mean	**1.056**	**0.998**	**0.374**	**1.858**	**1.484**

Table 3-9. Summary statistics for Lake Keowee lake level, expressed as meters below full pool. All values were calculated based on daily lake level measured at midnight. Range of May-June lake levels is maximum daily lake level minus minimum daily lake level.

	December-February lake level			May-June lake level		May-October lake level		
Year	**Mean**	**Lowest daily**	**Lowest 30-day average**	**Mean**	**Range, m**	**Mean**	**Lowest daily**	**Lowest 30-day average**
1999	0.58	1.37	0.75	0.43	0.89	0.77	1.39	1.30
2000	1.18	1.51	1.32	1.36	0.34	1.38	1.83	1.54
2001	1.78	1.95	1.83	1.55	0.64	1.59	1.89	1.72
2002	1.74	1.88	1.77	1.64	0.46	1.62	1.86	1.66
2003	1.48	1.83	1.60	0.17	0.31	0.30	0.83	0.64
2004	0.47	0.71	0.53	0.43	0.78	0.67	1.65	1.37
2005	0.76	1.37	1.03	0.28	0.69	0.59	2.22	1.91
2006	0.74	1.38	1.12	0.69	1.10	1.16	2.26	2.12
2007	0.91	1.39	1.19	0.86	1.19	1.04	2.19	1.46
2008	1.38	2.15	1.43	1.22	0.57	1.34	2.23	1.65
2009	1.29	1.57	1.34	1.24	0.88	1.20	1.52	1.30
2010	0.38	0.64	0.44	0.27	0.42	0.79	1.62	1.40
2011	1.04	1.41	1.23	0.84	1.09	1.10	1.53	1.34
2012	1.25	1.56	1.28	1.28	0.53	1.26	1.51	1.34
2013	1.16	1.53	1.22	-	-	-	-	-
Mean	1.07	1.48	1.21	0.88	0.70	1.06	1.75	1.48
Median	1.16	1.51	1.23	0.85	0.66	1.13	1.74	1.43
Minimum	0.38	0.64	0.44	0.17	0.31	0.30	0.83	0.64
Maximum	1.78	2.15	1.83	1.64	1.19	1.62	2.26	2.12

Table 3-10. Summary data for basinwide surface (0 - 10 m) chlorophyll concentrations (mg/m^3), based on chlorophyll measured monthly in the Keowee River and Little River basins of Lake Keowee. Basinwide mean concentrations were calculated based on data collected at Locations 500 and 502 (Little River basin) and Locations 504 and 505 (Keowee River basin).

	Mean annual chlorophyll		**Mean Dec-Feb chlorophyll**		**Mean May-Jun chlorophyll**		**Mean May-Oct chlorophyll**	
Year	**Keowee basin**	**Little basin**	**Keowee basin**	**Little basin**	**Keowee basin**	**Little basin**	**Keowee basin**	**Little basin**
1999	2.43	2.85	2.87	3.62	1.55	2.10	2.51	2.65
2000	2.17	2.35	1.94	2.55	1.69	1.57	2.43	2.38
2001	2.49	2.51	1.72	2.05	2.05	2.10	2.86	2.59
2002	2.02	2.22	2.07	2.80	1.55	2.01	2.24	2.23
2003	1.70	2.22	1.00	1.33	1.83	2.24	2.30	2.86
2004	1.67	2.11	1.50	1.81	1.86	2.40	1.74	2.03
2005	1.60	1.97	1.26	1.59	1.20	1.71	1.86	2.31
2006	1.31	1.87	1.34	1.63	1.06	1.62	1.53	1.89
2007	1.62	1.93	1.00	1.51	1.23	1.98	2.00	2.17
2008	1.73	2.16	1.60	1.87	1.45	2.21	1.89	2.25
2009	1.94	2.14	1.14	1.53	1.56	2.49	2.54	2.65
2010	2.03	2.54	1.33	1.61	1.99	2.59	2.52	2.89
2011	1.70	2.30	1.00	1.40	1.70	2.45	2.13	2.55
2012	2.14	2.64	1.80	2.68	1.98	2.32	2.56	2.89
Mean	**1.89**	**2.27**	**1.54**	**2.00**	**1.62**	**2.13**	**2.22**	**2.45**
Median	1.83	2.22	1.42	1.72	1.63	2.16	2.27	2.46
Minimum	1.31	1.87	1.00	1.33	1.06	1.57	1.53	1.89
Maximum	2.49	2.85	2.87	3.62	2.05	2.59	2.86	2.89

Table 3-11. Mean annual densities of major taxonomic groups of zooplankton, organisms/m^3, based on quarterly data collected at Location 508 in the Keowee River basin and Location 502 in the Little River basin of Lake Keowee, 1999-2012.

	Keowee River basin				**Little River basin**			
Year	**Copepoda**	**Cladocera**	**Rotifera**	**Total**	**Copepoda**	**Cladocera**	**Rotifera**	**Total**
1999	9535	11862	39630	61027	14790	7334	97525	119648
2000	14650	9669	20726	45046	21330	14980	36967	73277
2001	9733	7764	23124	40621	15402	8075	36039	59516
2002	13752	7531	14925	36209	15546	11115	16296	42957
2003	9981	6843	14340	31163	17503	9726	24366	51594
2004	8999	3967	11363	24329	12390	7380	15974	35744
2005	8906	7498	11052	27456	11966	8071	21731	41768
2006	12153	7306	18240	37698	22078	7863	25419	55360
2007	14988	7902	12858	35748	14958	8312	19578	42847
2008	8158	6610	7046	21814	13841	9519	10575	33935
2009	11239	7160	7394	25793	11065	4921	8344	24331
2010	8798	9068	9580	27446	9890	6110	10439	26440
2011	9828	4921	11757	26505	8606	4390	23155	36151
2012	8031	8290	10511	26832	8747	10167	19898	38812
Mean	**10625**	**7599**	**15182**	**33406**	**14151**	**8426**	**26165**	**48741**
Median	9780	7515	12307	29309	14316	8073	20814	42308
Minimum	8031	3967	7046	21814	8606	4390	8344	24331
Maximum	14988	11862	39630	61027	22078	14980	97525	119648

Table 3-12. Zooplankton taxa commonly observed on Lake Keowee, 2008-2012. Listed taxa comprised at least 15% of total zooplankton density at at least one location during February, May, August, or November.

Taxon	February	May	August	November
Copepoda	nauplii calanoid copepodid cyclopoid copepodid *Tropocyclops prasinus*	calanoid copepodid nauplii cyclopoid copepodid	cyclopoid copepodid nauplii calanoid copepodid *Tropocyclops prasinus*	nauplii *Tropocyclops prasinus* cyclopoid copepodid calanoid copepodid
Cladocera	*Bosmina longirostris*	*Bosmina longirostris* *Diaphanosoma brachyurum* *Holopedium amazonicum*	*Bosminopsis deitersi* *Bosmina longirostris* *Diaphanosoma brachyurum*	*Bosmina longirostris*
Rotifera	*Keratella taurocephala* *Keratella cochlearis* *Sinantherina socialis* *Collotheca* spp. *Collotheca balatonica* *Polyarthra vulgaris* *Polyarthra* spp. *Conochilus unicornis*	*Keratella taurocephala* *Keratella cochlearis* *Keratella* spp. *Ptygura libra* *Conochilus unicornis*	*Conochiloides dossuarius* *Collotheca mutabilis* *Ptygura libra* *Trichocerca cylindrica* *Conochilus unicornis* *Keratella taurocephala* *Collotheca balatonica* *Collotheca* spp. *Keratella cochlearis*	*Conochilus unicornis* *Ptygura libra* *Collotheca balatonica* *Keratella cochlearis* *Keratella taurocephala* *Keratella* spp. *Trichocerca cylindrica*

Table 3-13. Densities of copepoda, cladocera, and rotifera observed at locations on Lake Keowee, as sampled in 20-m-to-surface net tows carried out quarterly in 2012.

			Organisms/m^3			
Year	**Month**	**Location**	**Copepoda**	**Cladocera**	**Rotifera**	**Total zooplankton**
2012	February	500	4264	4519	63766	72550
2012	May		13437	4008	30997	48442
2012	August		26187	12869	64315	103372
2012	November		23756	10541	9338	43634
	Annual mean		**16911**	**7984**	**42104**	**67000**
2012	February	502	4847	5214	16233	26295
2012	May		12541	15781	26662	54984
2012	August		10811	15467	34067	60345
2012	November		6790	4207	2628	13625
	Annual mean		**8747**	**10167**	**19898**	**38812**
2012	February	505	4740	11603	18577	34920
2012	May		13103	15032	28639	56773
2012	August		9021	11567	18264	38853
2012	November		13491	3500	8140	25131
	Annual mean		**10089**	**10426**	**18405**	**38919**
2012	February	507	3375	3535	6089	12999
2012	May		30187	7666	99581	137433
2012	August		23754	21439	43236	88430
2012	November		16833	6832	39819	63484
	Annual mean		**18537**	**9868**	**47181**	**75587**
2012	February	508	3329	4961	7992	16281
2012	May		13120	9235	14308	36663
2012	August		10922	13674	12084	36680
2012	November		4752	5291	7661	17704
	Annual mean		**8031**	**8290**	**10511**	**26832**

Table 3-14. Littoral density (fish/km) of species likely to prey on blueback herring and threadfin shad in Lake Keowee, based on electrofishing carried out 1999-2011 on the upper Keowee River basin (Highway 11 area); the lower Keowee River basin (Oconee Nuclear Station discharge area); and the Little River basin.

		Littoral density, fish/km						
Basin	**Year**	**Largemouth bass**	**Redeye bass**	**Spotted bass**	**Smallmouth bass**	**Hybrid black basses**	**Total black basses**	**Black crappie**
Keowee, upper	1999	13.3	7.7	4.7	2.3	0	28.0	0
Keowee, upper	2002	11.3	2.3	6.3	0	0	20.0	0
Keowee, upper	2005	4.0	1.0	12.3	0	0	17.3	0
Keowee, upper	2008	12.0	0	10.0	1.0	0.7	23.7	0
Keowee, upper	2010	7.7	0	20.3	10.0	1.3	39.3	0
Keowee, upper	2011	9.7	2.7	8.0	0.3	2.7	23.3	0
	Mean	**9.7**	**2.3**	**10.3**	**2.3**	**0.8**	**25.3**	**0**
Keowee, lower	1999	4.7	3.3	5.0	0.3	0	13.3	0
Keowee, lower	2002	3.0	0.3	7.3	0	0	10.7	0
Keowee, lower	2005	1.3	0	9.7	0	0	11.0	0.3
Keowee, lower	2008	6.0	0	5.7	0	0	11.7	0
Keowee, lower	2010	4.7	0	14.0	0	0	18.7	0
Keowee, lower	2011	4.0	0	9.3	0	0	13.3	0.3
	Mean	**3.9**	**0.6**	**8.5**	**0.1**	**0**	**13.1**	**0.1**
Little	1999	10.3	5.0	21.0	0	0	36.3	1.7
Little	2002	2.3	0	8.0	0.3	0	10.7	0
Little	2005	5.7	0	20.3	0	0	26.0	0
Little	2008	5.0	0	24.7	0	0	29.7	0
Little	2010	1.0	0.7	40.7	0	0	42.3	0.3
Little	2011	6.0	0	29.0	0	0	35.0	0.7
	Mean	**5.1**	**0.9**	**23.9**	**0.1**	**0**	**30.0**	**0.4**

Table 3-15. Littoral biomass (kg/km) of species likely to prey on blueback herring and threadfin shad in Lake Keowee, based on electrofishing carried out 1999-2011 on the upper Keowee River basin (Highway 11 area); the lower Keowee River basin (Oconee Nuclear Station discharge area); and the Little River basin.

		Littoral biomass, kg/km						
Basin	**Year**	**Largemouth bass**	**Redeye bass**	**Spotted bass**	**Smallmouth bass**	**Hybrid black basses**	**Total black basses**	**Black crappie**
Keowee, upper	1999	3.085	1.557	0.821	0.118	0	5.581	0
Keowee, upper	2002	3.158	0.608	0.183	0	0	3.949	0
Keowee, upper	2005	0.912	0.148	1.036	0	0	2.096	0
Keowee, upper	2008	2.536	0	1.323	0.037	0.030	3.927	0
Keowee, upper	2010	2.680	0	2.037	0.334	0.309	5.360	0
Keowee, upper	2011	0.935	0.256	1.042	0.043	0.088	2.364	0
	Mean	**2.218**	**0.428**	**1.074**	**0.089**	**0.071**	**3.880**	**0**
Keowee, lower	1999	1.962	0.187	0.477	0.014	0	2.641	0
Keowee, lower	2002	1.852	0.030	1.146	0	0	3.027	0
Keowee, lower	2005	0.314	0	0.562	0	0	0.876	0.041
Keowee, lower	2008	2.919	0	0.274	0	0	3.193	0
Keowee, lower	2010	0.817	0	1.346	0	0	2.162	0
Keowee, lower	2011	1.355	0	1.648	0	0	3.002	0.021
	Mean	**1.536**	**0.036**	**0.909**	**0.002**	**0**	**2.484**	**0.010**
Little	1999	3.968	0.379	1.642	0	0	5.990	0.445
Little	2002	2.270	0	1.097	0.039	0	3.406	0
Little	2005	2.823	0	4.429	0	0	7.252	0
Little	2008	2.538	0	3.518	0	0	6.056	0
Little	2010	0.194	0.021	3.822	0	0	4.037	0.095
Little	2011	3.654	0	3.294	0	0	6.949	0.325
	Mean	**2.575**	**0.067**	**2.967**	**0.007**	**0**	**5.615**	**0.144**

Table 3-16. Summary statistics for Jocassee Pumped Storage Station pumping flows observed 1999 through February 2013. All values are calculated based on daily mean pumping flows, m^3/sec.

	JPSS pumping flows, m^3/sec						
		December-February			May-October		
Year	**Mean annual**	**Mean**	**Maximum daily**	**Maximum 30-day average**	**Mean**	**Maximum daily**	**Maximum 30-day average**
1999	89.78	66.10	234.56	81.92	109.16	292.12	202.50
2000	97.56	72.95	280.05	115.07	100.12	251.43	128.45
2001	118.08	39.70	189.02	63.29	175.13	390.86	228.06
2002	149.20	65.54	207.76	74.99	189.64	352.97	235.51
2003	159.40	175.82	400.38	222.02	159.53	332.63	216.26
2004	148.64	142.74	313.49	175.38	171.47	376.03	237.55
2005	159.45	123.53	366.37	170.45	184.22	347.10	231.81
2006	138.76	120.04	316.69	129.21	166.98	362.90	249.18
2007	135.02	68.65	203.40	90.80	167.03	364.24	240.86
2008	159.53	120.76	307.92	157.81	194.17	395.64	252.67
2009	132.90	123.68	271.55	138.20	163.59	328.86	232.66
2010	125.75	102.52	267.43	114.24	168.52	342.34	249.46
2011	117.94	54.39	174.23	58.40	175.54	372.16	256.74
2012	124.55	81.99	275.32	98.68	155.17	345.40	210.98
2013	-	91.39	394.37	120.46	-	-	-
Mean	**132.61**	**96.65**	**280.17**	**120.73**	**162.88**	**346.76**	**226.62**
Median	133.96	91.39	275.32	115.07	167.78	350.03	234.08
Minimum	89.78	39.70	174.23	58.40	100.12	251.43	128.45
Maximum	159.53	175.82	400.38	222.02	194.17	395.64	256.74

Table 3-17. Summary statistics for generation flow at Keowee Hydroelectric Station, 1999-2013. All values were calculated based on daily mean generation flows. December-February data are associated with the year for January-February data. Maximum 30-day average is the maximum 30-day moving average observed December 30 through the end of February (see Methods).

		December-February generation flow, m^3/sec			May-October generation flow, m^3/sec		
Year	**Mean annual flow, m^3/sec**	**Mean**	**Maximum daily**	**Maximum 30-day average**	**Mean**	**Maximum daily**	**Maximum 30-day average**
1999	18.363	26.870	230.654	58.339	17.358	195.589	36.998
2000	13.384	10.288	124.526	18.235	17.307	218.788	31.838
2001	8.459	10.045	232.121	17.937	9.652	163.858	27.736
2002	13.614	2.871	97.461	8.613	8.234	164.124	27.194
2003	26.915	6.894	192.123	16.301	37.854	334.248	63.210
2004	27.484	27.883	213.588	35.429	26.396	171.324	56.899
2005	31.647	37.017	194.923	94.213	46.541	326.782	79.485
2006	19.579	17.486	175.324	29.665	23.970	206.522	38.398
2007	12.219	12.524	136.126	19.537	19.257	205.989	45.286
2008	9.199	13.481	145.059	21.545	2.864	90.928	9.973
2009	18.460	12.353	189.323	30.816	16.859	179.190	34.354
2010	27.241	58.093	357.714	79.076	23.525	353.581	41.642
2011	19.158	16.270	142.925	23.505	17.364	157.191	40.949
2012	15.720	23.663	131.993	30.012	16.295	178.657	26.727
2013	-	32.287	266.785	61.037	-	-	-
Mean	18.674	20.535	188.710	36.284	20.248	210.484	40.049
Median	18.412	16.270	189.323	29.665	17.361	187.390	37.698
Minimum	8.459	2.871	97.461	8.613	2.864	90.928	9.973
Maximum	31.647	58.093	357.714	94.213	46.541	353.581	79.485

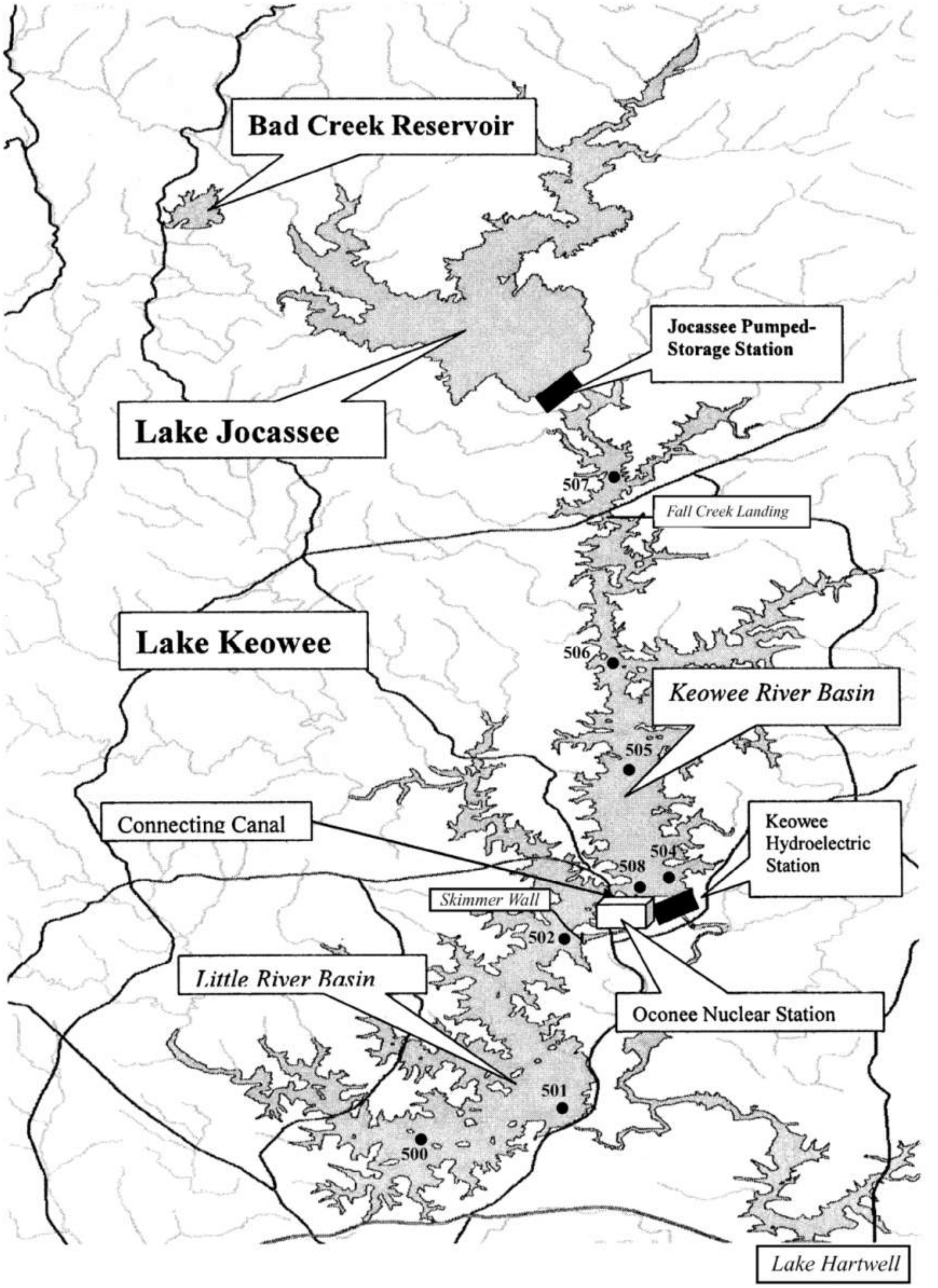


Figure 3-1. Lake Keowee, South Carolina. Figure modified from Barwick et al. (2007).

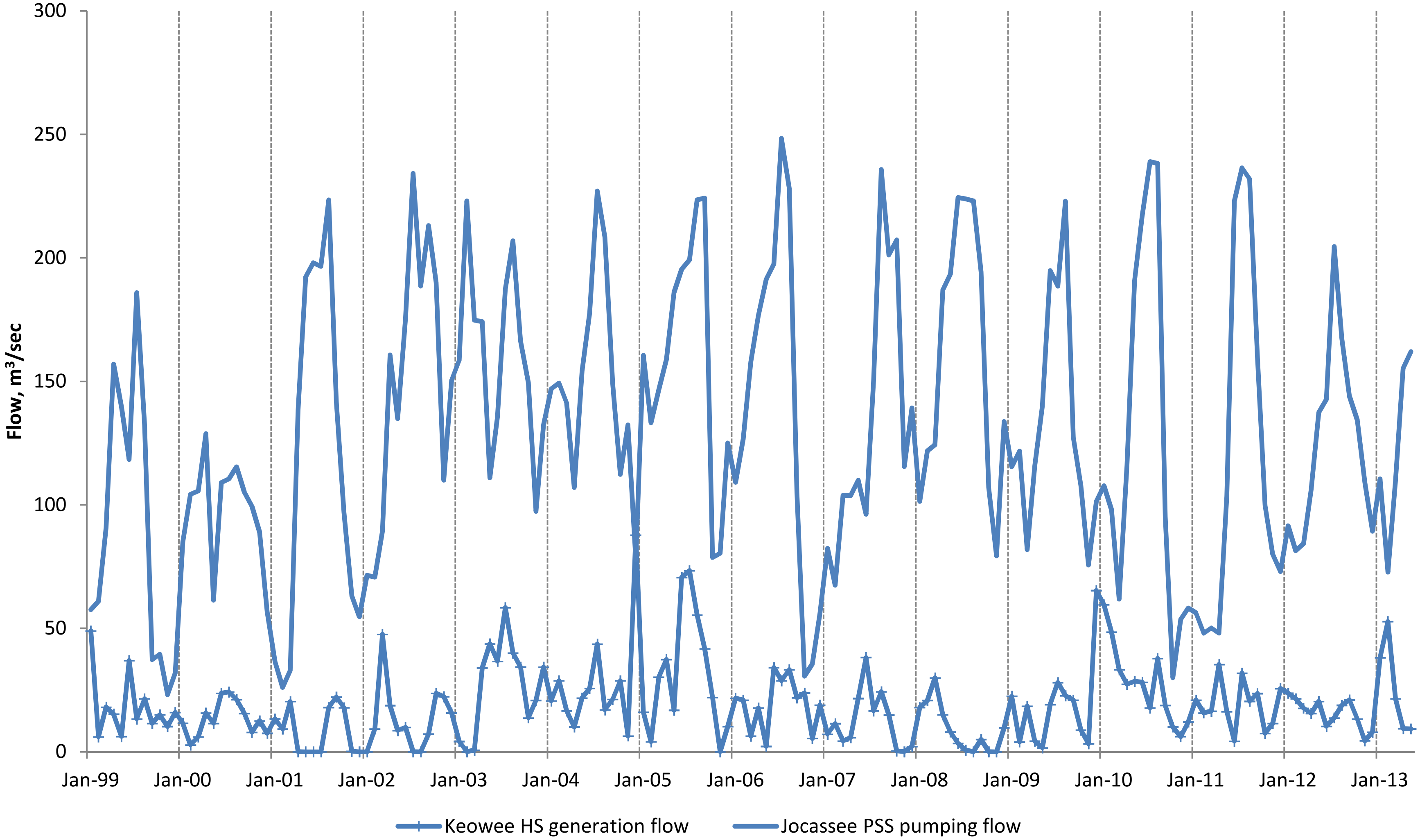


Figure 3-2. Monthly mean generation flow at Keowee Hydroelectric Station and monthly mean pumping flow at Jocassee Pumped Storage Station, January 1999 through May 2013.

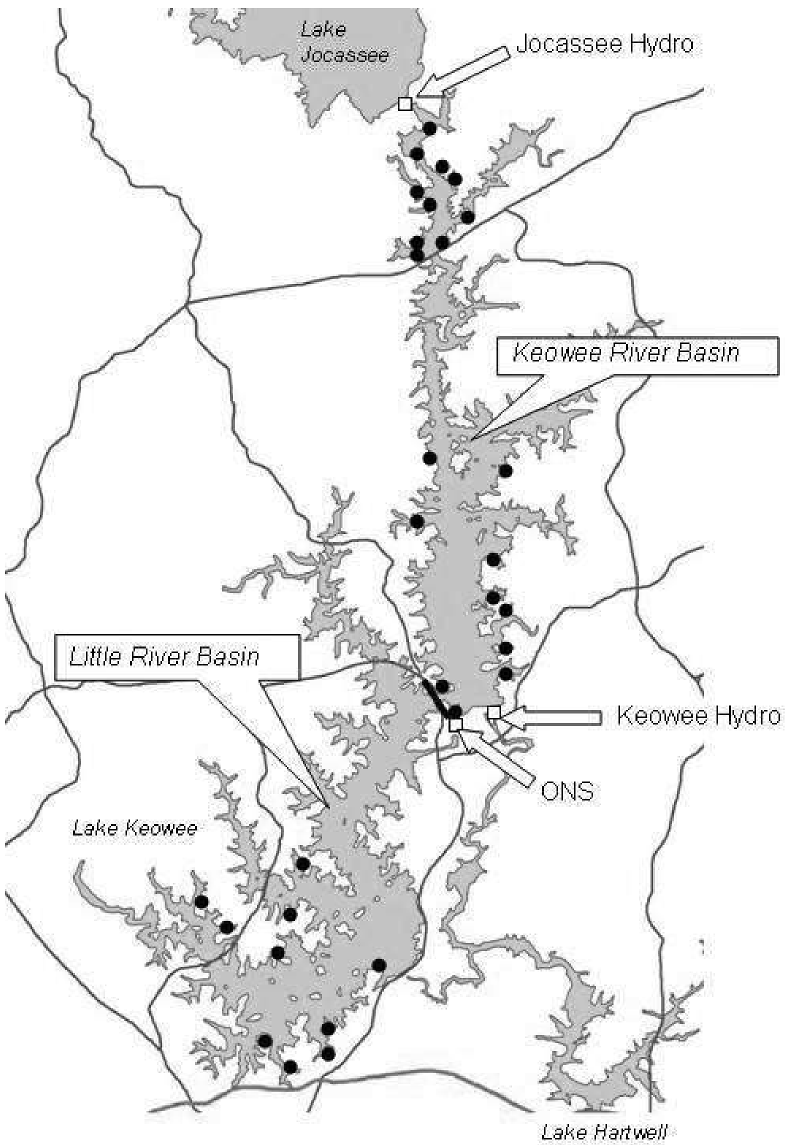


Figure 3-3. Lake Keowee, South Carolina, with electrofishing transects indicated (figure courtesy D.J. Coughlan, Duke Energy).

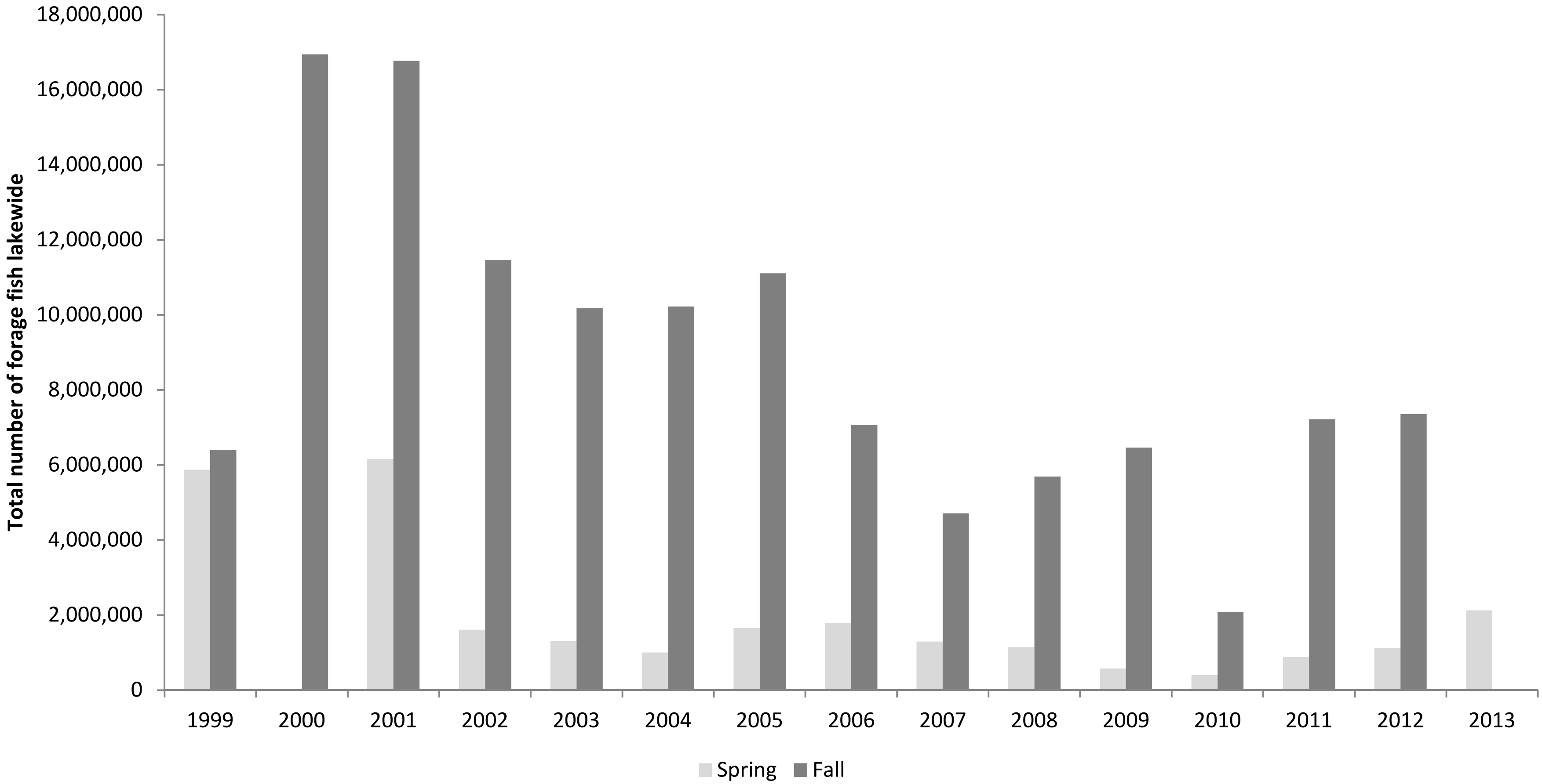


Figure 3-4. Total number of forage fish lakewide in spring and fall on Lake Keowee, spring 1999 through spring 2013, based on hydroacoustics sampling.

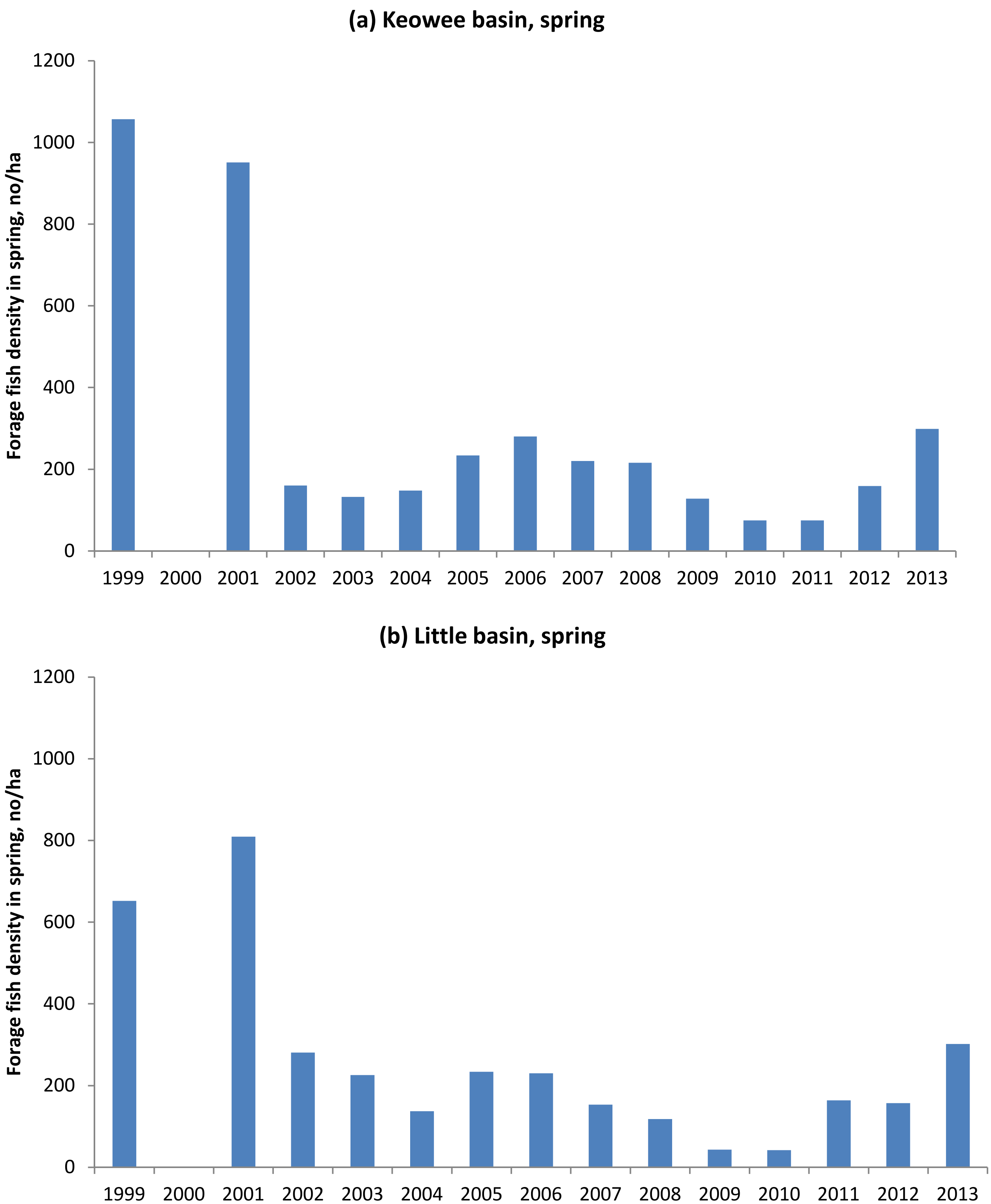


Figure 3-5. Spring forage fish densities on the (a) Keowee River basin and (b) Little River basin of Lake Keowee, 1999-2013, based on hydroacoustics sampling.

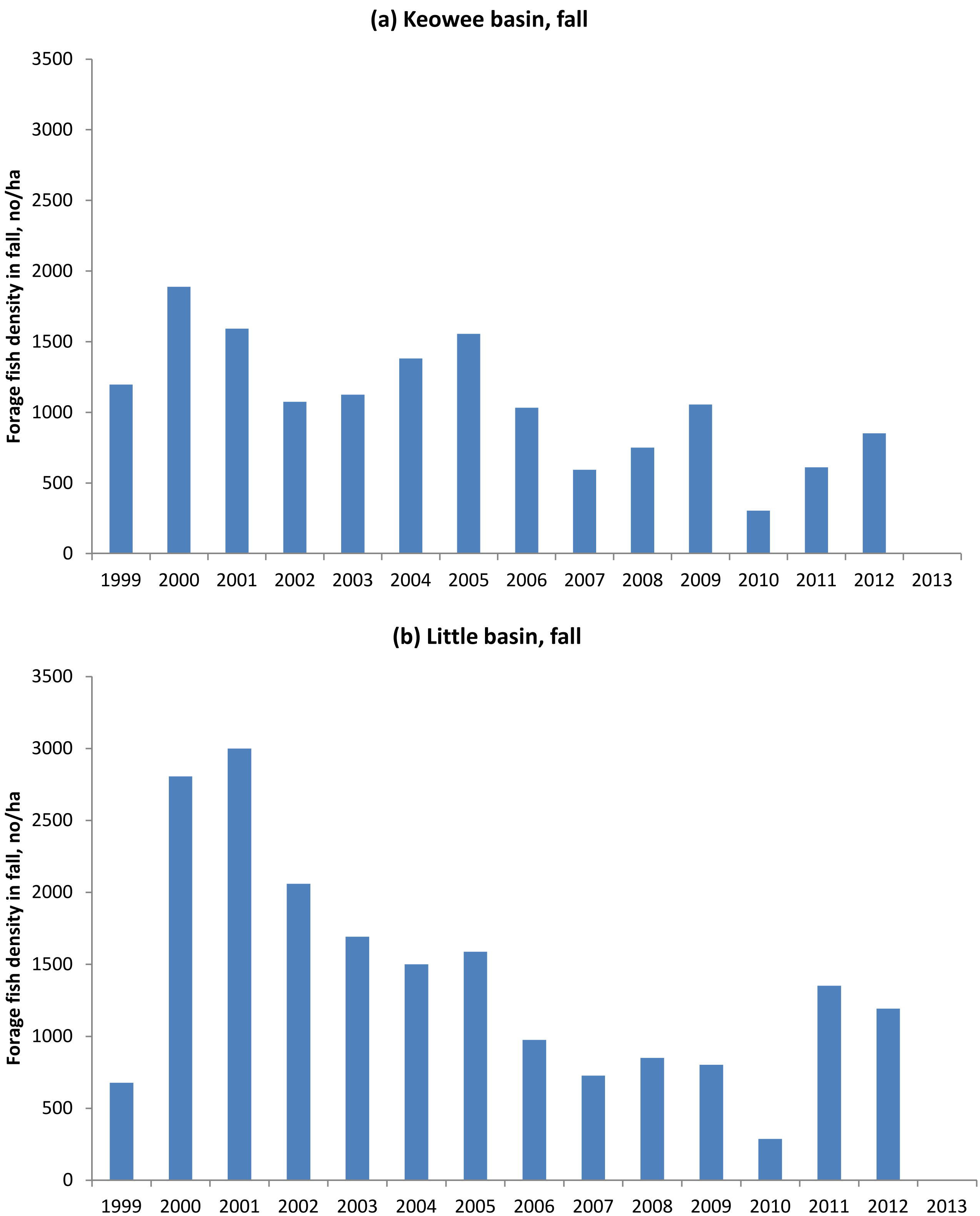
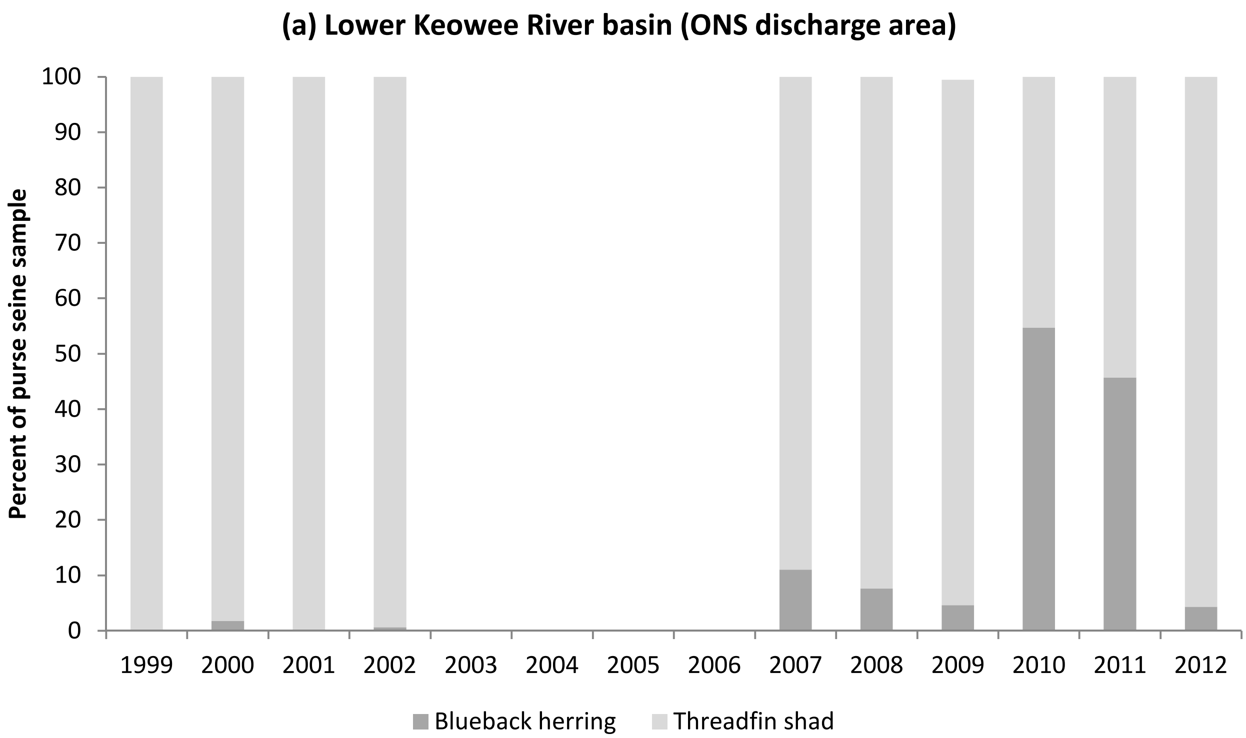


Figure 3-6. Fall forage fish densities on the (a) Keowee River basin and (b) Little River basin of Lake Keowee, 1999-2013, based on hydroacoustics sampling.



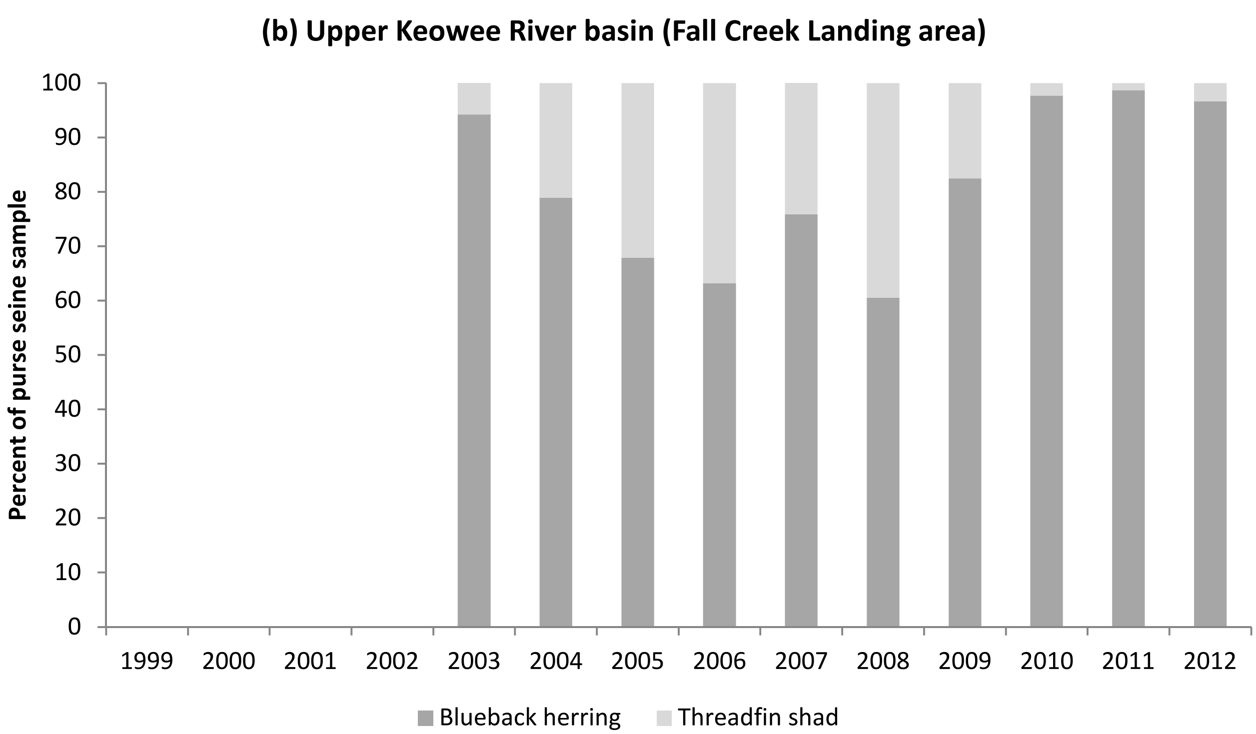


Figure 3-7 (page 1 of 2). Percent of pelagic forage fish community consisting of blueback herring and threadfin shad in the (a) lower Keowee River basin, (b) upper Keowee River basin, and (c) upper Little River basin, based on fall purse seine sampling 1999-2012.

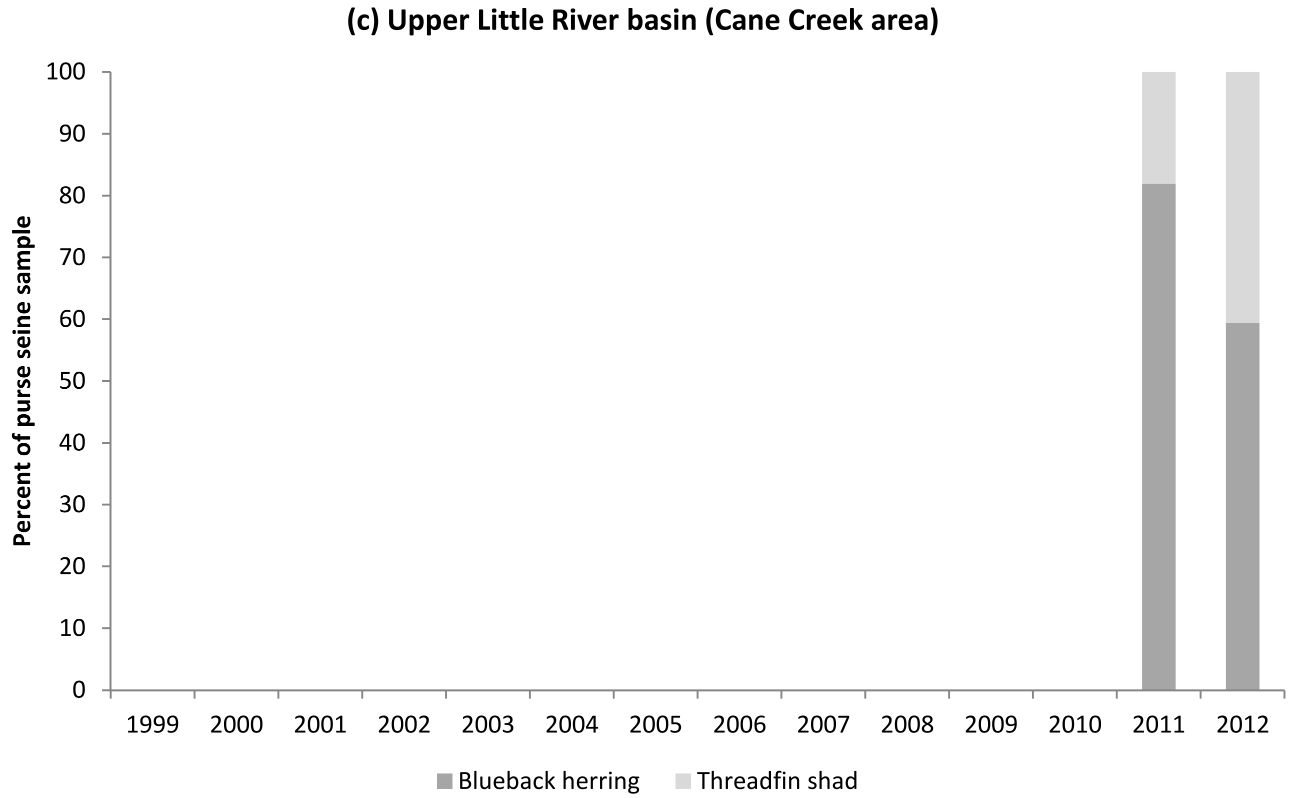


Figure 3-7 (page 2 of 2). Percent of pelagic forage fish community consisting of blueback herring and threadfin shad in the (a) lower Keowee River basin, (b) upper Keowee River basin, and (c) upper Little River basin, based on fall purse seine sampling 1999-2012.

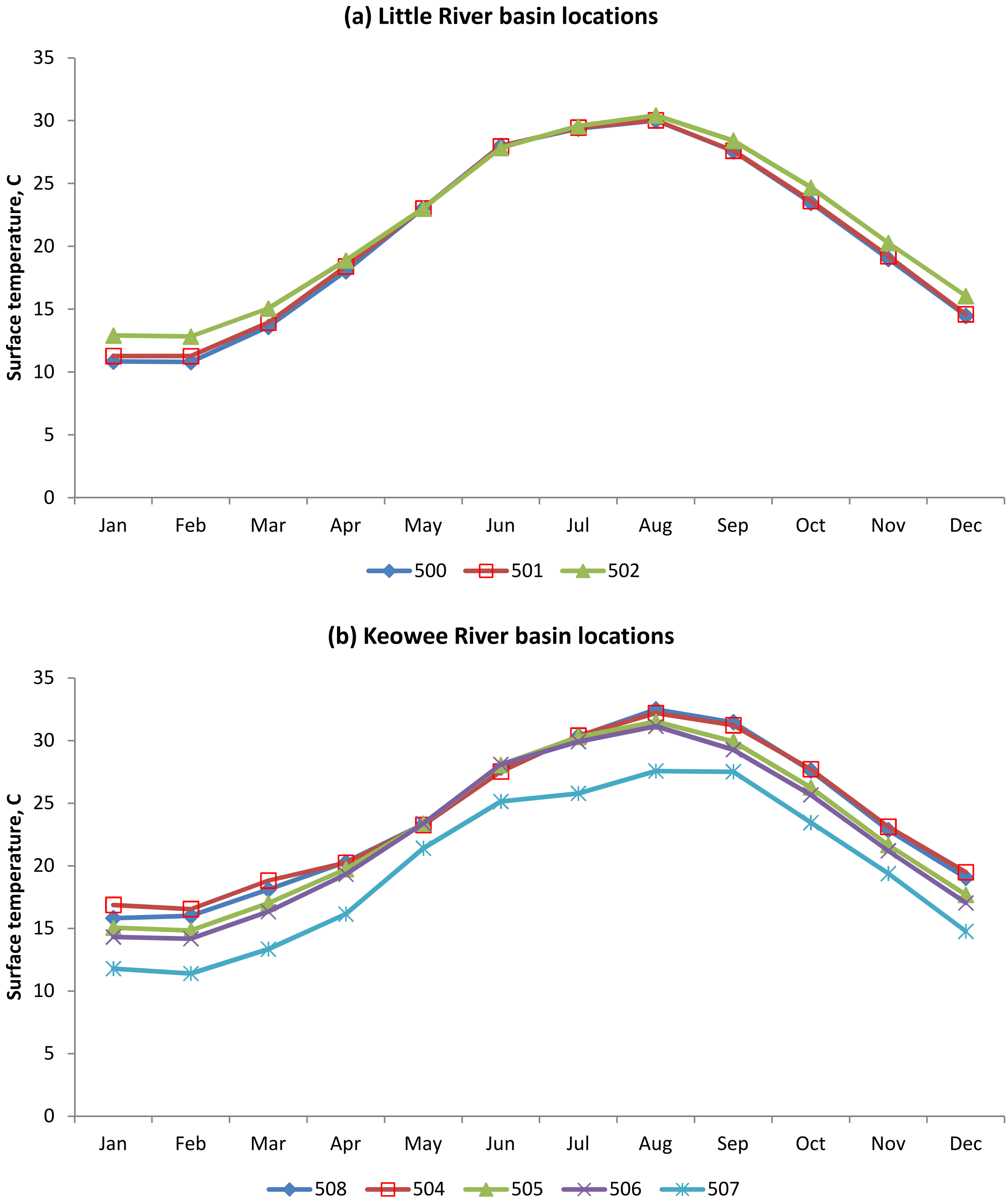


Figure 3-8. Mean seasonal and spatial variation in surface (0-5 m mean) temperatures at locations on the (a) Little River basin and (b) Keowee River basin of Lake Keowee, averaged over years 1999 through 2012.

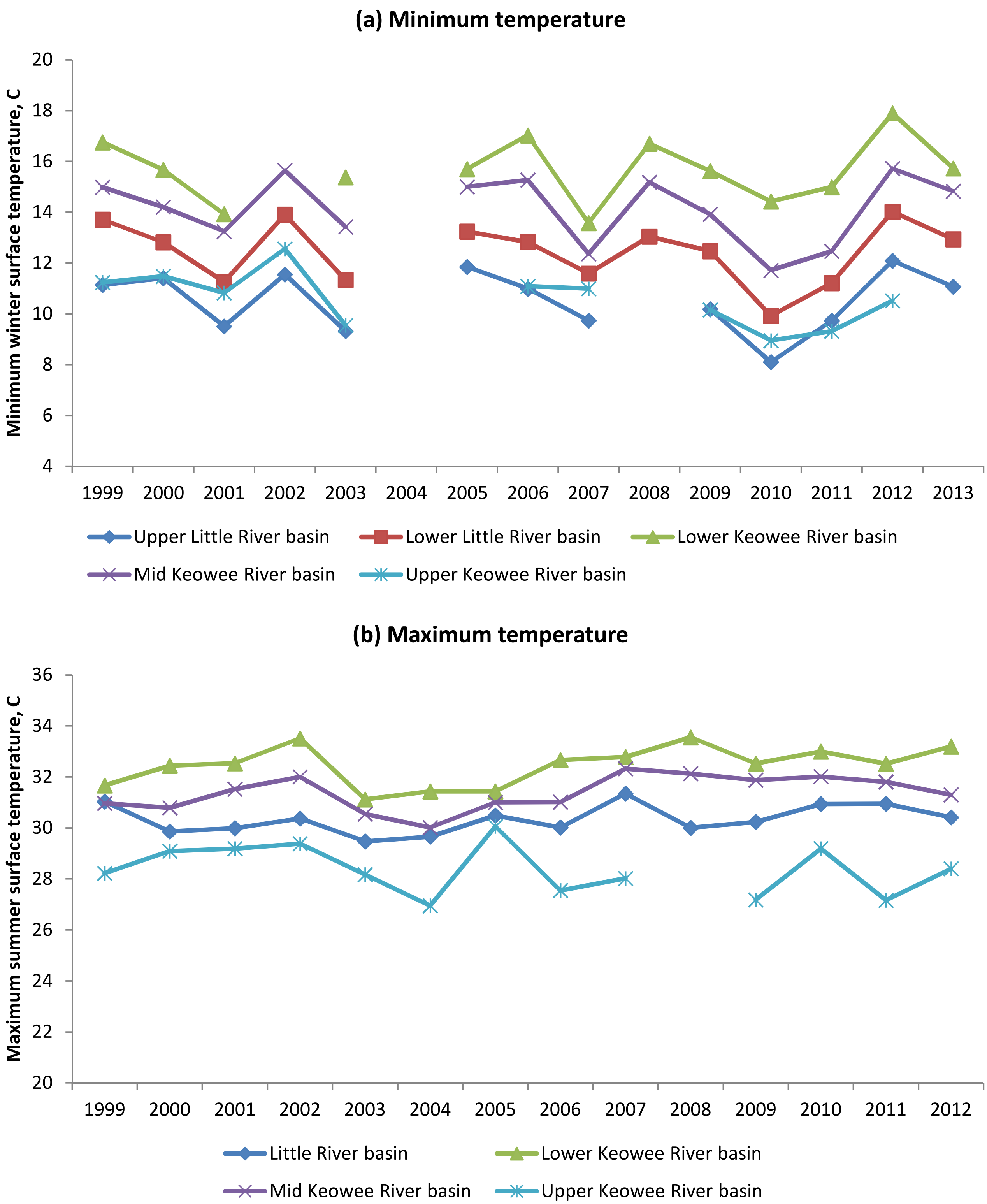
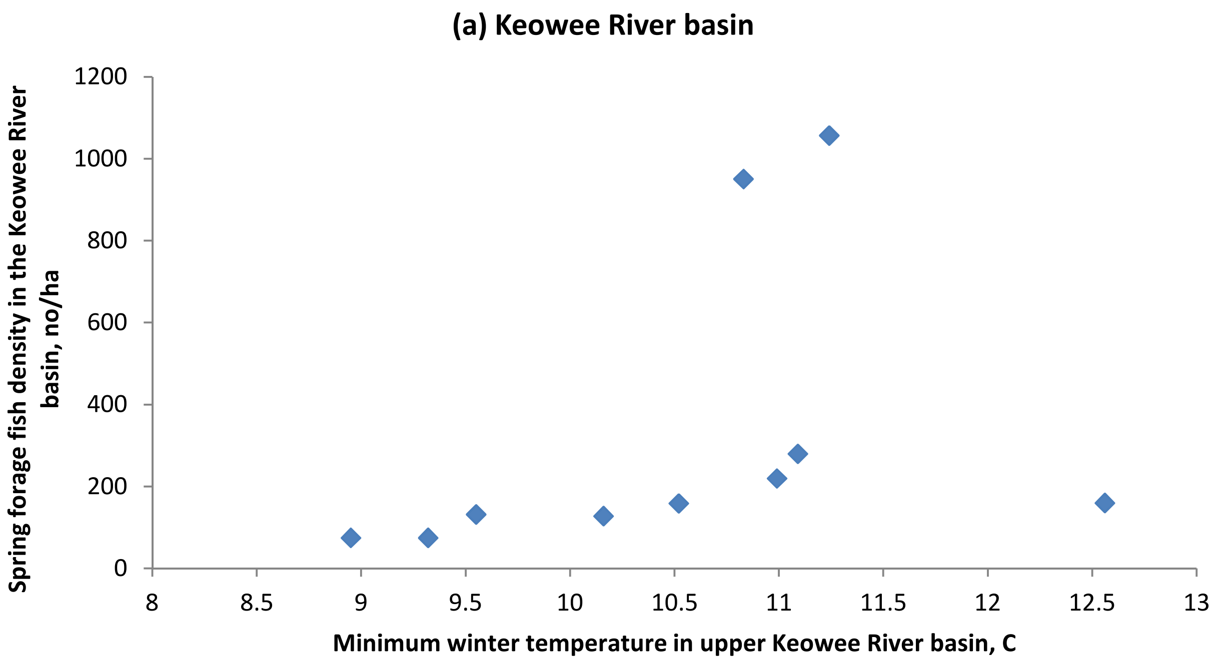


Figure 3-9. (a) Minimum annual and (b) maximum annual surface (0-5 m mean) temperature observed on basins of Lake Keowee, January 1999 – May 2013.



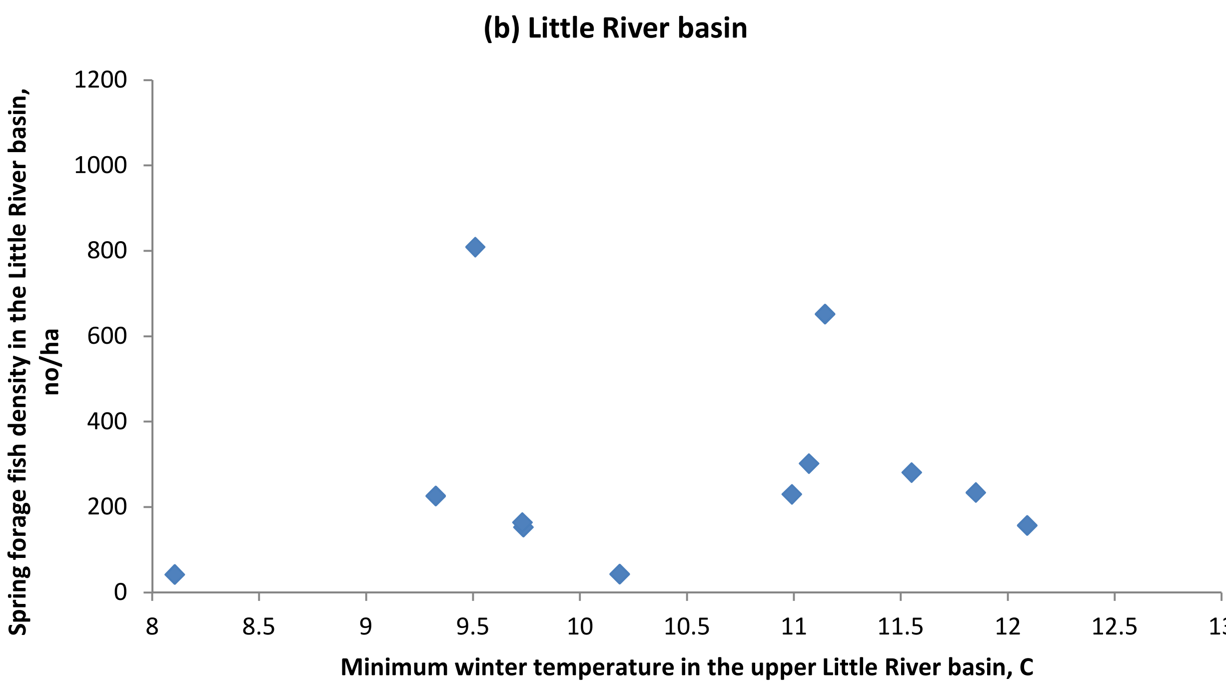


Figure 3-10. (a) Spring forage fish density in the Keowee River basin vs. minimum winter temperature in the upper Keowee River basin (Location 507); and (b) spring forage fish density in the Little River basin vs. minimum winter temperature in the upper Little River basin (mean of Locations 500 and 501). Data were collected 1999-2013. No spring forage fish data were available for 2000; no temperature data were available for the upper Keowee River basin in 2004, 2005, 2008, and 2013; and no temperature data were available for the upper Little River basin in 2004 and 2008.

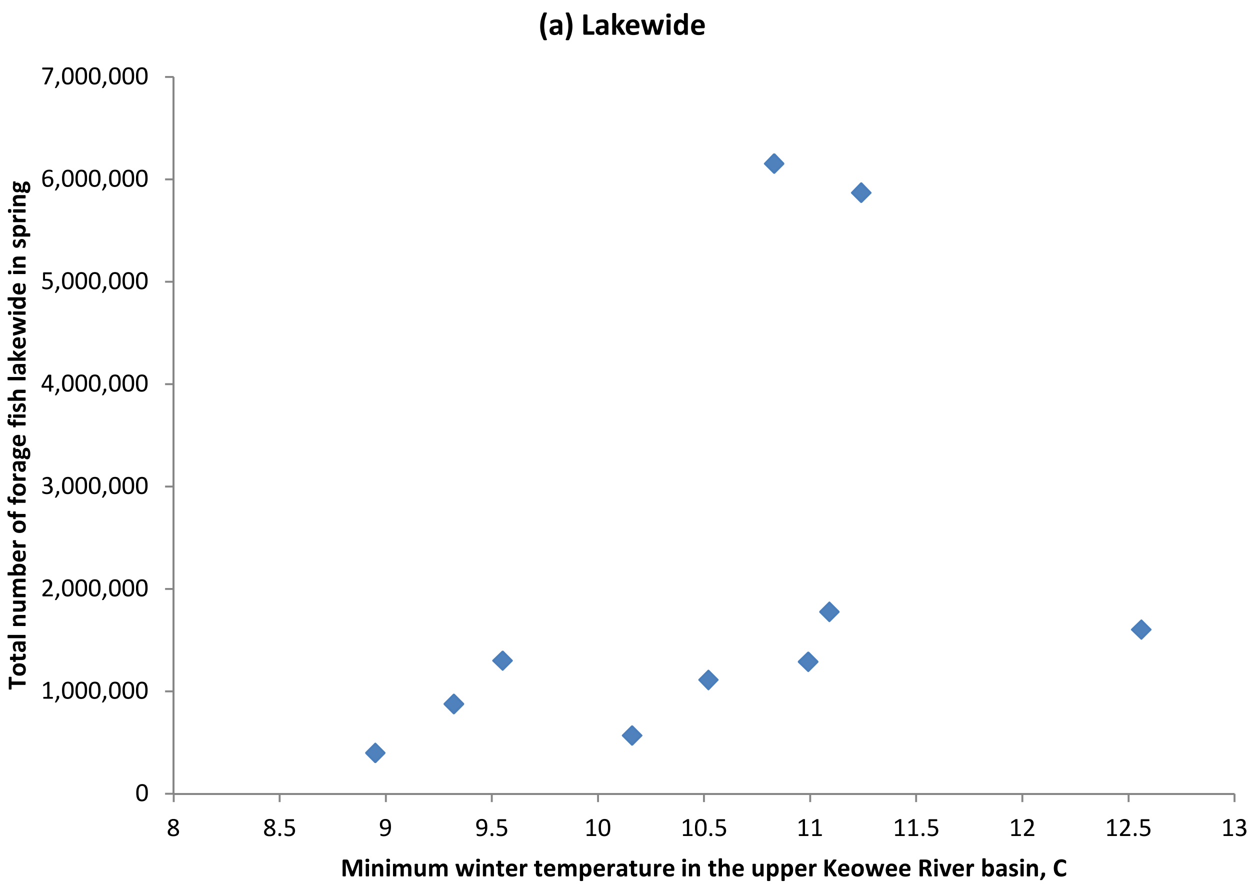


Figure 3-11. Total number of forage fish lakewide in spring on Lake Keowee, vs. minimum winter surface (0-5 m) temperature in the upper Keowee River basin (Location 507), 1999-2012. No spring data were available for 2000; no winter temperature data were available in 2004, 2005, 2008, and 2013.

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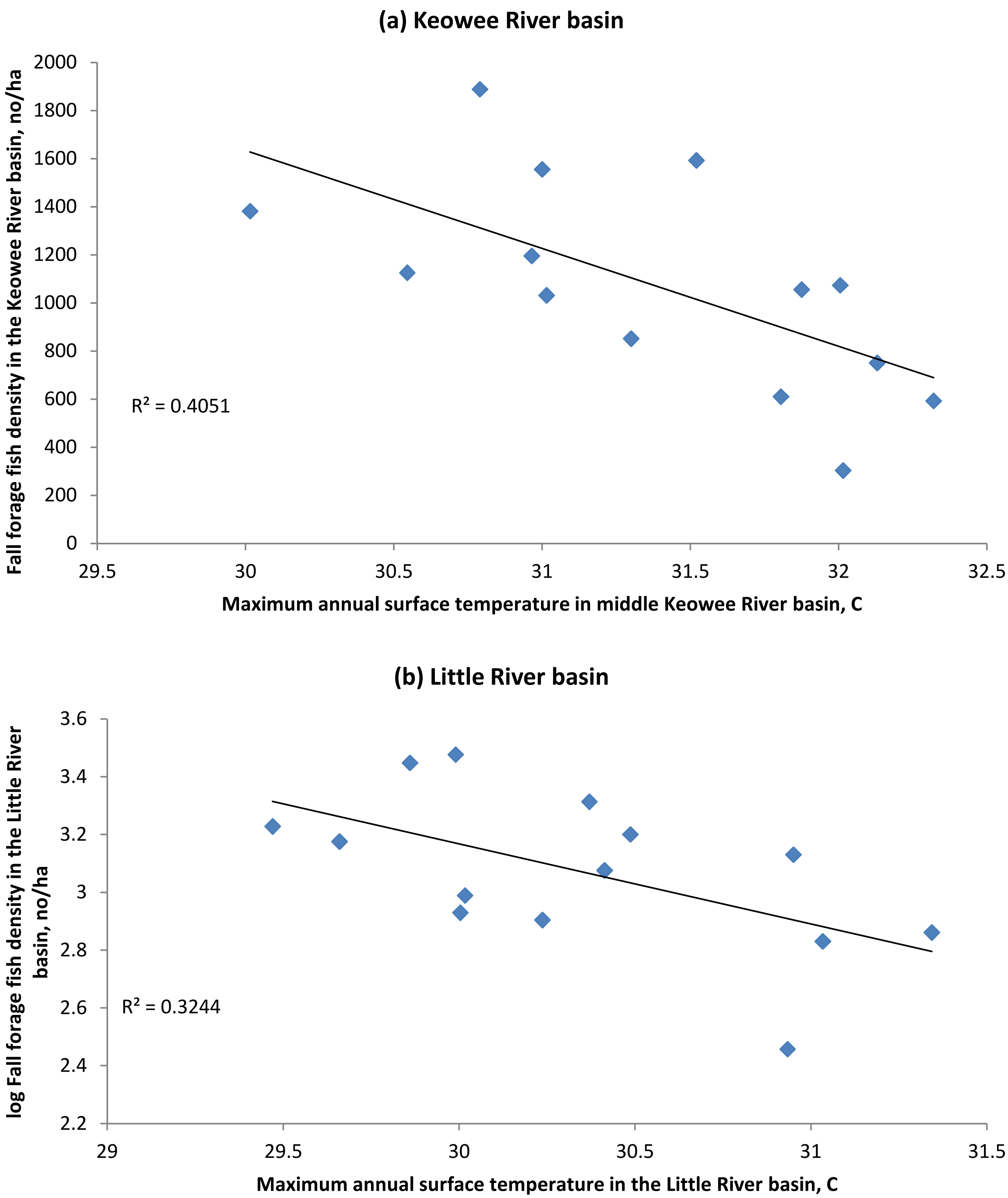
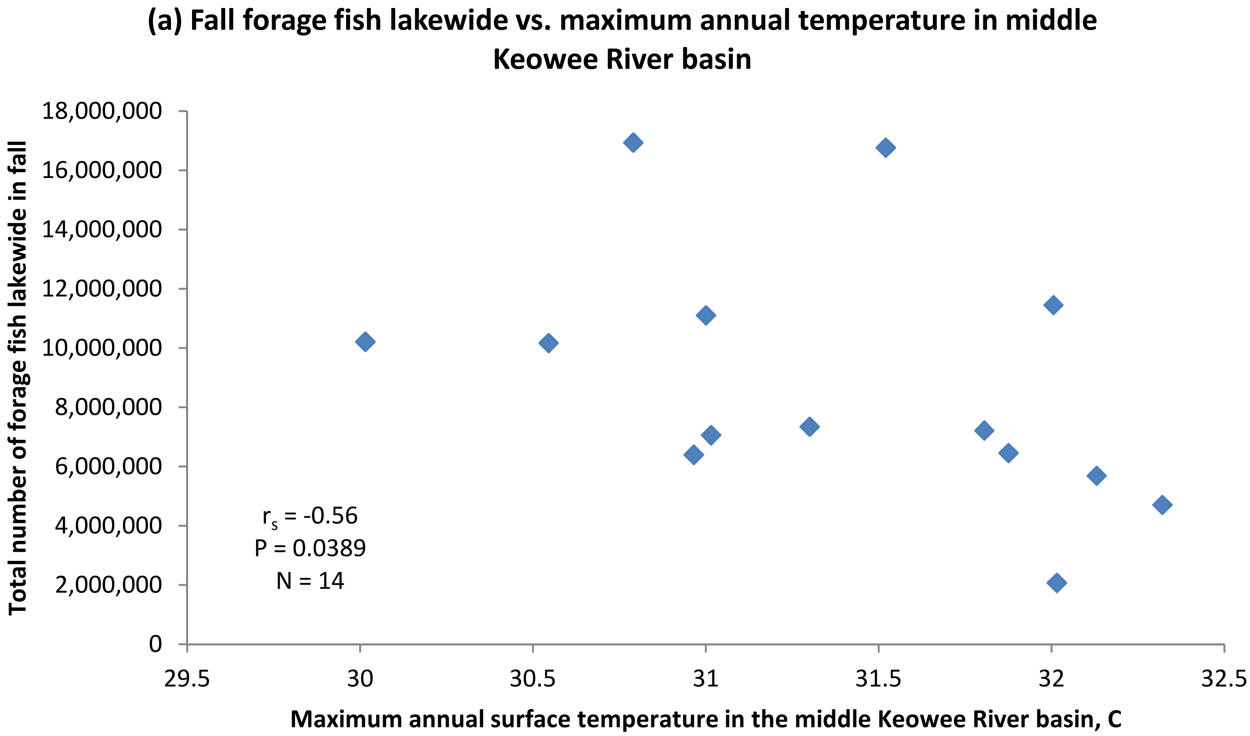


Figure 3-12. (a) Fall forage fish density in the Keowee River basin of Lake Keowee vs. maximum annual surface (0-5 m) temperature in the middle section of the Keowee River basin (mean of Locations 505 and 506), and (b) fall forage fish density in the Little River basin vs. maximum annual surface (0-5 m) temperature in the Little River basin (mean of Locations 500, 501, 502), 1999-2012.



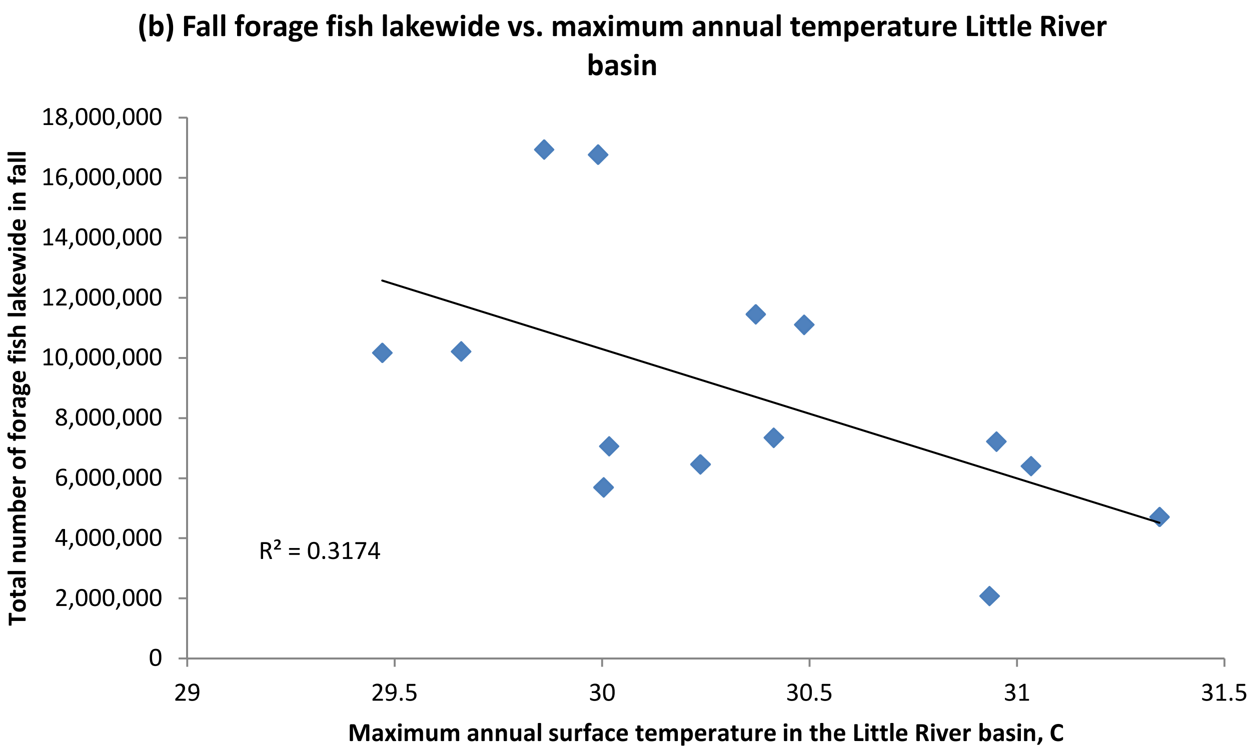
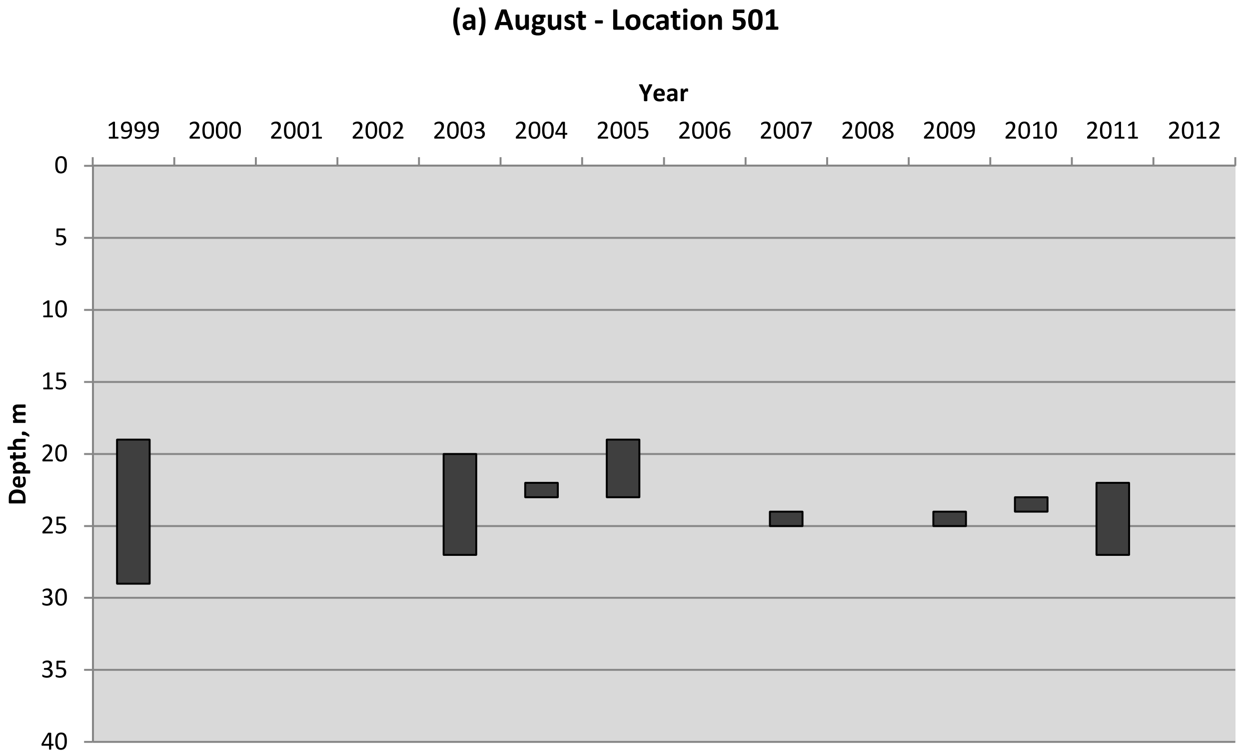


Figure 3-13. Total number of forage fish lakewide in fall on Lake Keowee, vs. (a) maximum annual surface (0-5 m) temperature in the middle section of the Keowee River basin (mean of Locations 505 and 506) and (b) maximum annual surface (0-5 m) temperature in the Little River basin (mean of Locations 500, 501, 502), 1999-2012.



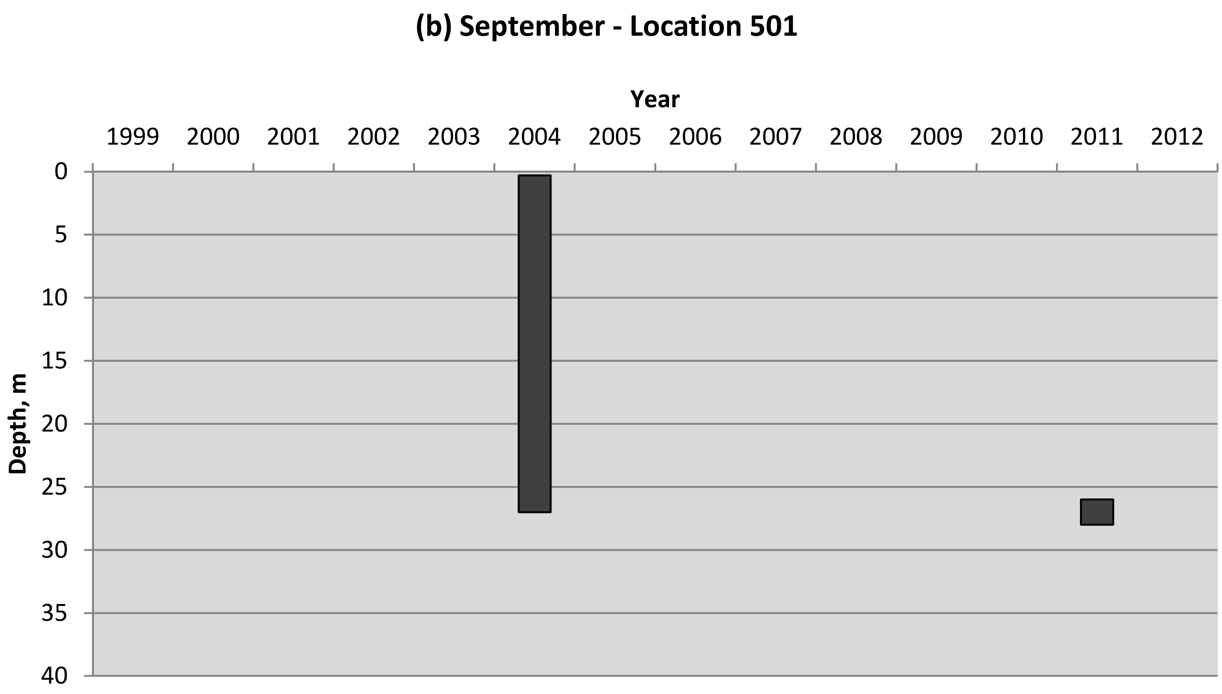
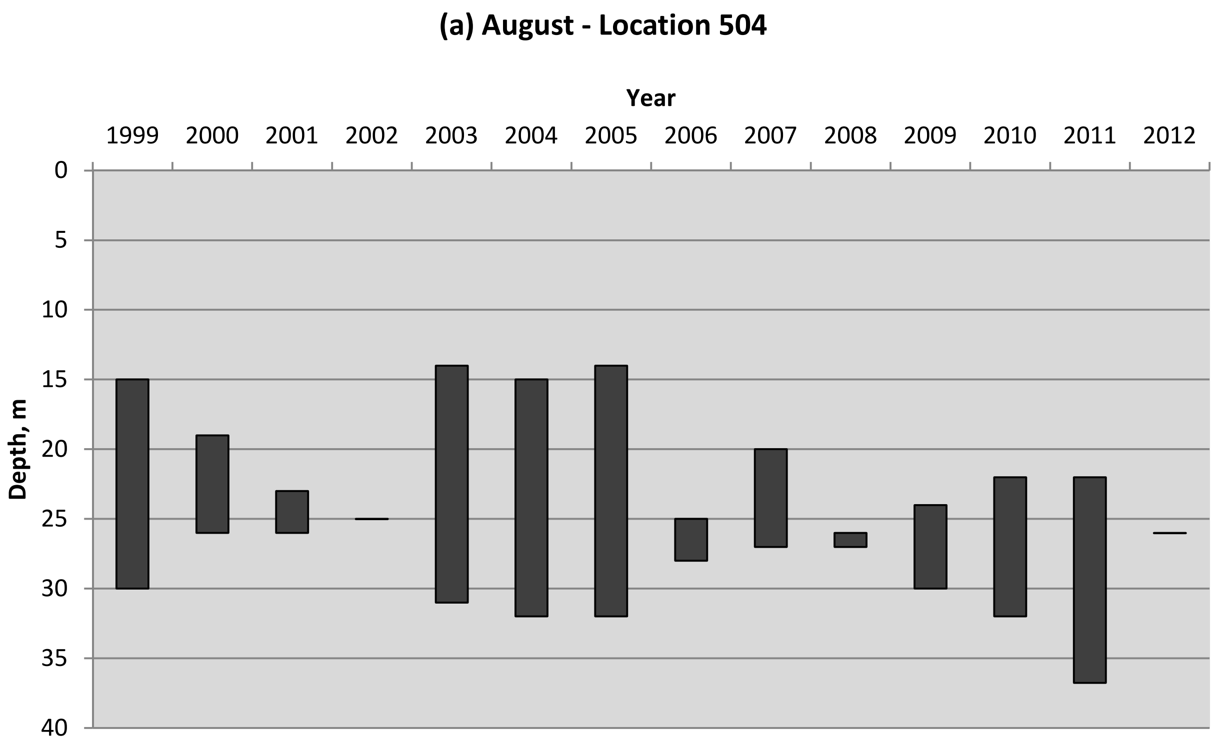


Figure 3-14. Blueback herring habitat available at Location 501 in (a) August and (b) September, based on habitat restrictions of temperature ≤26 C and dissolved oxygen ≥2.5 mg/L. Layer of the water column in which habitat is suitable is indicated by black bar. Absence of a bar indicates that no habitat as defined was available.



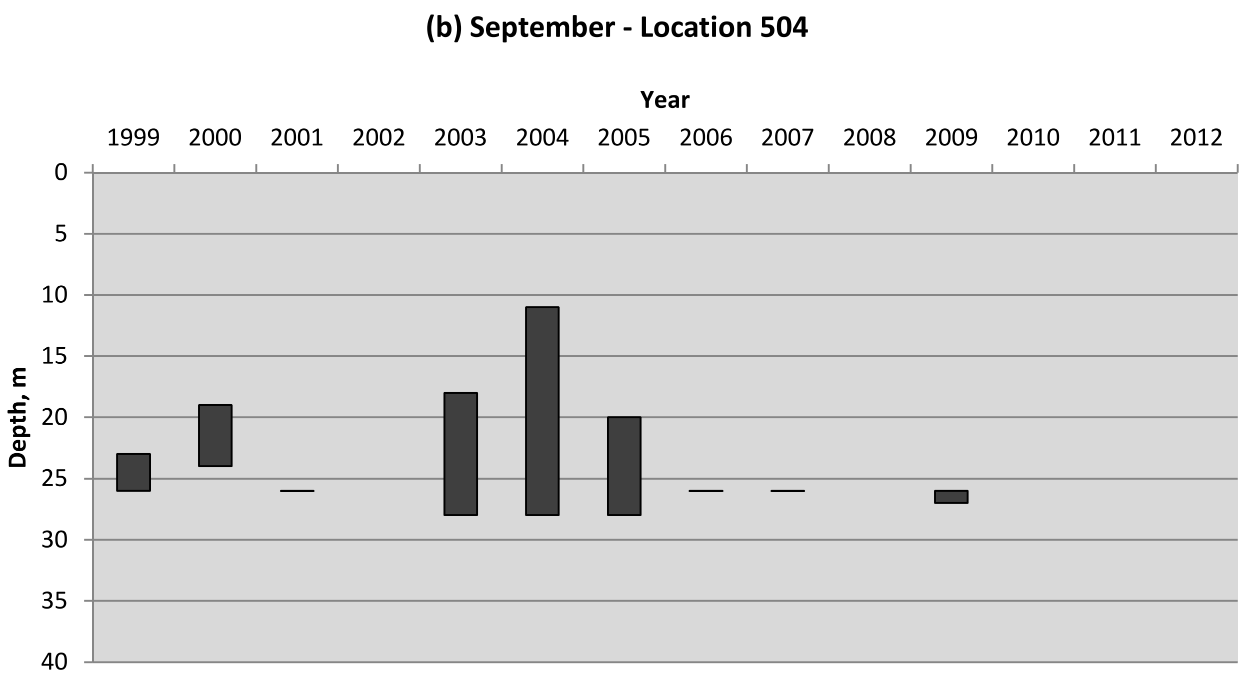


Figure 3-15. Blueback herring habitat available at Location 504 in (a) August and (b) September, based on habitat restrictions of temperature ≤26 C and dissolved oxygen ≥2.5 mg/L. Layer of the water column in which habitat is suitable is indicated by black bar. Absence of a bar indicates that no habitat as defined was available.

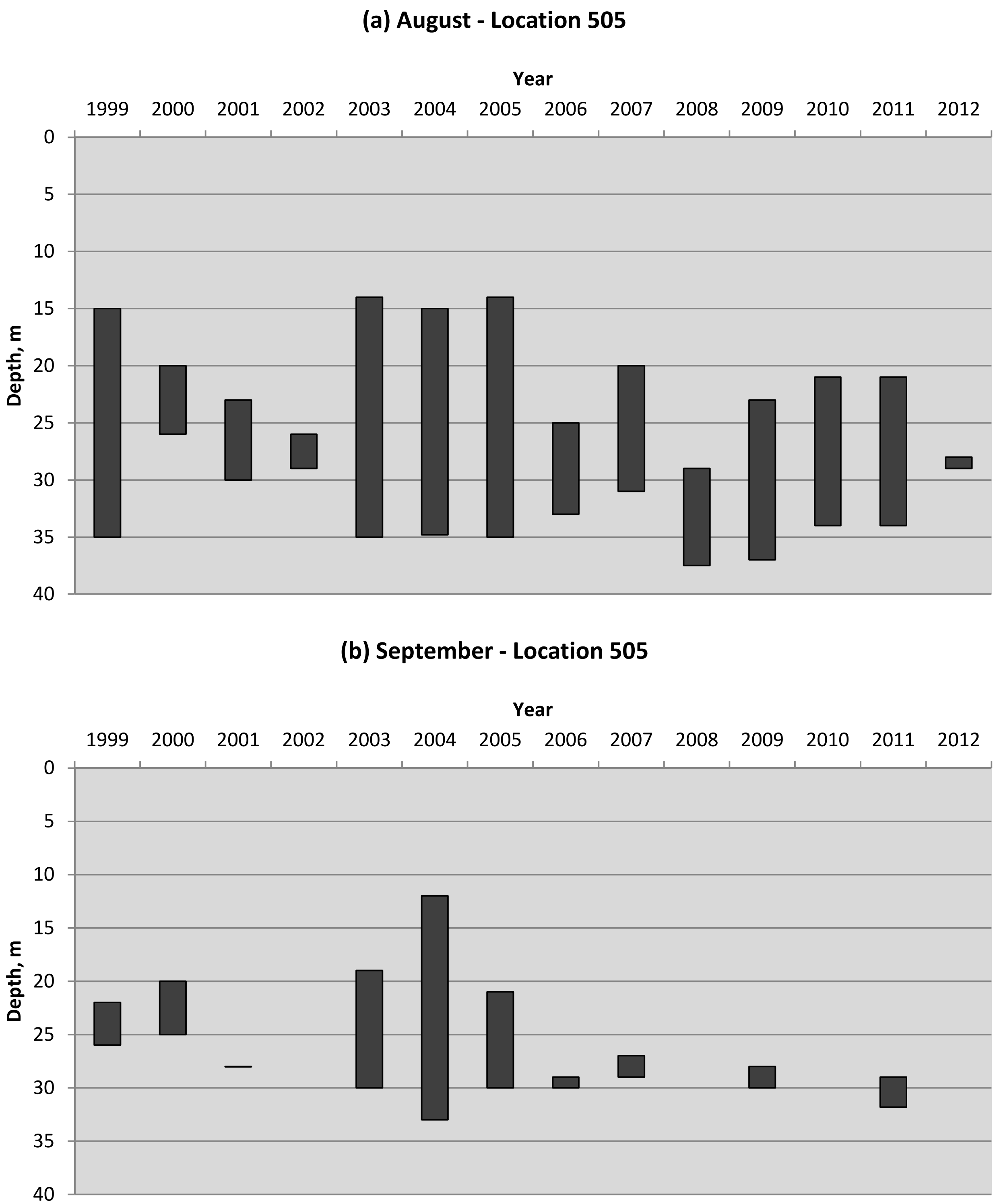


Figure 3-16. Blueback herring habitat available at Location 505 in (a) August and (b) September, based on habitat restrictions of temperature ≤26 C and dissolved oxygen ≥2.5 mg/L. Layer of the water column in which habitat is suitable is indicated by black bar. Absence of a bar indicates that no habitat as defined was available.

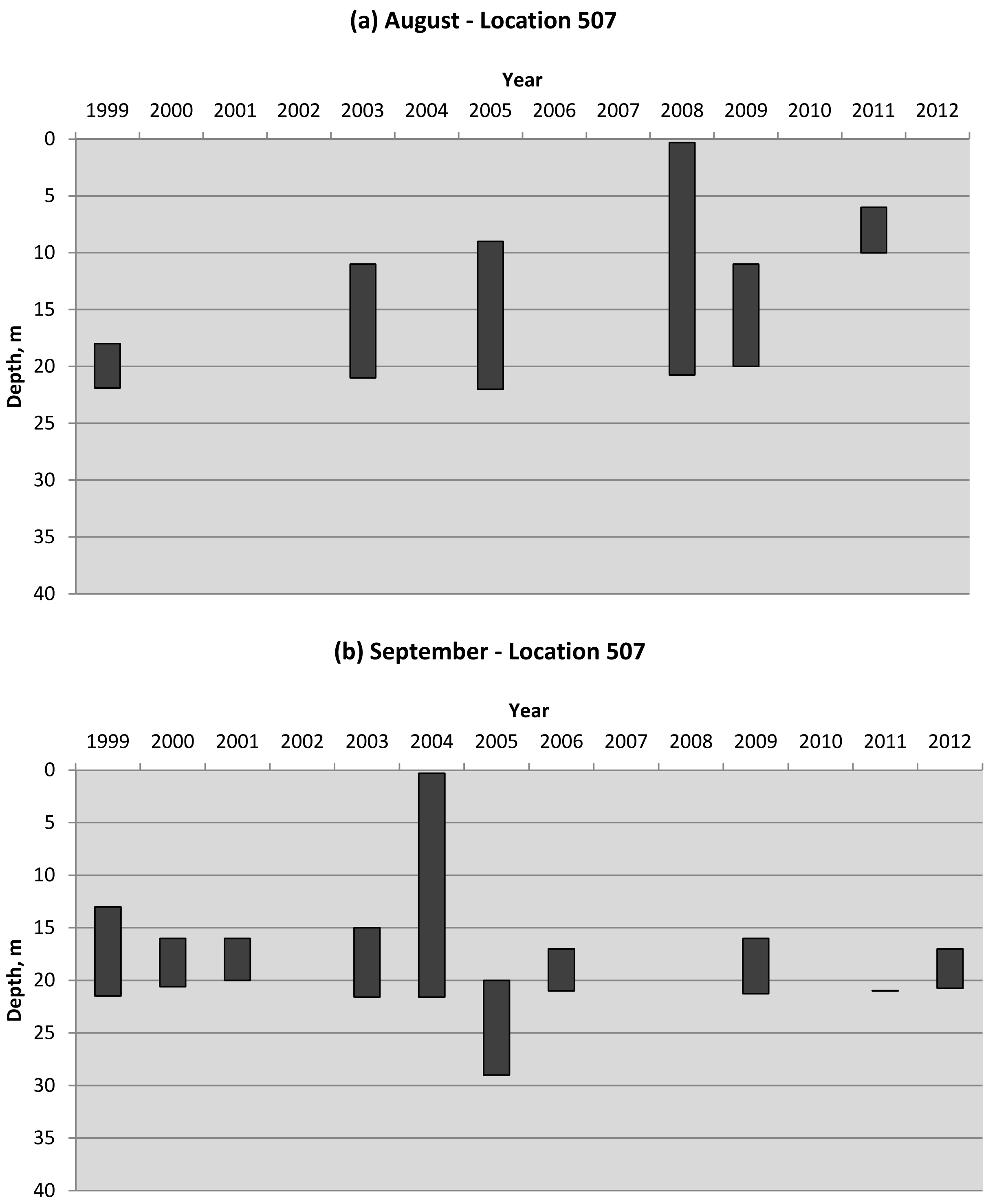


Figure 3-17. Blueback herring habitat available at Location 507 in (a) August and (b) September, based on habitat restrictions of temperature ≤26 C and dissolved oxygen ≥2.5 mg/L. Layer of the water column in which habitat is suitable is indicated by black bar. Absence of a bar indicates that no habitat as defined was available.

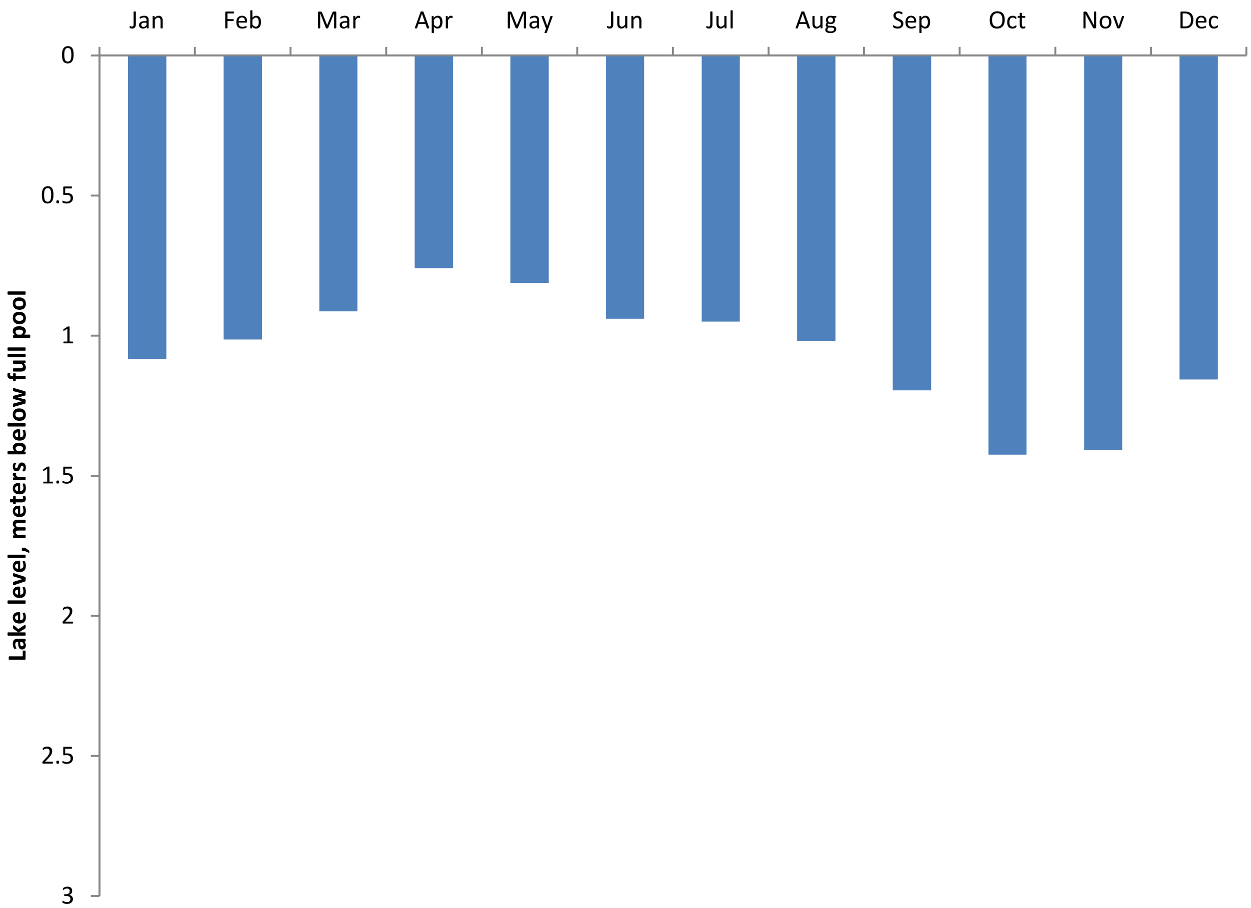


Figure 3-18. Seasonal variation in monthly mean Lake Keowee lake level averaged over the years 1999-2012.

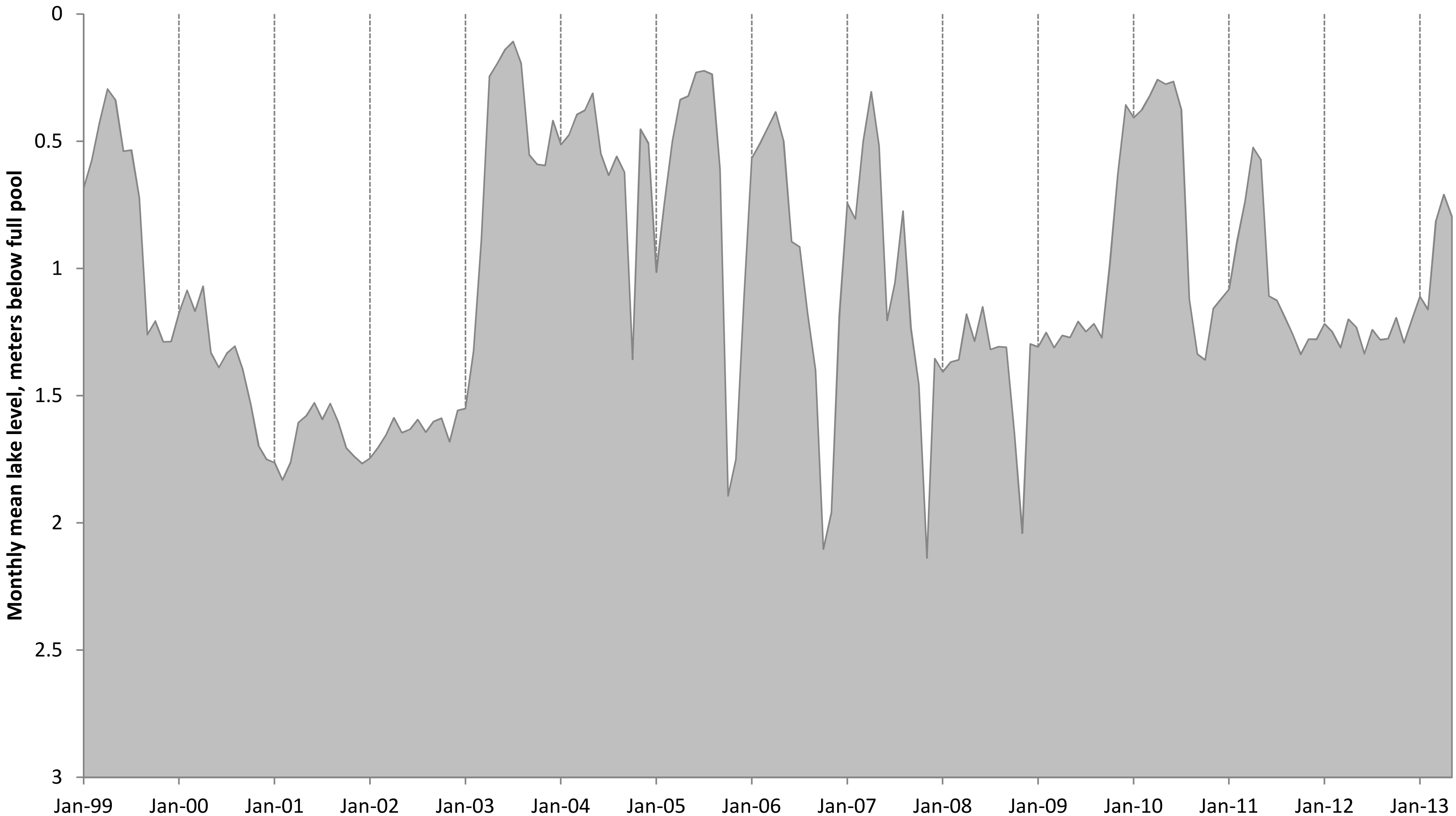


Figure 3-19. Lake Keowee monthly mean lake level expressed as meters below full pool, January 1999 through May 2013.

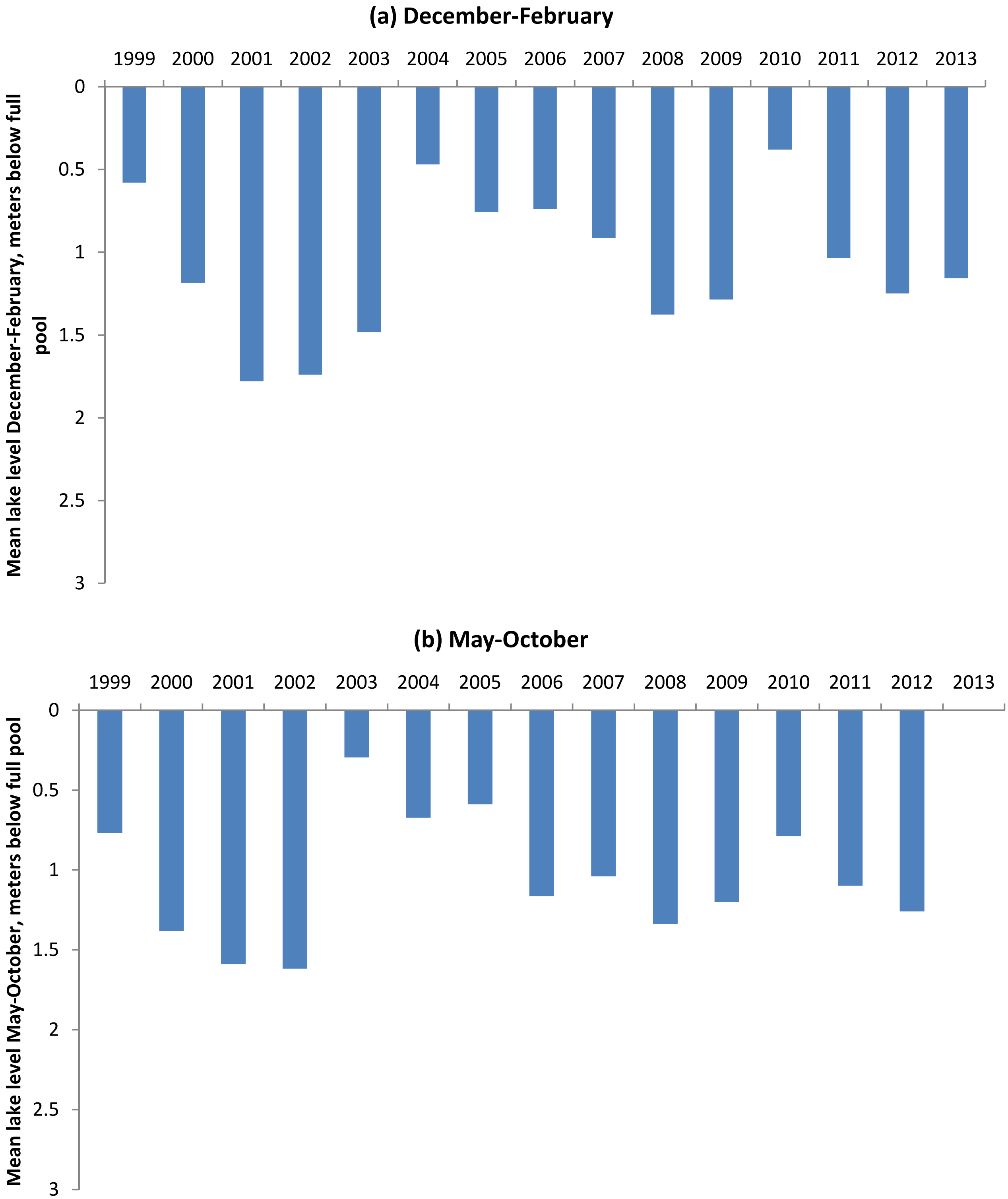


Figure 3-20. Mean Lake Keowee lake level observed (a) December-February, 1999-2013; and (b) May-October, 1999-2012.

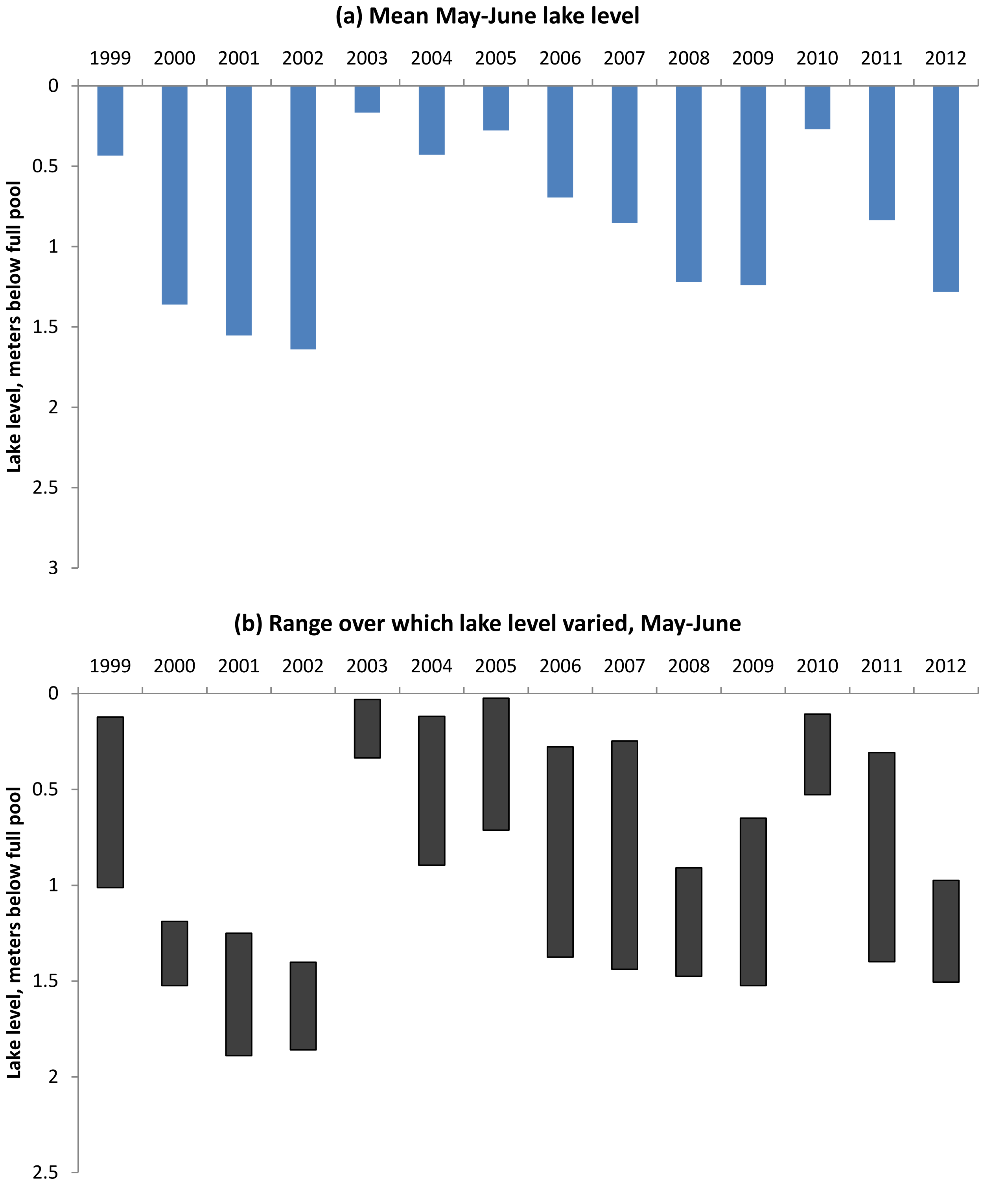


Figure 3-21. (a) Mean lake level observed May-June, and (b) range over which lake level varied in May and June, 1999-2012. Bars in (b) are bounded by minimum and maximum daily lake levels observed May-June.

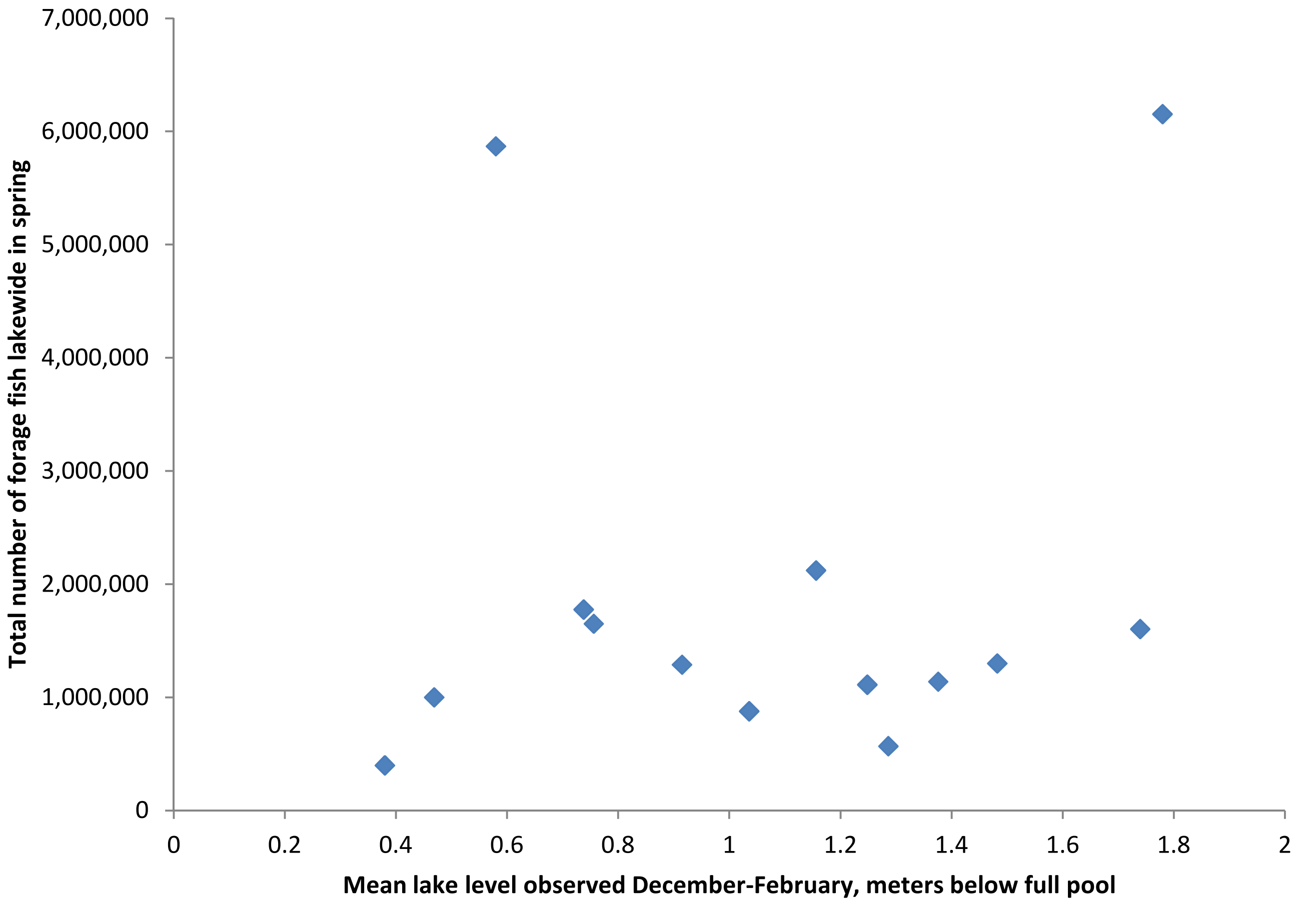


Figure 3-22. Total number of forage fish on Lake Keowee in spring vs. mean lake level December-February, meters below full pool, 1999-2013.

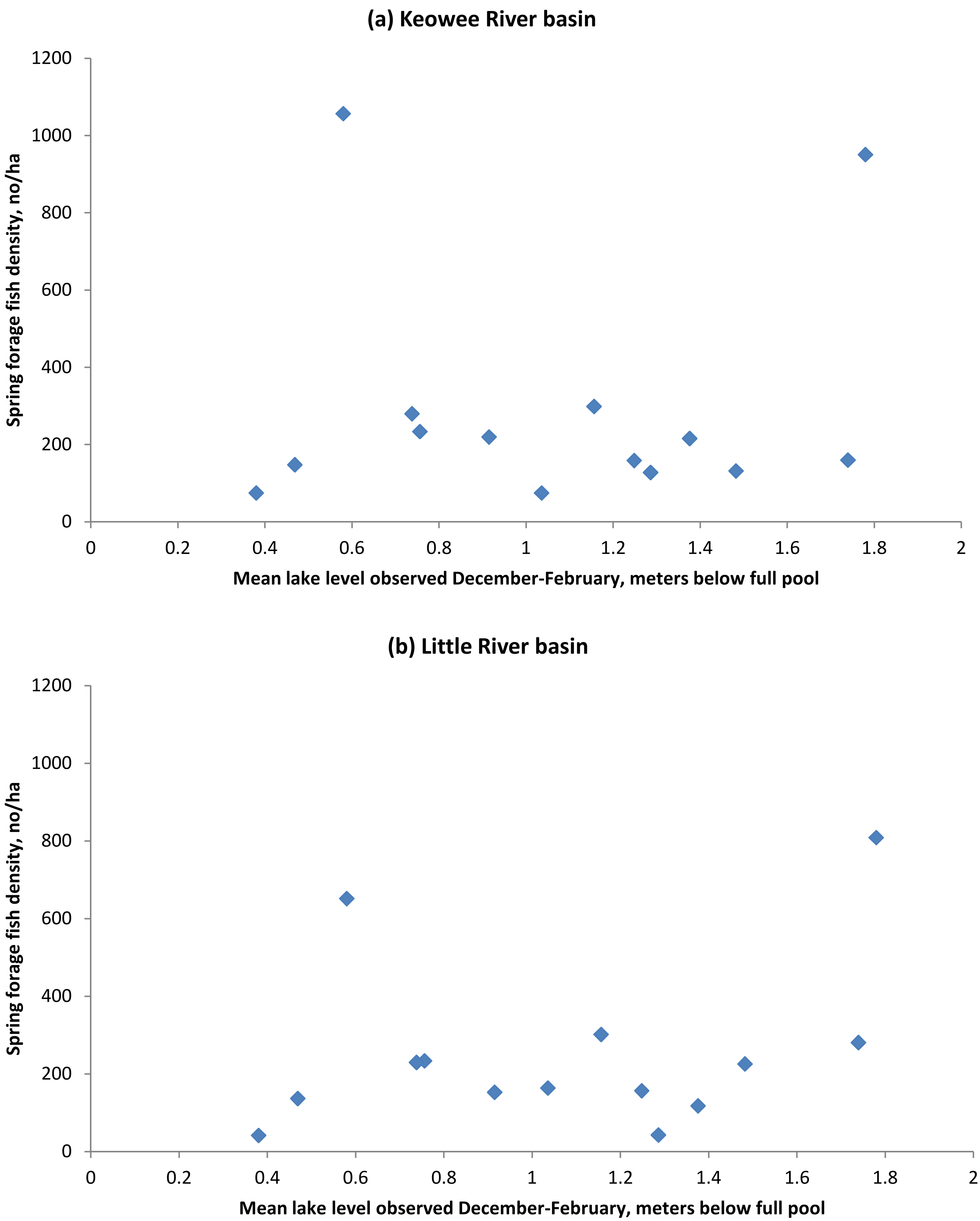


Figure 3-23. Spring forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. mean lake level December-February, meters below full pool, 1999-2013.

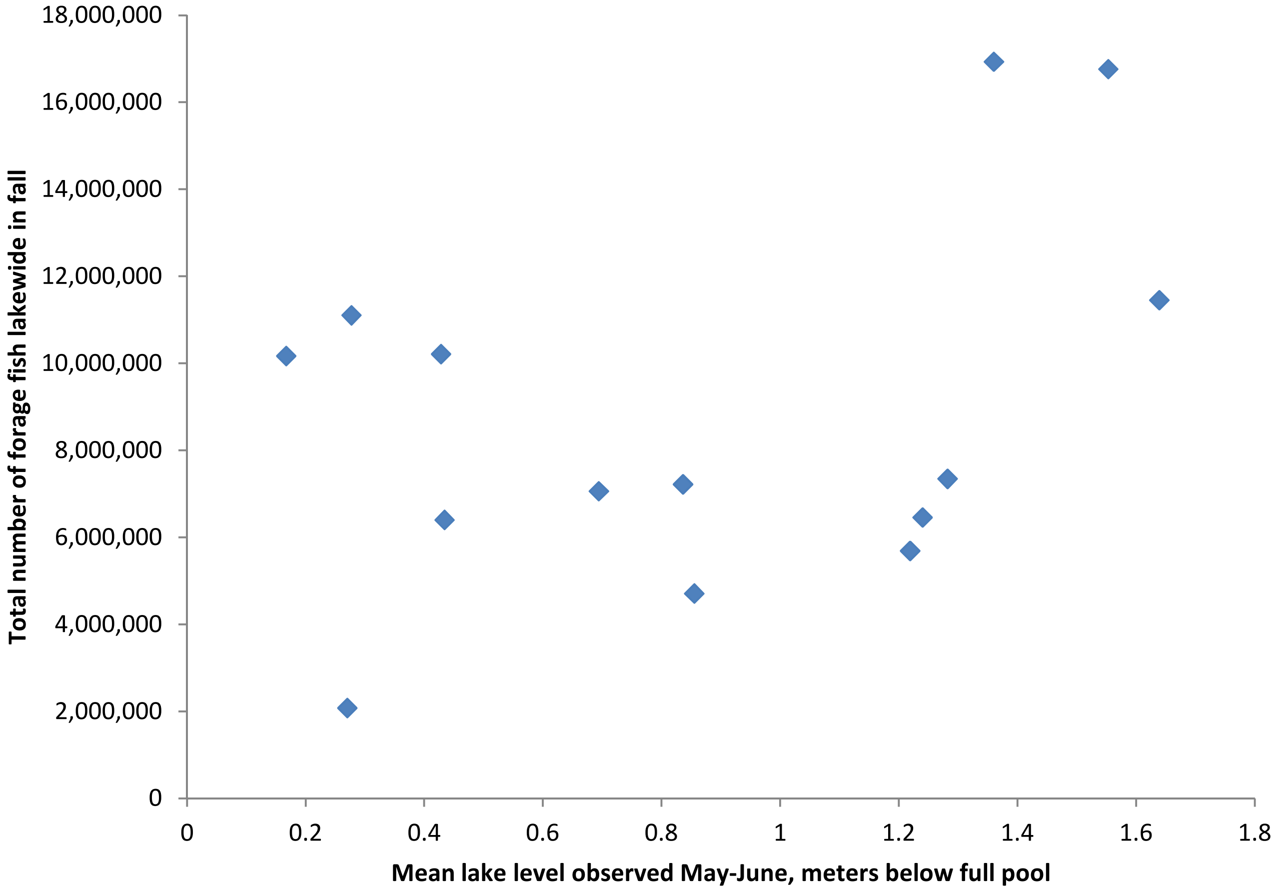


Figure 3-24. Total number of forage fish on Lake Keowee in fall vs. mean lake level May-June, 1999-2012.

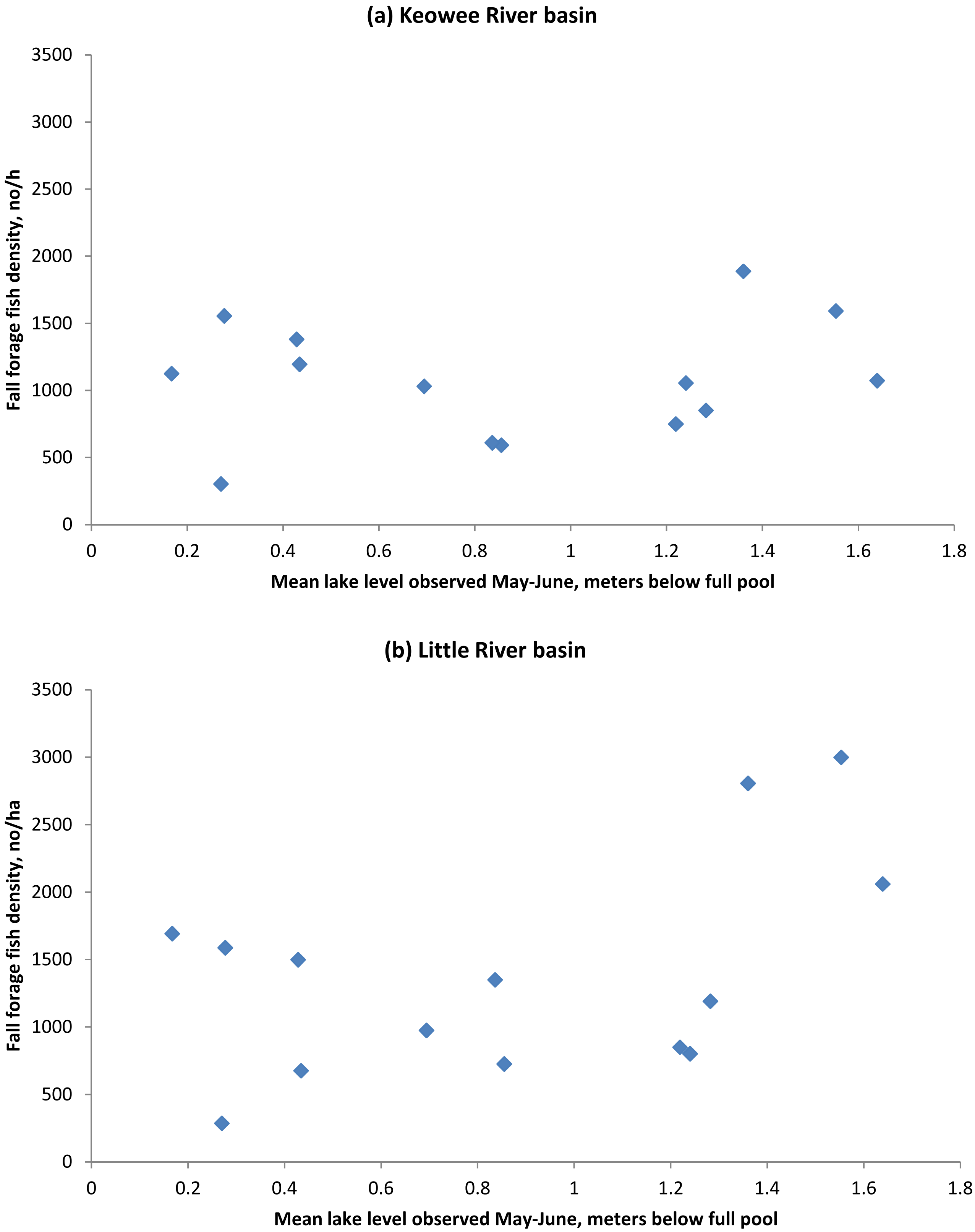


Figure 3-25. Fall forage fish densities in the (a) Keowee River basin and (b) Little River basin on Lake Keowee, vs. mean lake level observed May-June, 1999-2012.

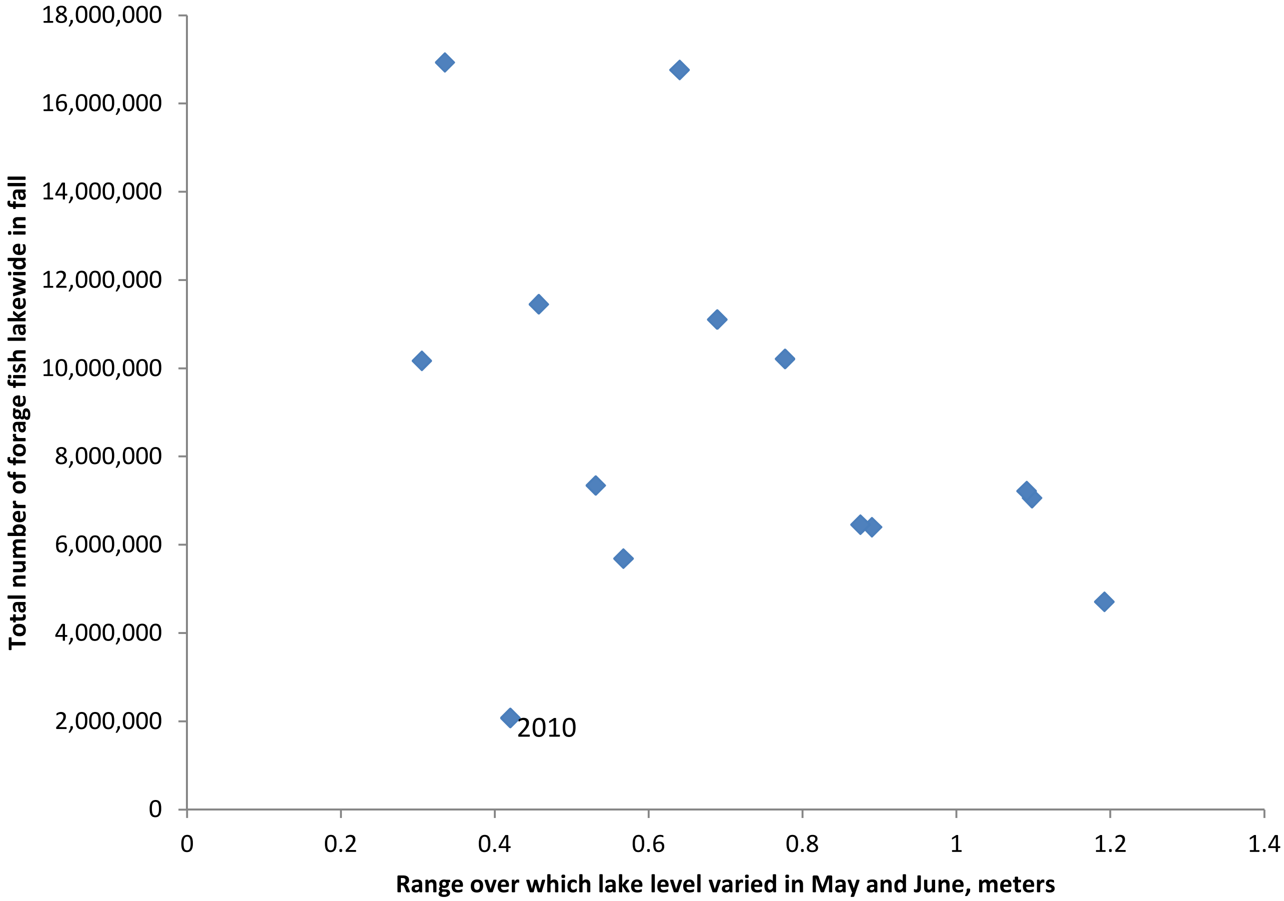


Figure 3-26. Total number of forage fish in Lake Keowee during fall vs. range in meters over which lake level varied in May and June, 1999-2012.

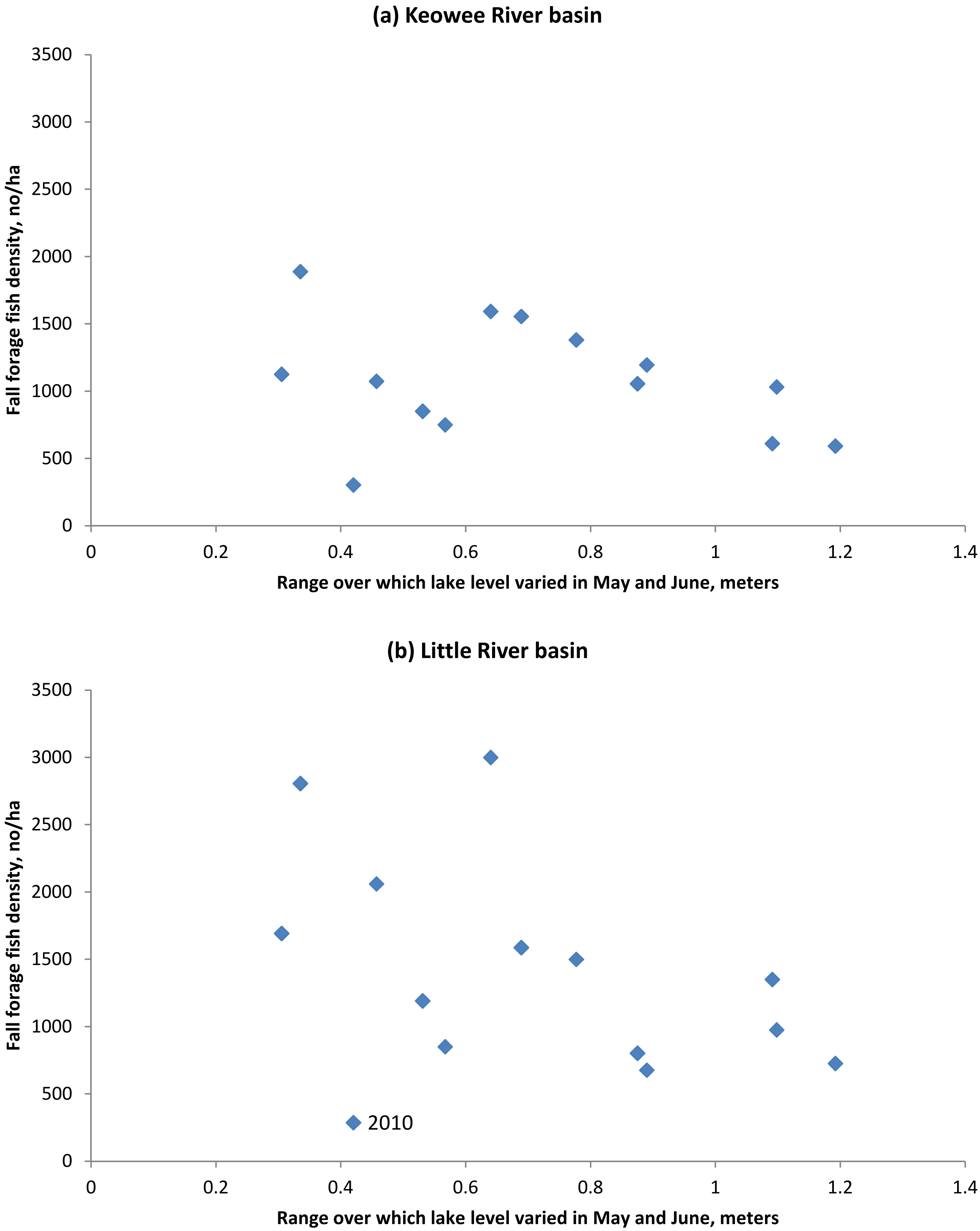


Figure 3-27. Fall forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. range in meters over which lake level varied in May and June, 1999-2012.

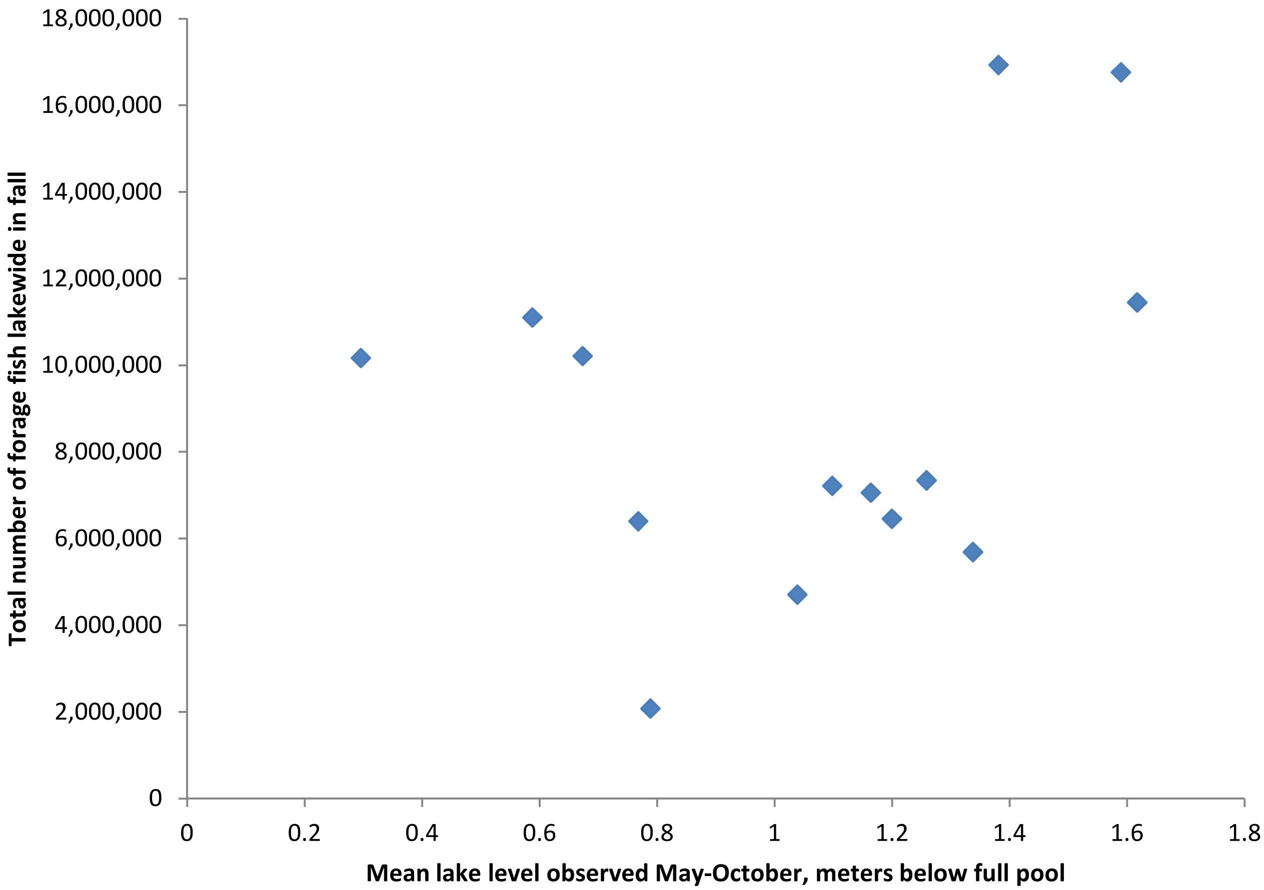


Figure 3-28. Total number of forage fish lakewide on Lake Keowee in fall, vs. mean lake level May-October, 1999-2012.

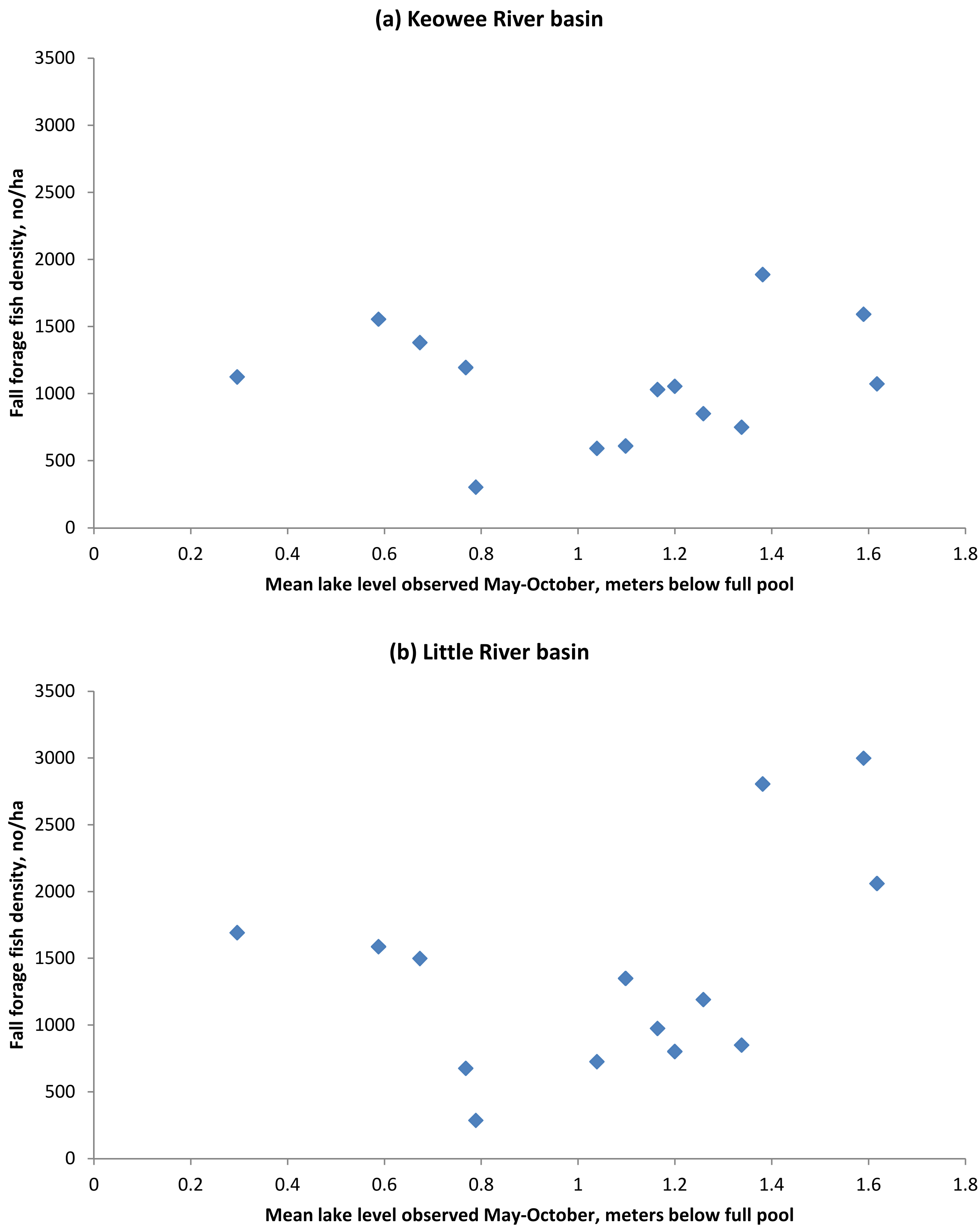


Figure 3-29. Fall forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee vs. mean lake level May-October, 1999-2012.

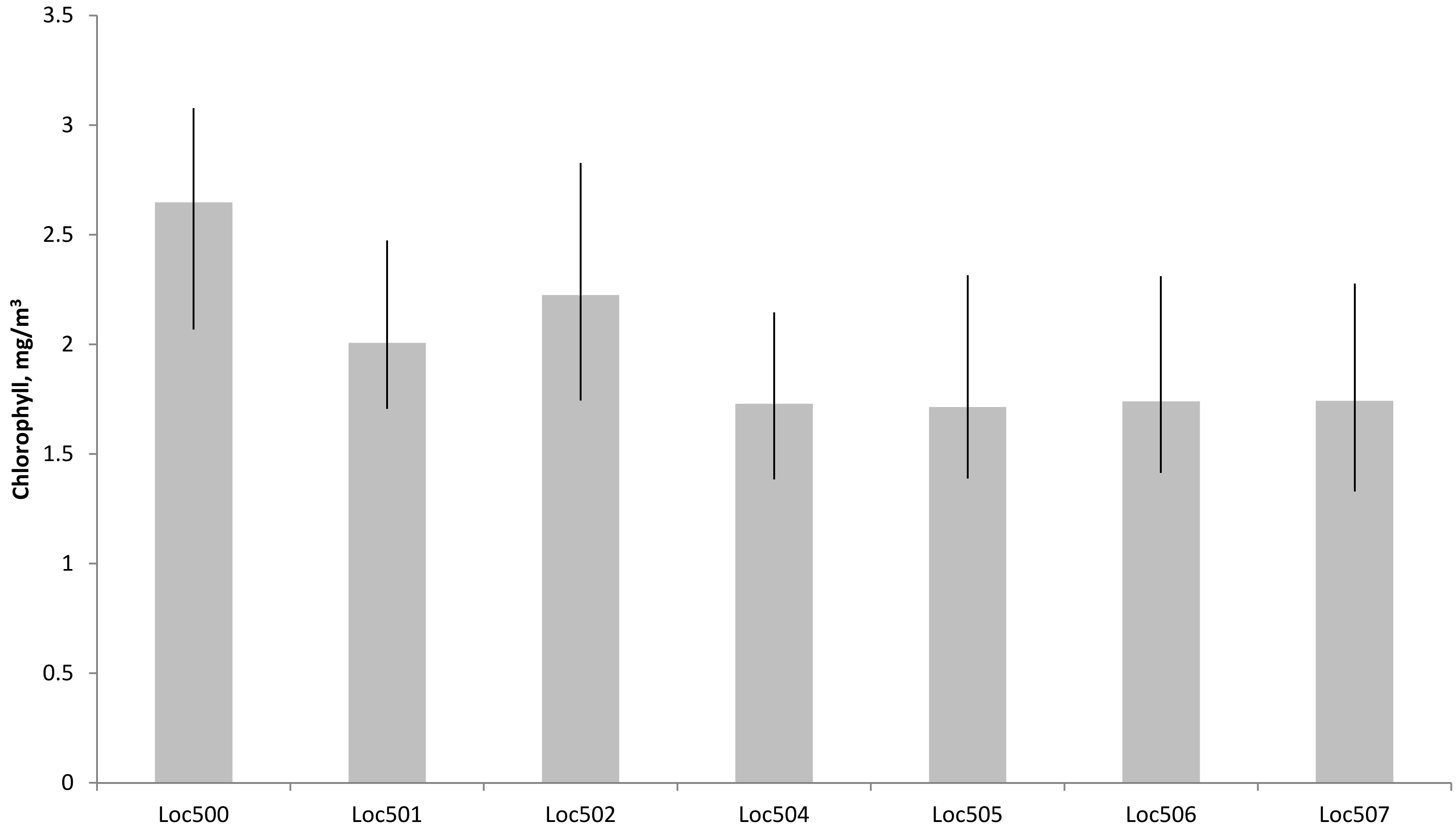


Figure 3-30. Median surface (0-10 m) chlorophyll concentrations at locations on Lake Keowee based on data collected monthly, 2011-2012. Lines are bounded by 25% and 75% quantiles. Locations 500, 501, and 502 are in the Little River basin; Locations 504, 505, 506, and 507 are in the Keowee River basin.

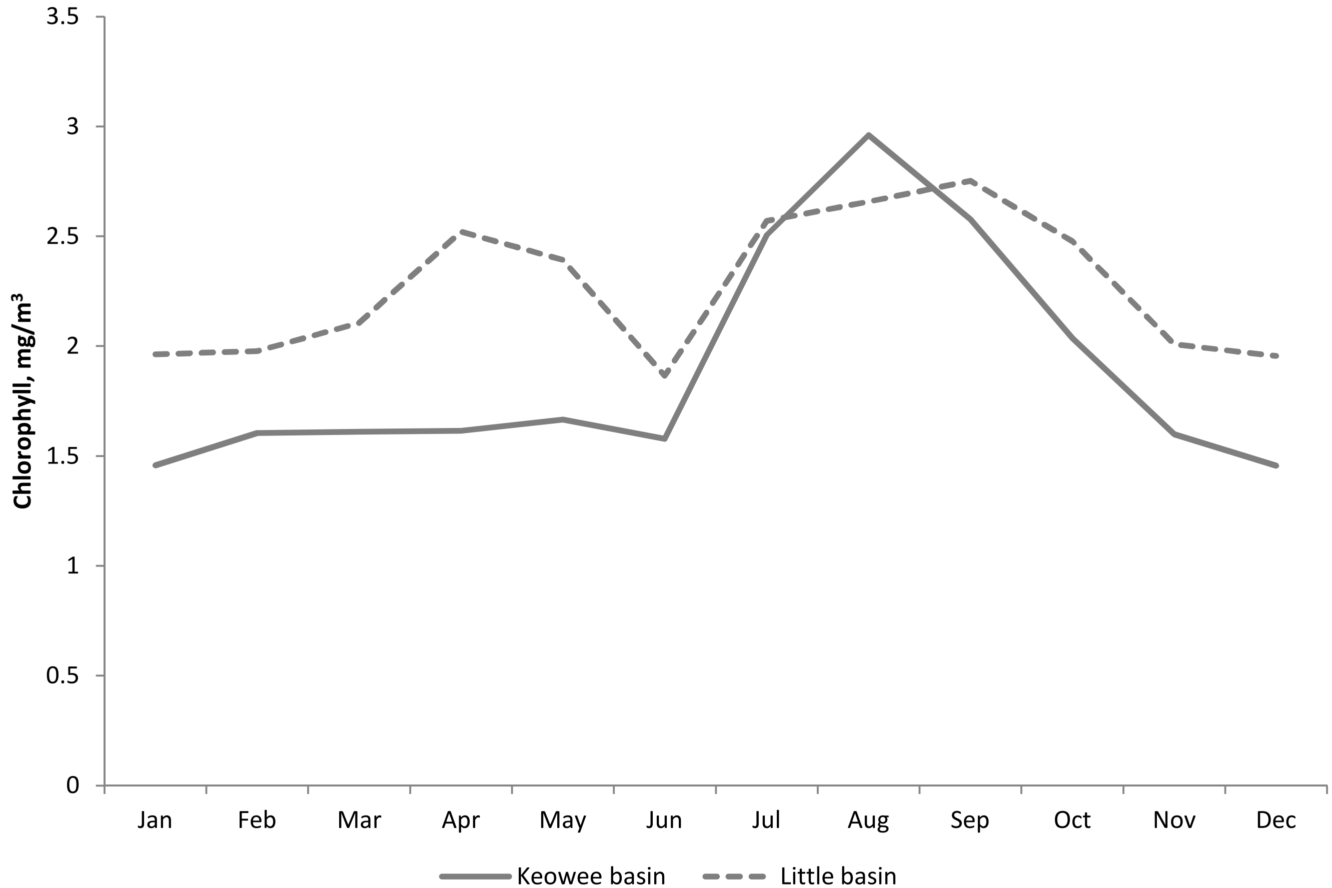


Figure 3-31. Average seasonal variation observed in basinwide surface (0-10 m) chlorophyll concentrations on the Keowee River and Little River basins of Lake Keowee, based on data collected 1999-2012.

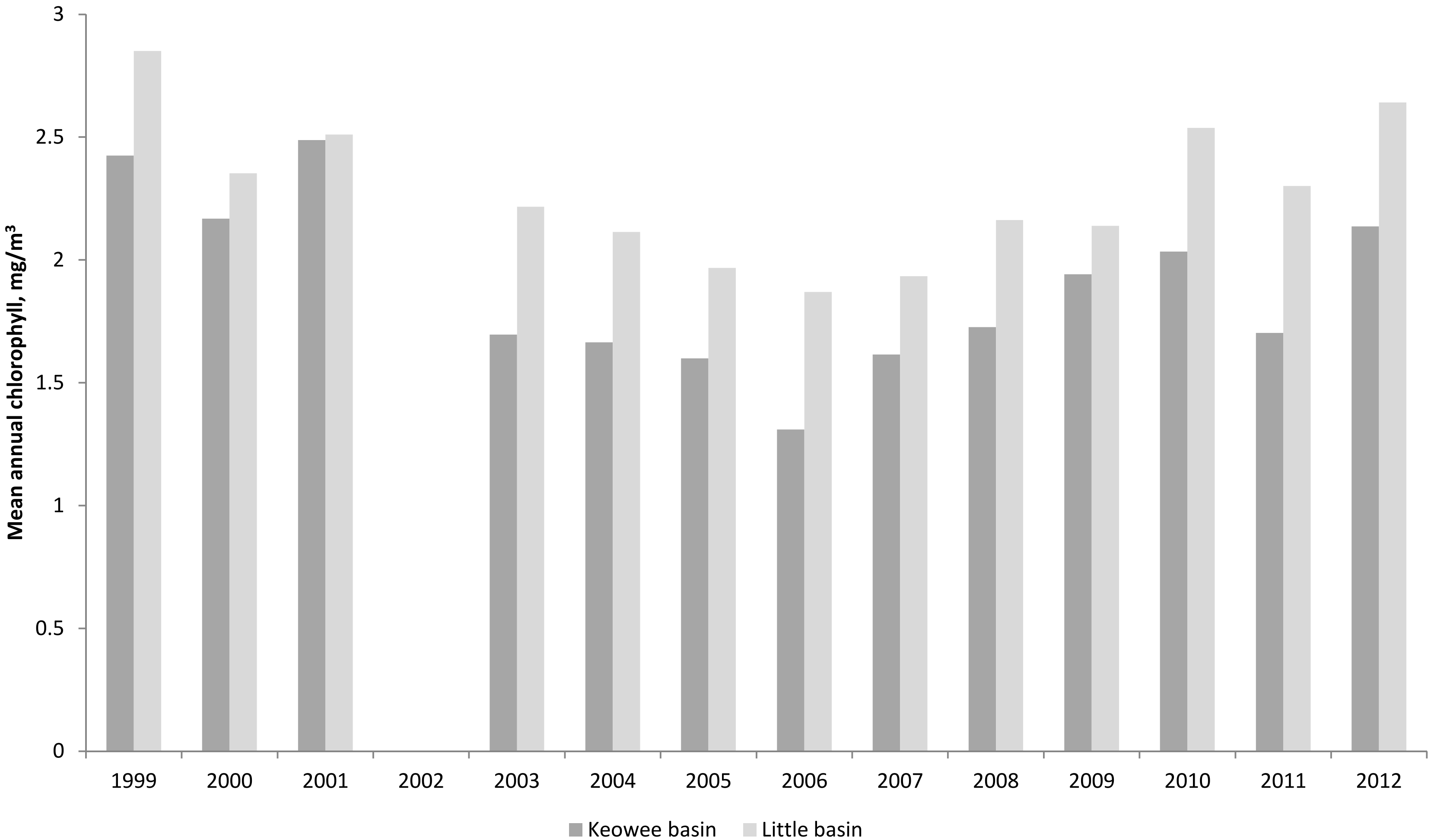


Figure 3-32. Temporal variation in mean annual basinwide surface (0-10 m) chlorophyll concentrations in the Keowee River and Little River basins of Lake Keowee, 1999-2012.

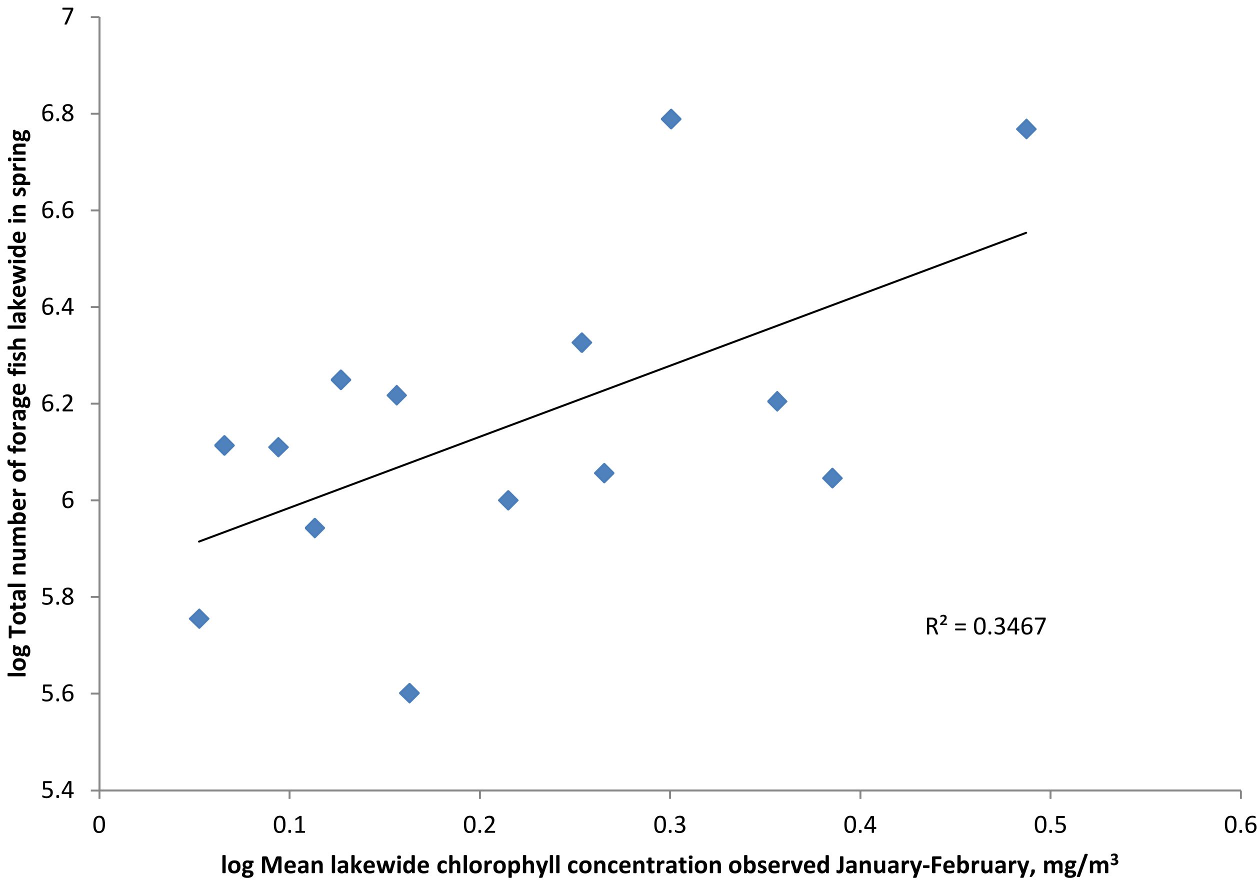
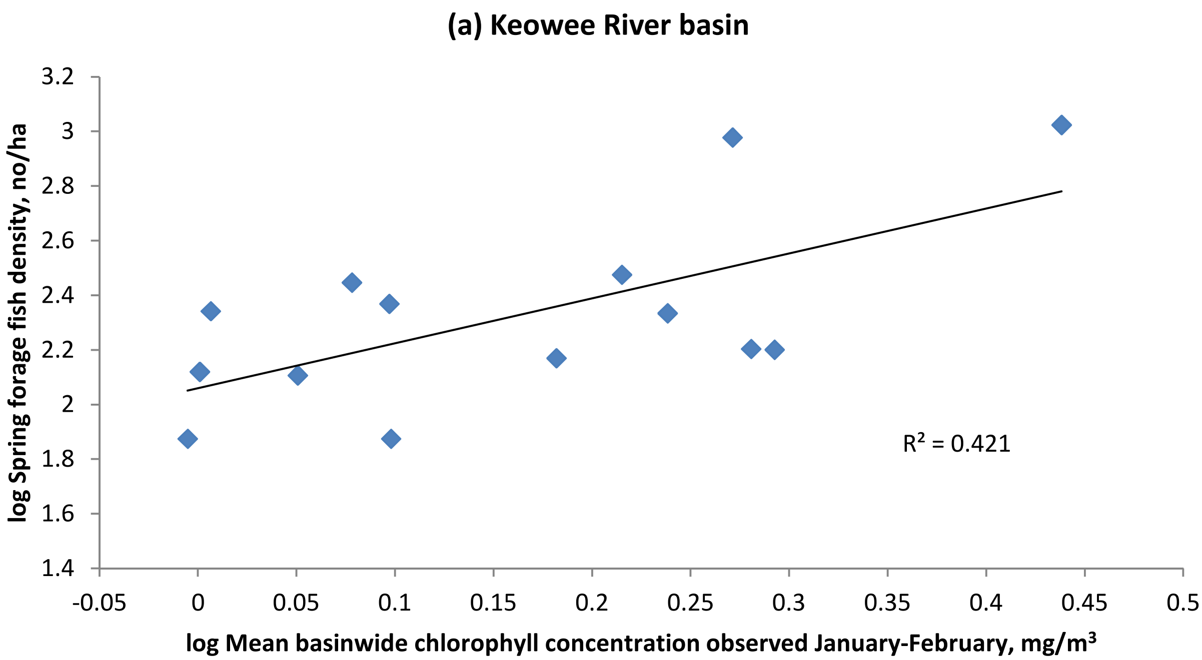


Figure 3-33. Total number of forage fish in Lake Keowee in spring vs. mean lakewide surface (0-10 m) chlorophyll concentration observed January-February, 1999-2013.



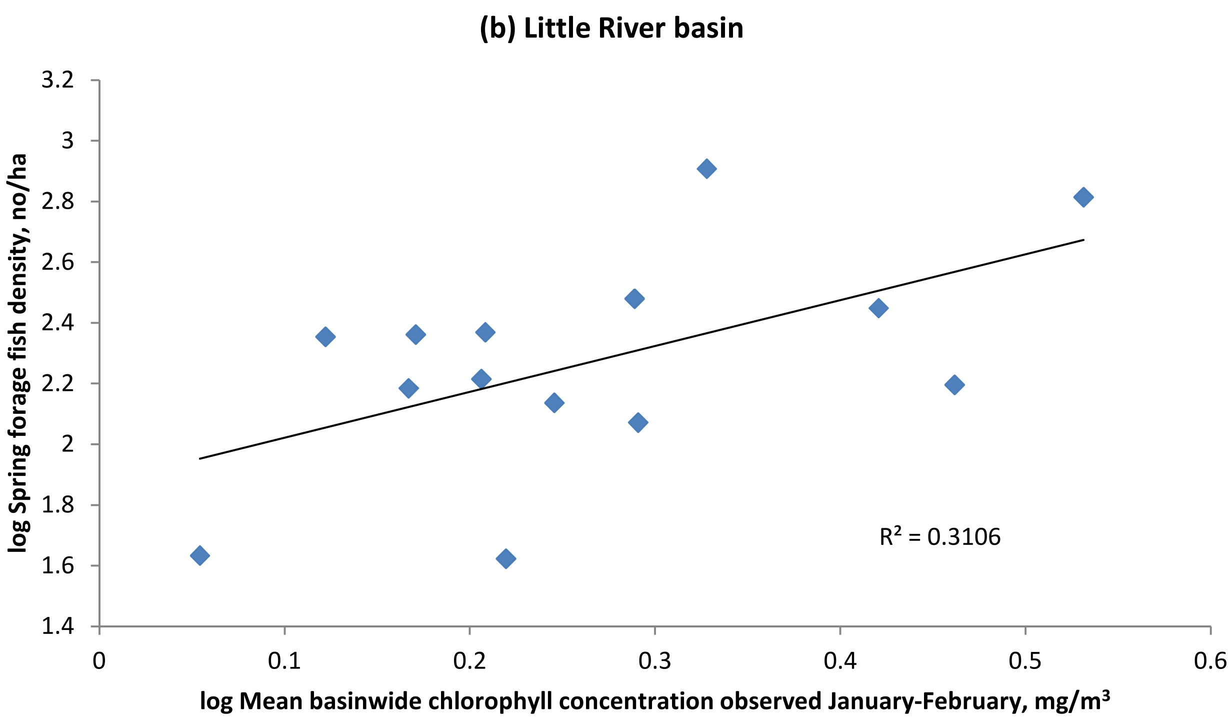


Figure 3-34. Spring forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. mean basinwide surface (0-10 m) chlorophyll concentrations observed January-February, 1999-2013.

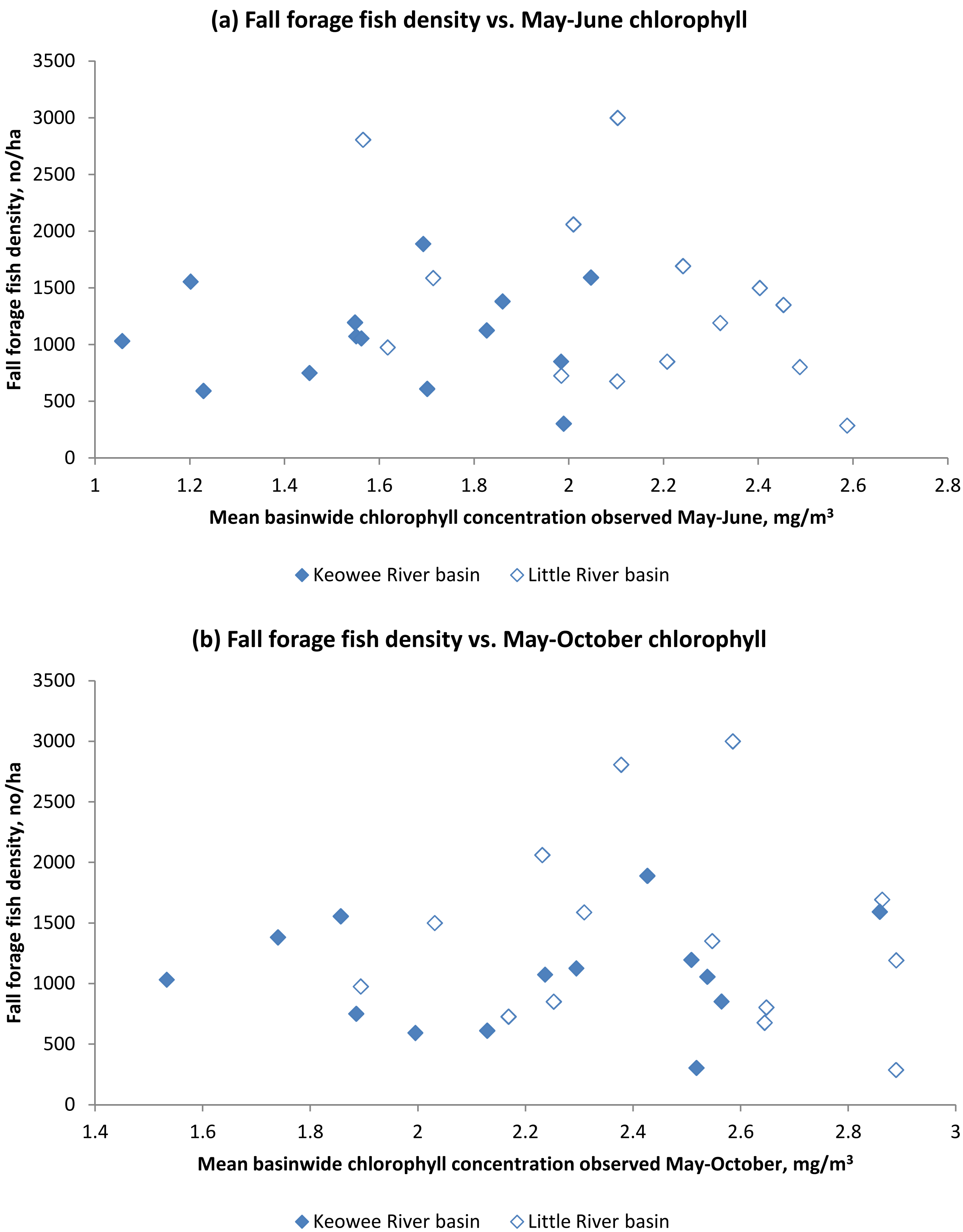


Figure 3-35. Fall forage fish densities in basins of Lake Keowee vs. mean basinwide surface (0-10 m) chlorophyll concentrations observed (a) May-June, and (b) May-October, 1999-2012.

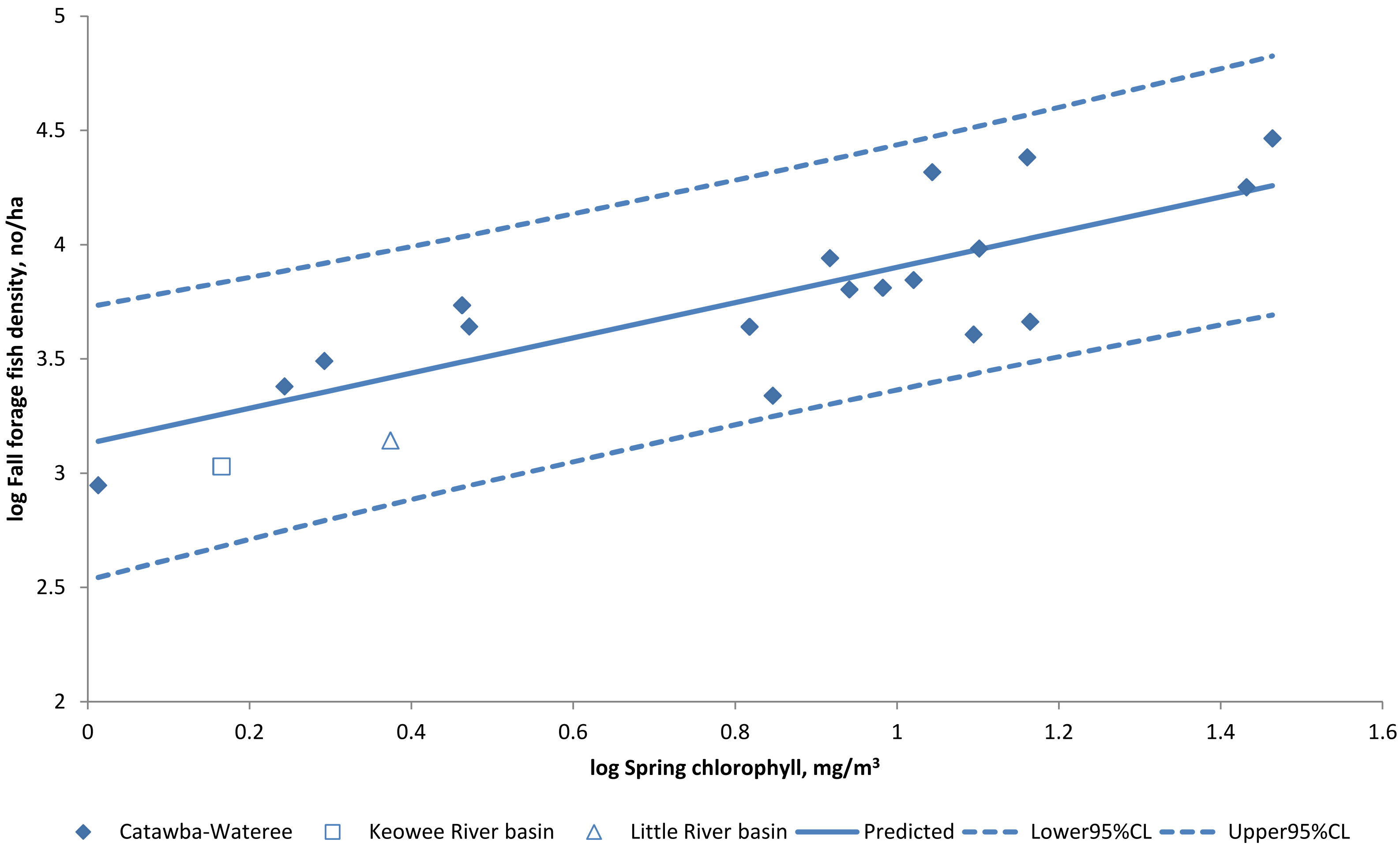


Figure 3-36. Mean of 1999-2012 data for April-May surface (0-5 m) basinwide chlorophyll concentration and fall forage fish density data for two basins of Lake Keowee, superimposed on a plot of a regression relating fall forage fish densities to mean April-May surface (0-5 m) chlorophyll concentrations. Regression was developed using data from 18 sites on nine reservoirs on the Catawba and Wateree Rivers in North and South Carolina (Rodriguez 2005). Regression equation: $\log_{10}$ Fall forage fish density (fish/ha) = 3.1303 + 0.7705 $\log_{10}$ Spring chlorophyll concentration (mg/m^3) (R^2=0.6339; Pr>F<0.0001; N=18). Basinwide mean chlorophyll concentrations for Lake Keowee were calculated using data from Locations 500 and 502 (Little River basin), and Locations 504 and 505 (Keowee River basin).

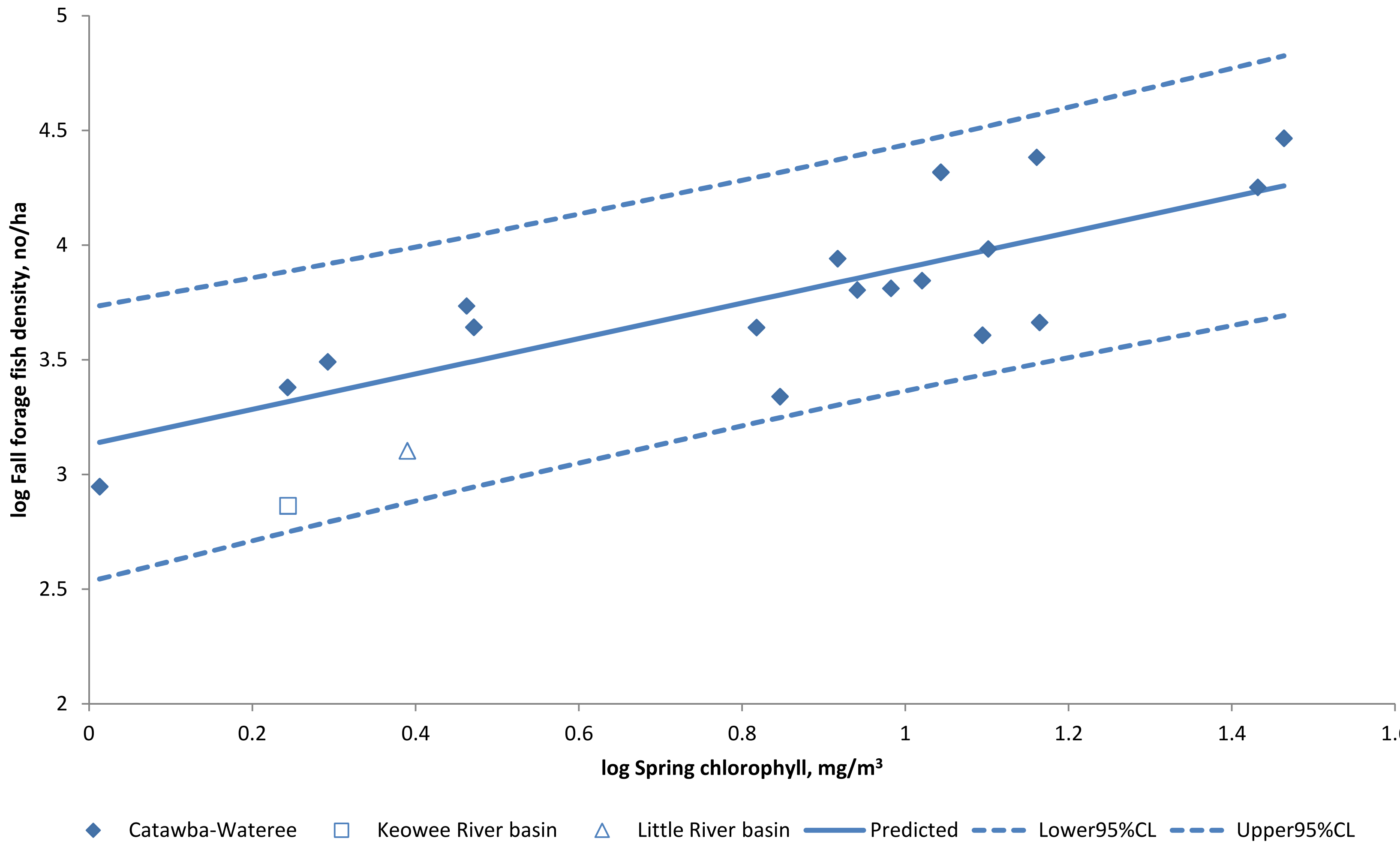


Figure 3-37. Mean April-May surface (0-5 m) basinwide chlorophyll concentrations and mean fall forage fish densities measured 2011-2012 on two basins of Lake Keowee, superimposed on a plot of a regression relating fall forage fish densities to mean April-May surface (0-5 m) chlorophyll concentrations. Regression was developed based on data from 18 sites on nine reservoirs on the Catawba and Wateree Rivers in North and South Carolina (Rodriguez 2005). Regression equation: $\log_{10}$ Fall forage fish density (fish/ha) = 3.1303 + 0.7705 $\log_{10}$ Spring chlorophyll concentration (mg/m^3) (R^2=0.6339; Pr>F<0.0001; N=18). Basinwide mean chlorophyll concentrations for Lake Keowee were calculated using data from Locations 500 and 502 (Little River basin), and Locations 504 and 505 (Keowee River basin).

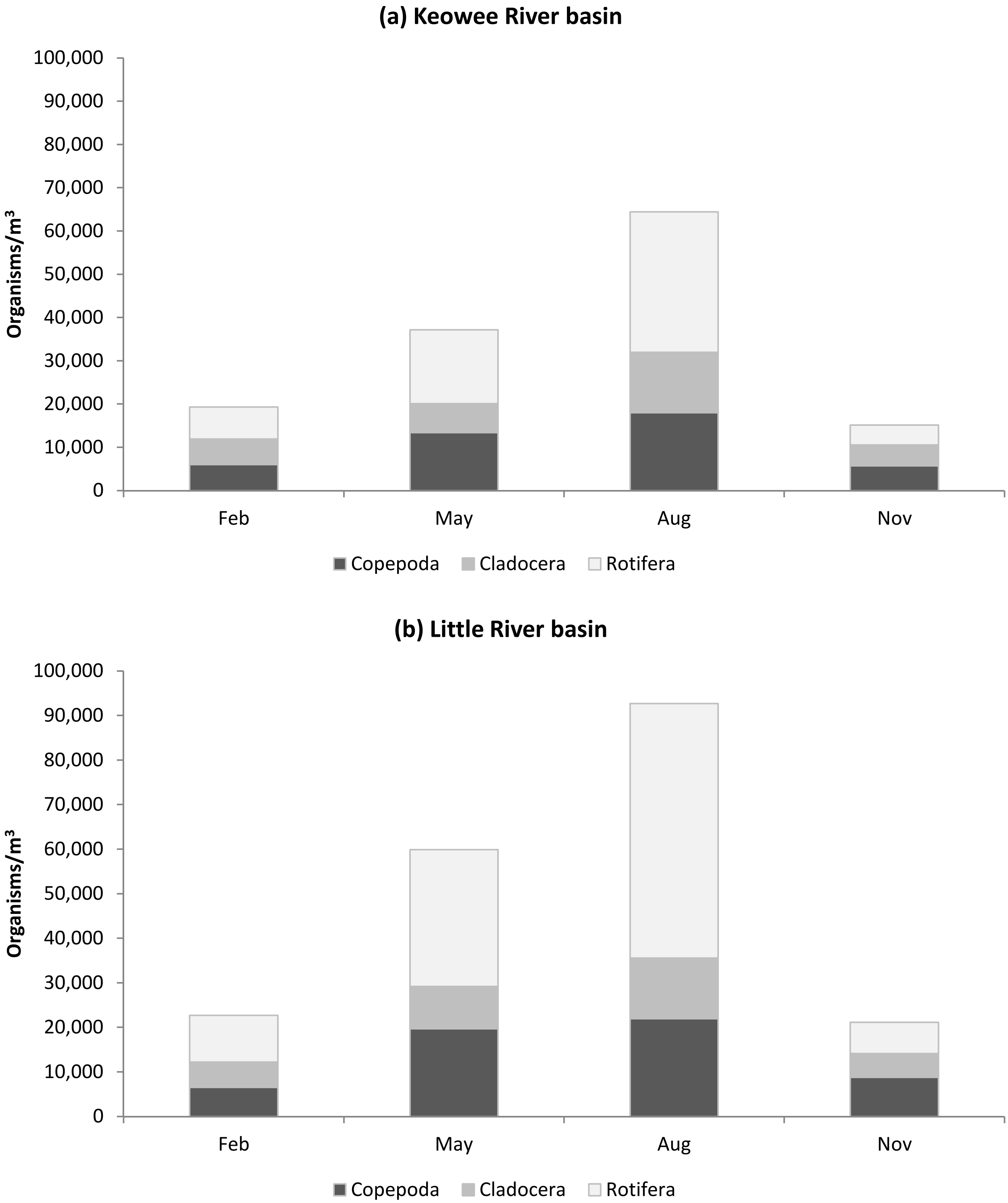


Figure 3-38. Mean seasonal variation in zooplankton densities in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, based on data collected 1999-2012 at Locations 508 (Keowee River basin) and 502 (Little River basin).

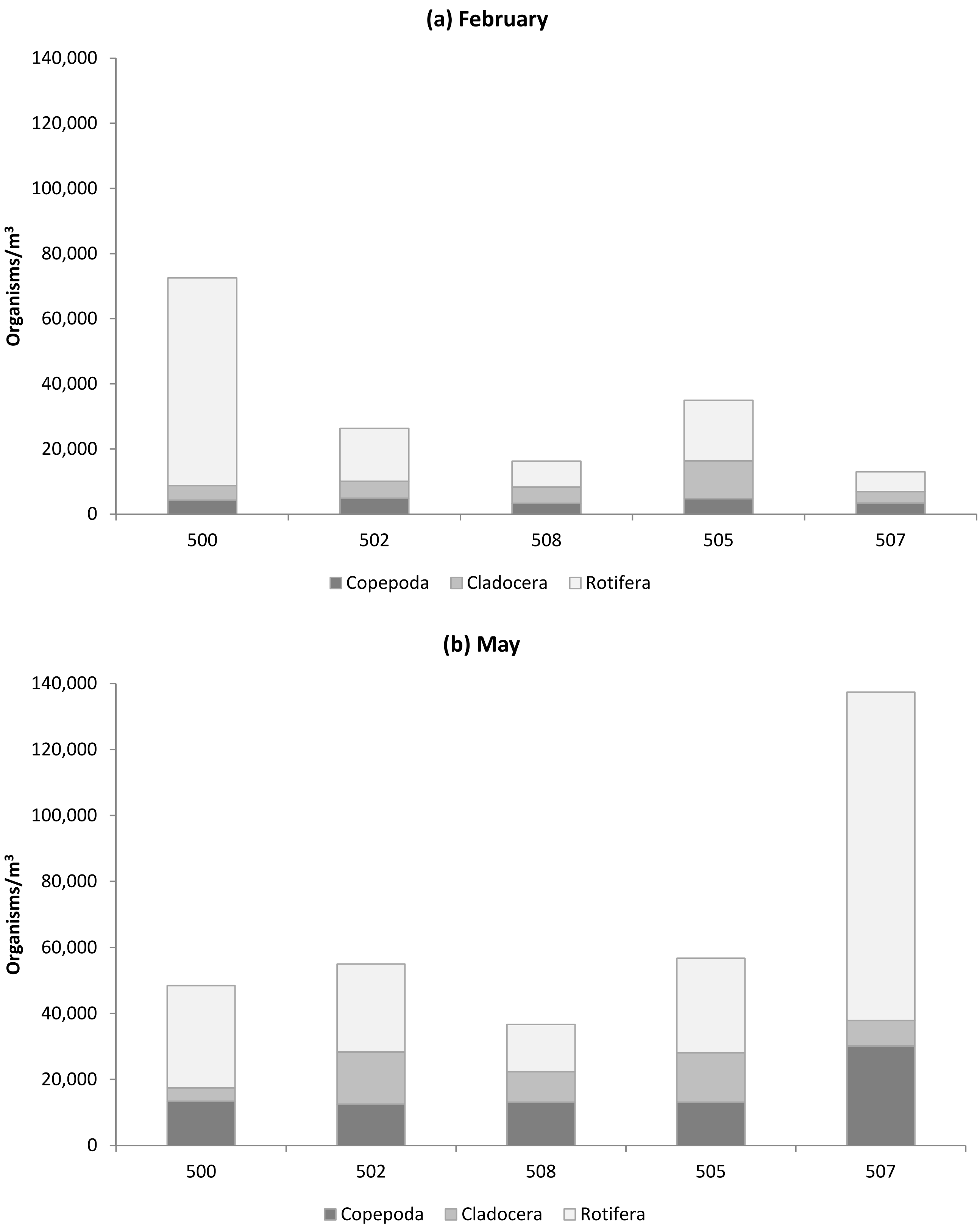
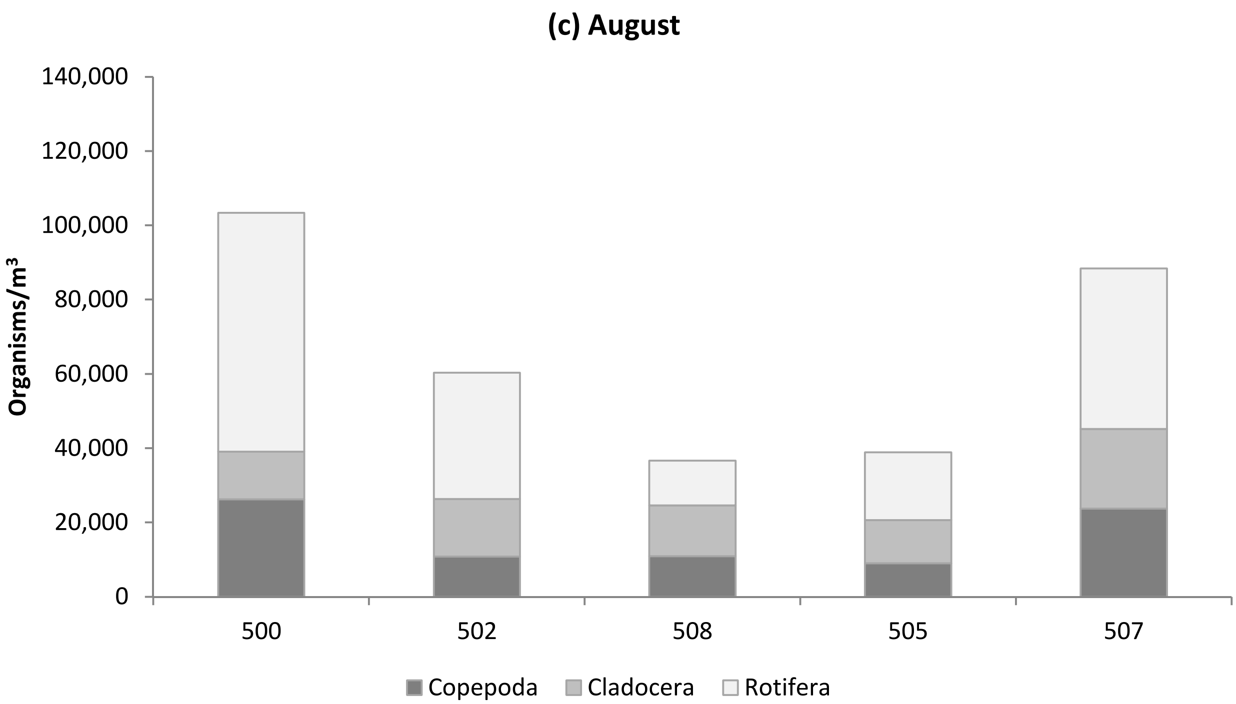


Figure 3-39 (page 1 of 2). Spatial variation in densities of major zooplankton taxa on Lake Keowee measured in (a) February, (b) May, (c) August, and (d) November 2012.



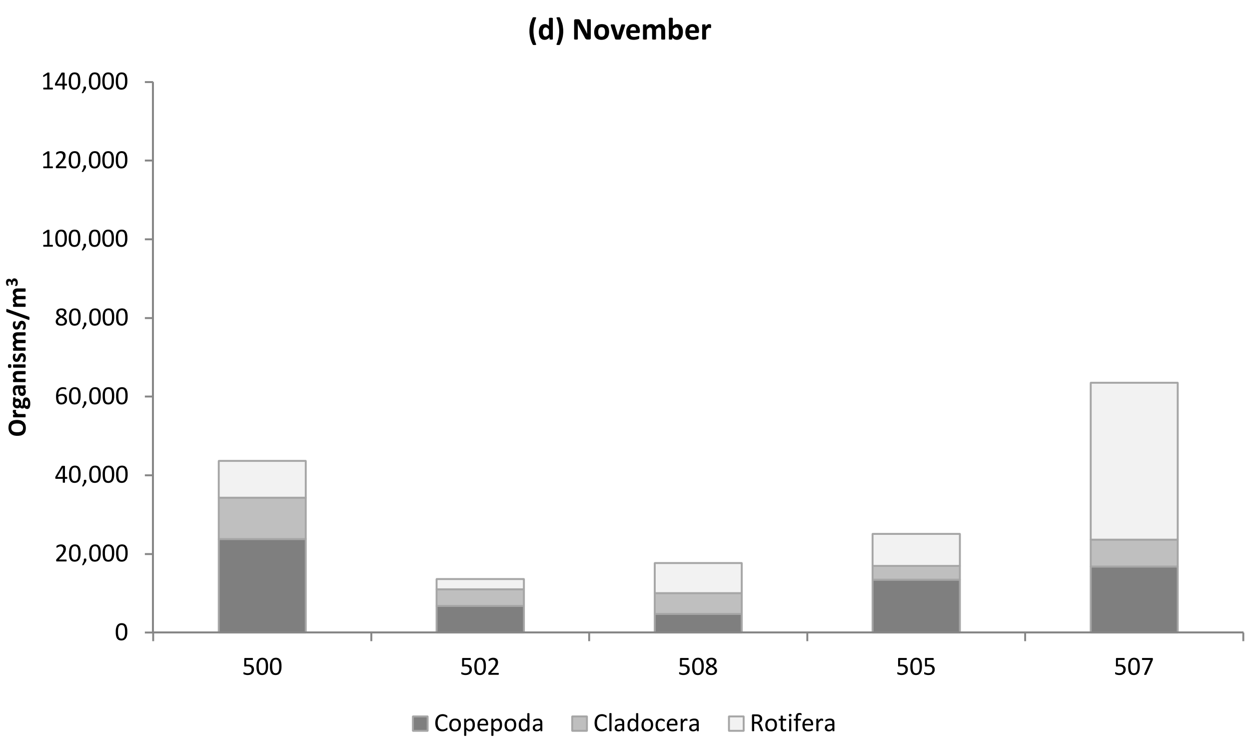


Figure 3-39 (page 2 of 2). Spatial variation in densities of major zooplankton taxa on Lake Keowee measured in (a) February, (b) May, (c) August, and (d) November 2012.

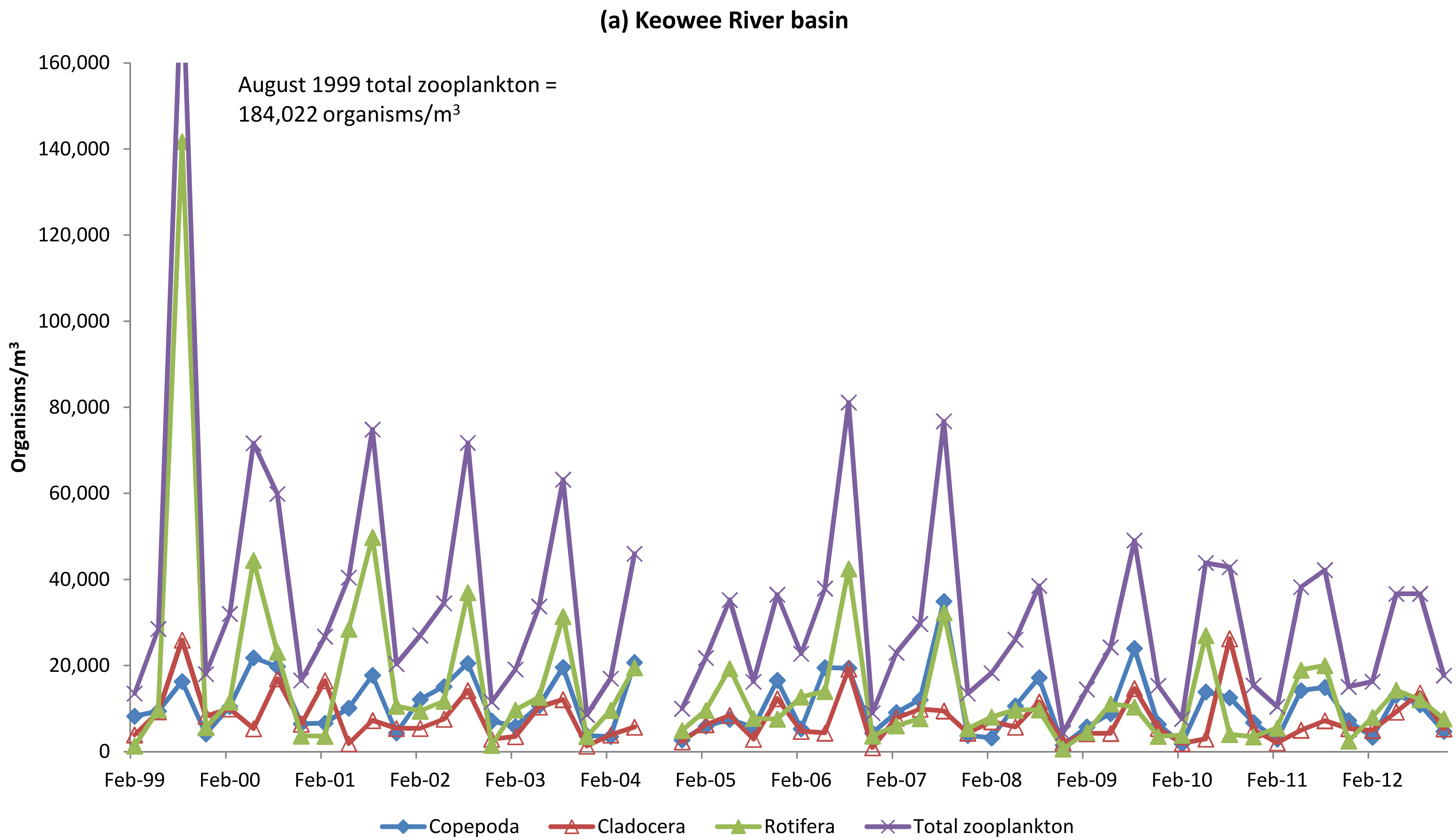


Figure 3-40 (page 1 of 2). Long-term variation in densities of major taxonomic groups of zooplankton in the (a) Keowee River basin (Location 508) and (b) Little River basin (Location 502) of Lake Keowee, February 1999 through November 2012.

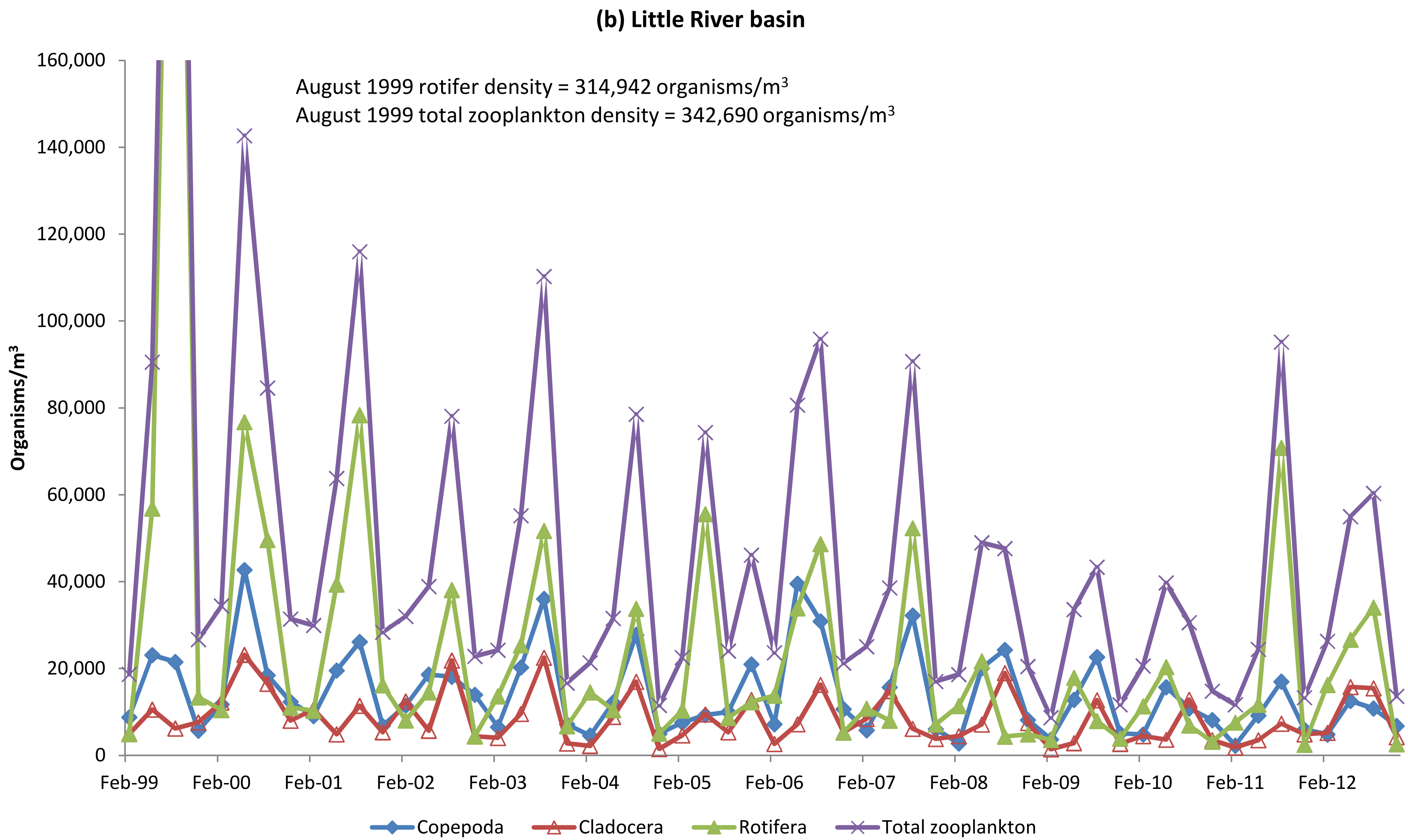


Figure 3-40 (page 2 of 2). Longterm variation in densities of major taxonomic groups of zooplankton in the (a) Keowee River basin (Location 508) and (b) Little River basin (Location 502) of Lake Keowee, February 1999 through November 2012.

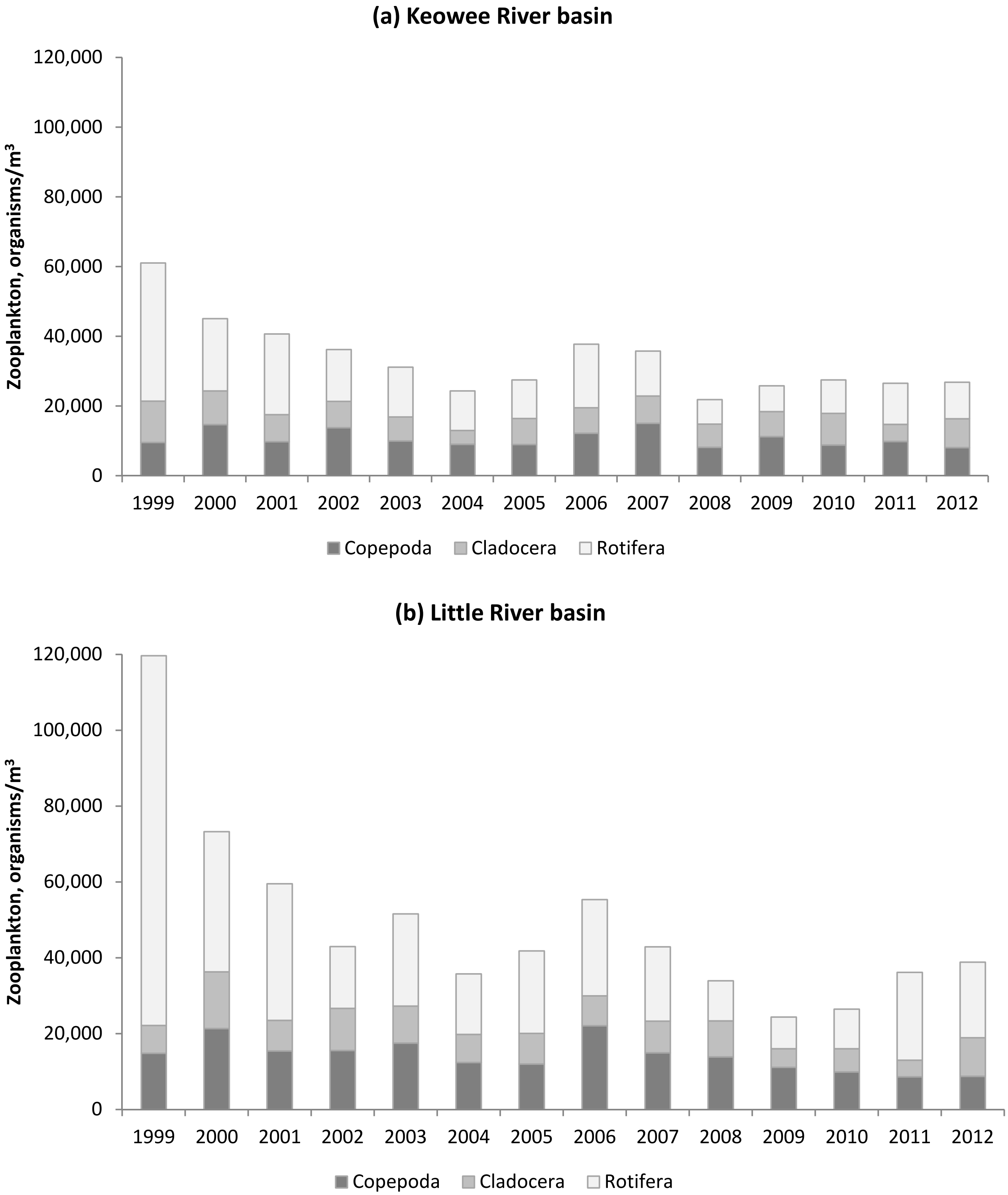


Figure 3-41. Long-term temporal variation in mean annual densities of zooplankton in the (a) Keowee River basin (Location 508) and (b) Little River basin (Location 502) of Lake Keowee, 1999-2012, based on data collected quarterly in February, May, August, and November.

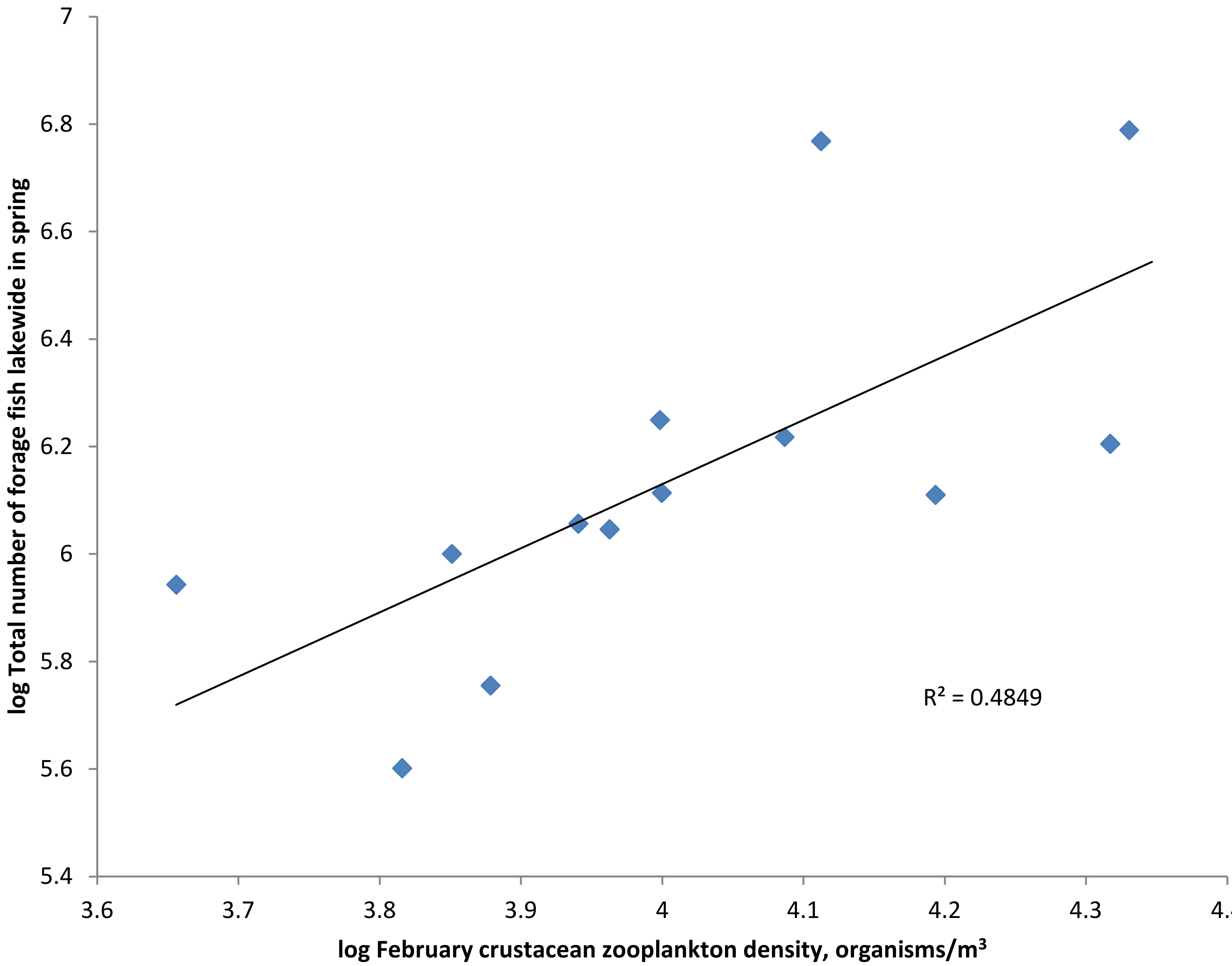
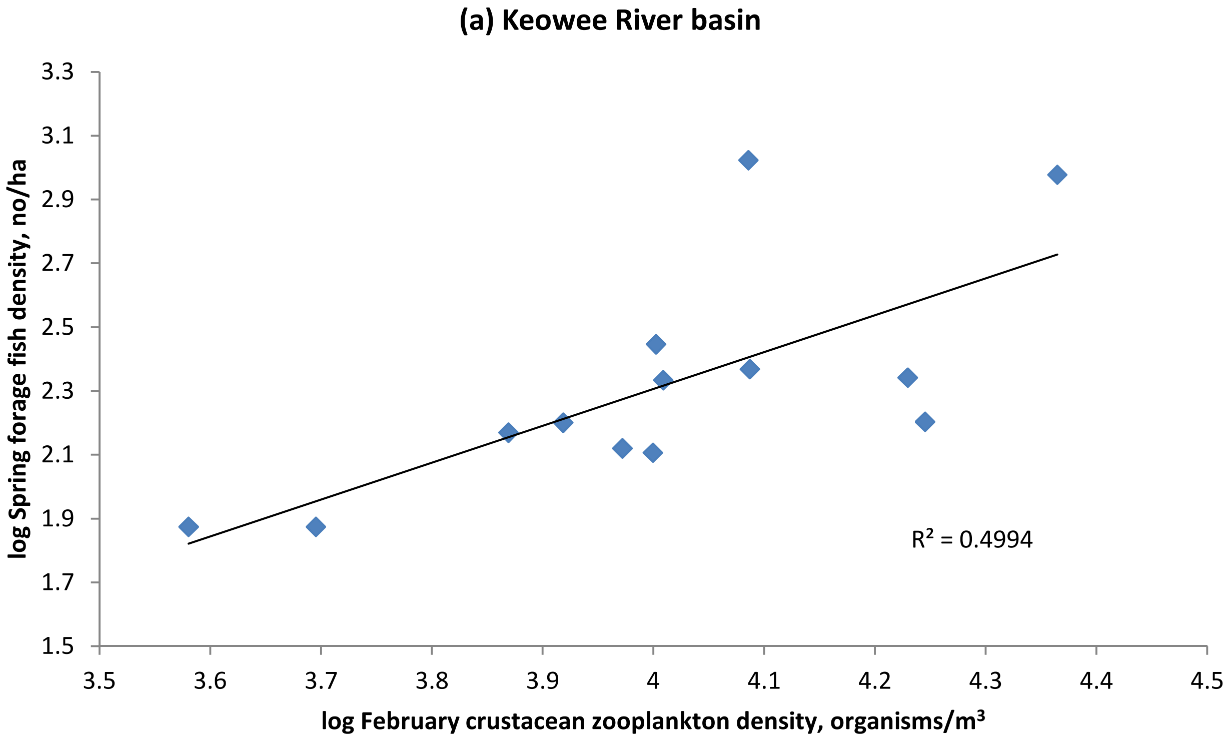


Figure 3-42. Total number of forage fish lakewide in Lake Keowee in spring, vs. mean lakewide density of crustacean zooplankton (sum of copepoda and cladoceran) in February, 1999-2012. Mean lakewide density of zooplankton was calculated based on data collected at Locations 502 and 508.



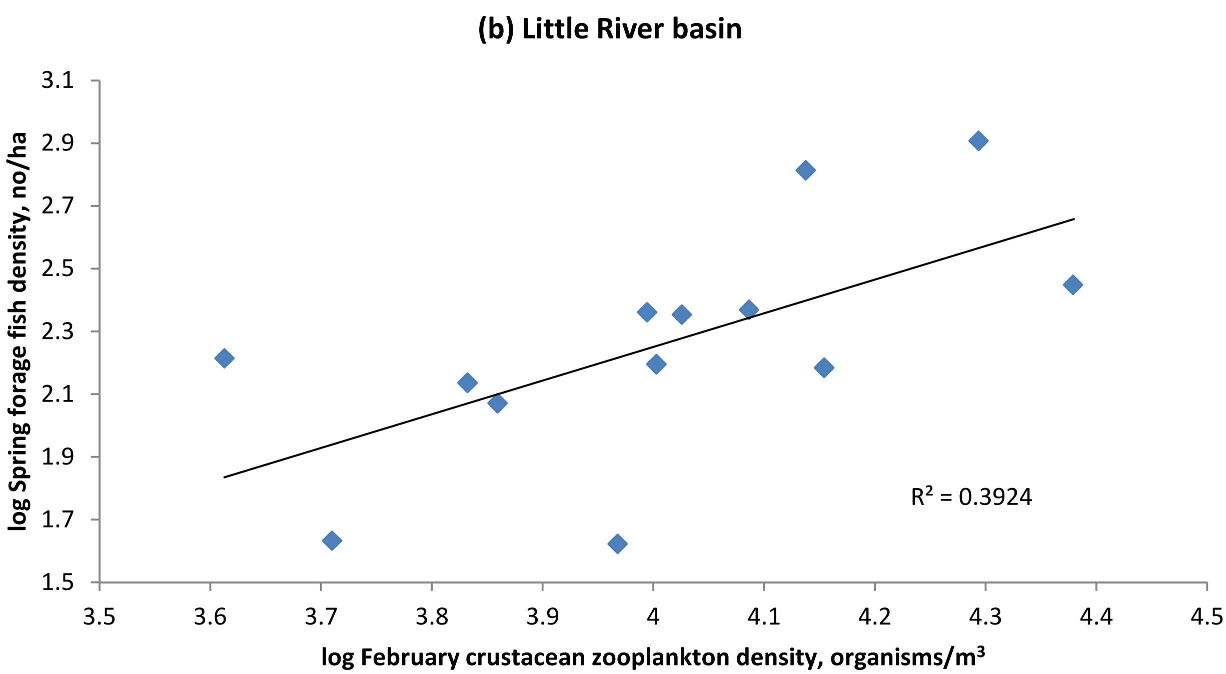


Figure 3-43. (a) Spring forage fish density in the Keowee River basin vs. density of crustacean zooplankton in February at Location 508; and (b) spring forage fish density in the Little River basin vs. density of crustacean zooplankton in February at Location 502, 1999-2012. Total crustacean zooplankton is the sum of copepoda and cladocera.

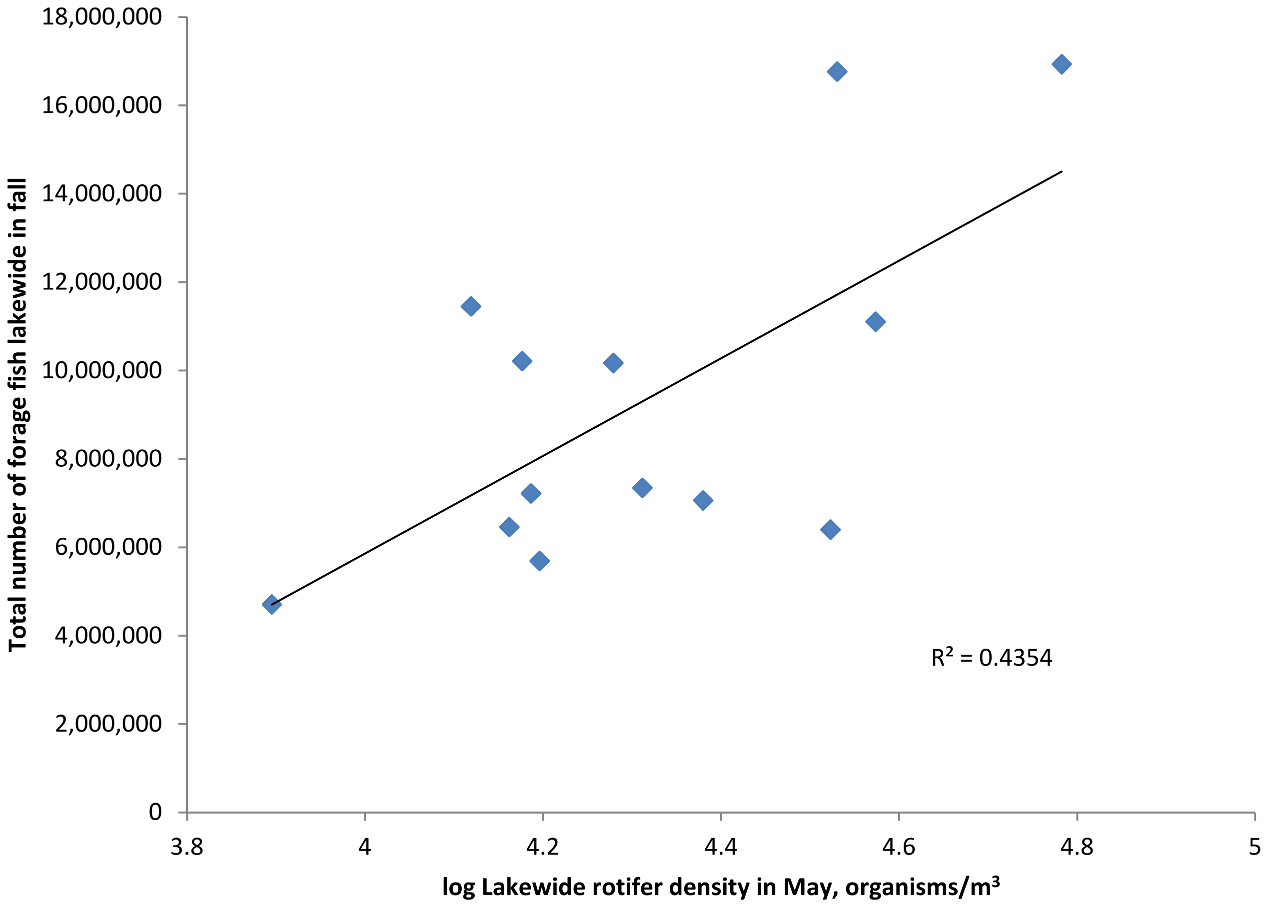


Figure 3-44. Total number of forage fish lakewide in fall on Lake Keowee vs. mean lakewide rotifer density in May, 1999-2012. Lakewide rotifer density was calculated as the mean of densities observed at Locations 502 and 508.

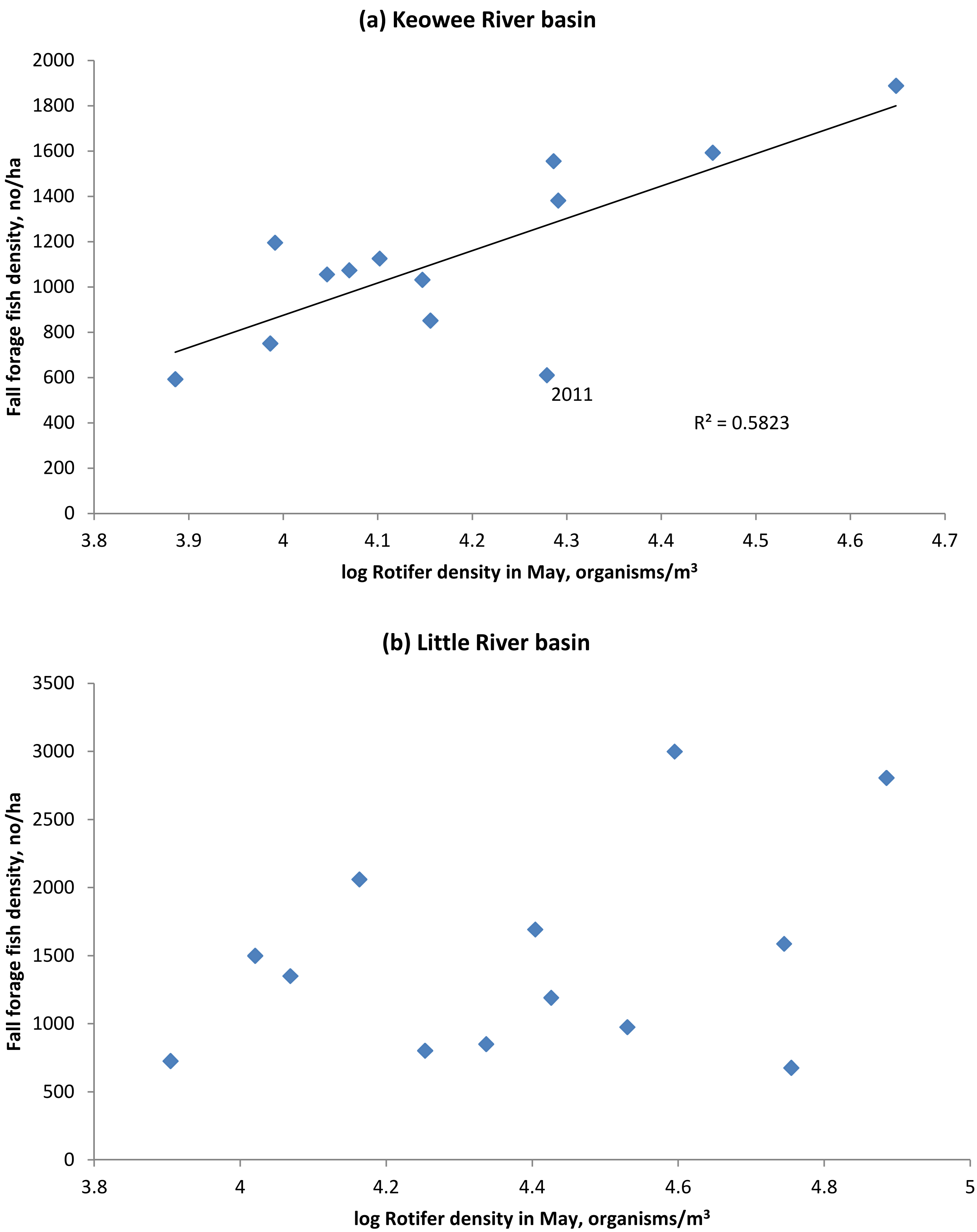
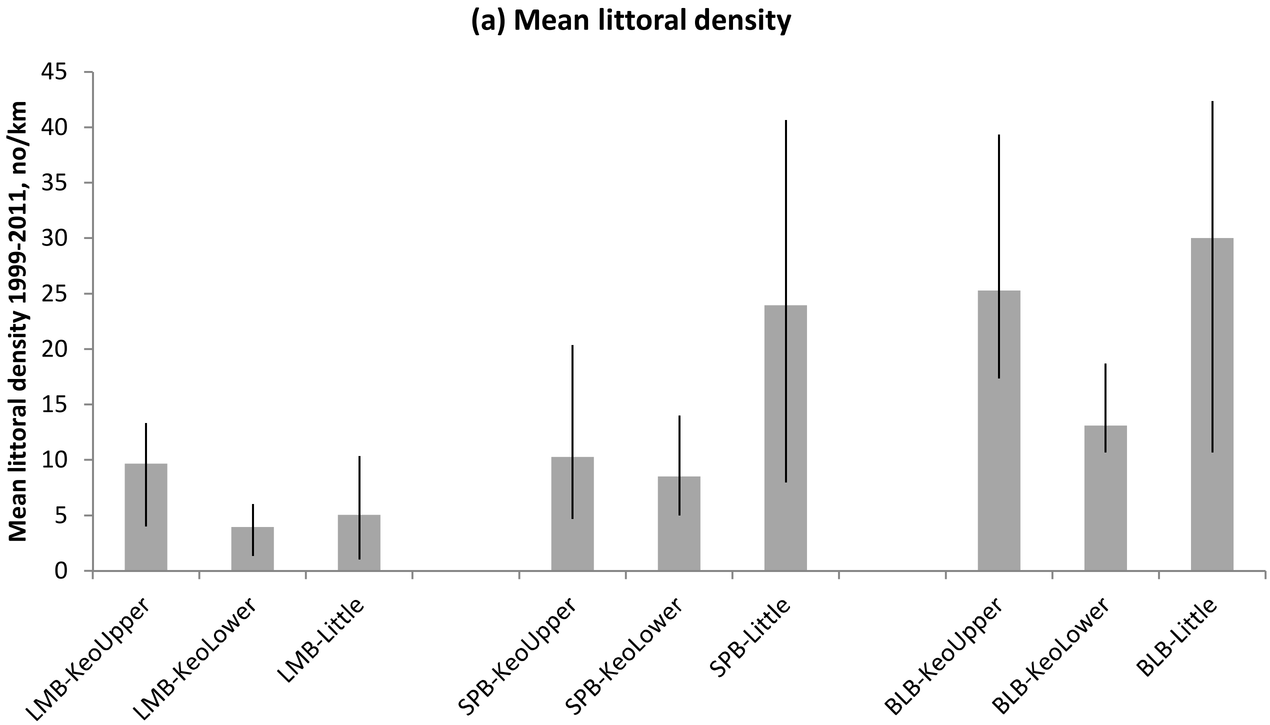


Figure 3-45. Fall forage fish densities in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. basin densities of rotifers in May, 1999-2012.



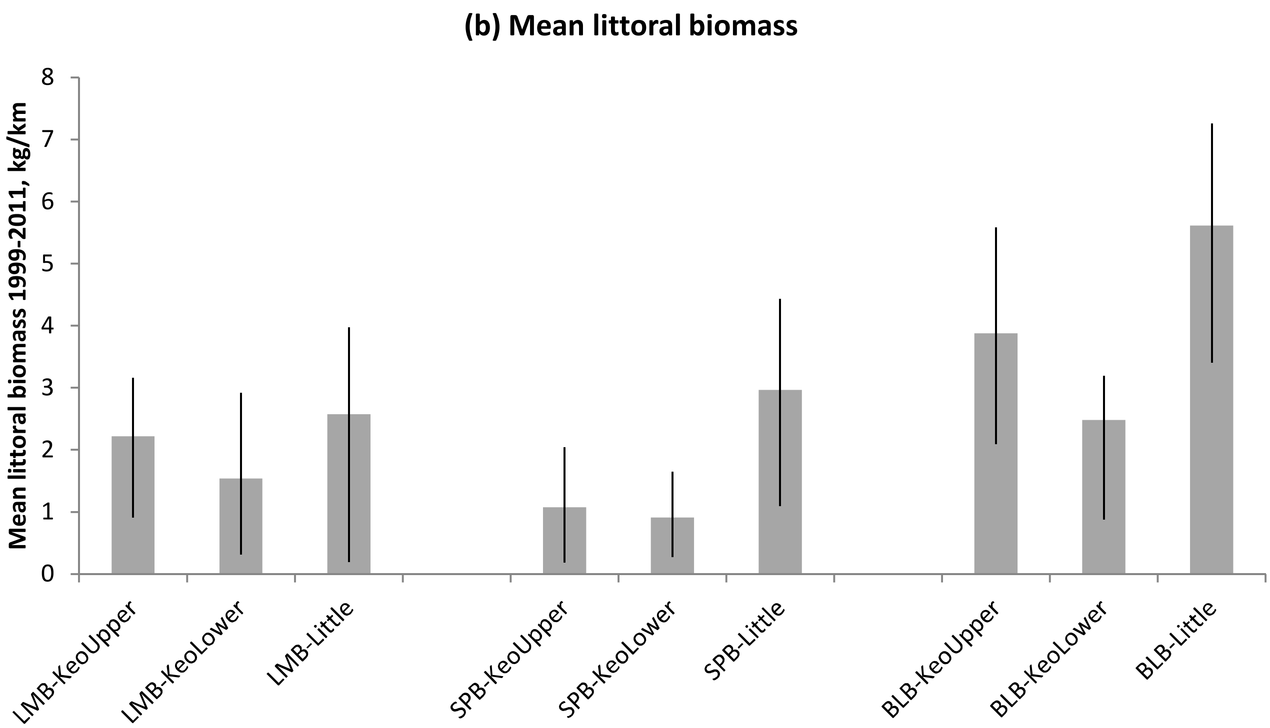


Figure 3-46. Littoral (a) density and (b) biomass of largemouth bass (LMB), spotted bass (SPB), and total black basses (BLB) from spring shoreline electrofishing, averaged over the years 1999-2011, in three areas of Lake Keowee: upper Keowee River basin (KeoUpper); lower Keowee River basin (KeoLower); and Little River basin (Little). Lines are bounded by minimum and maximum values.

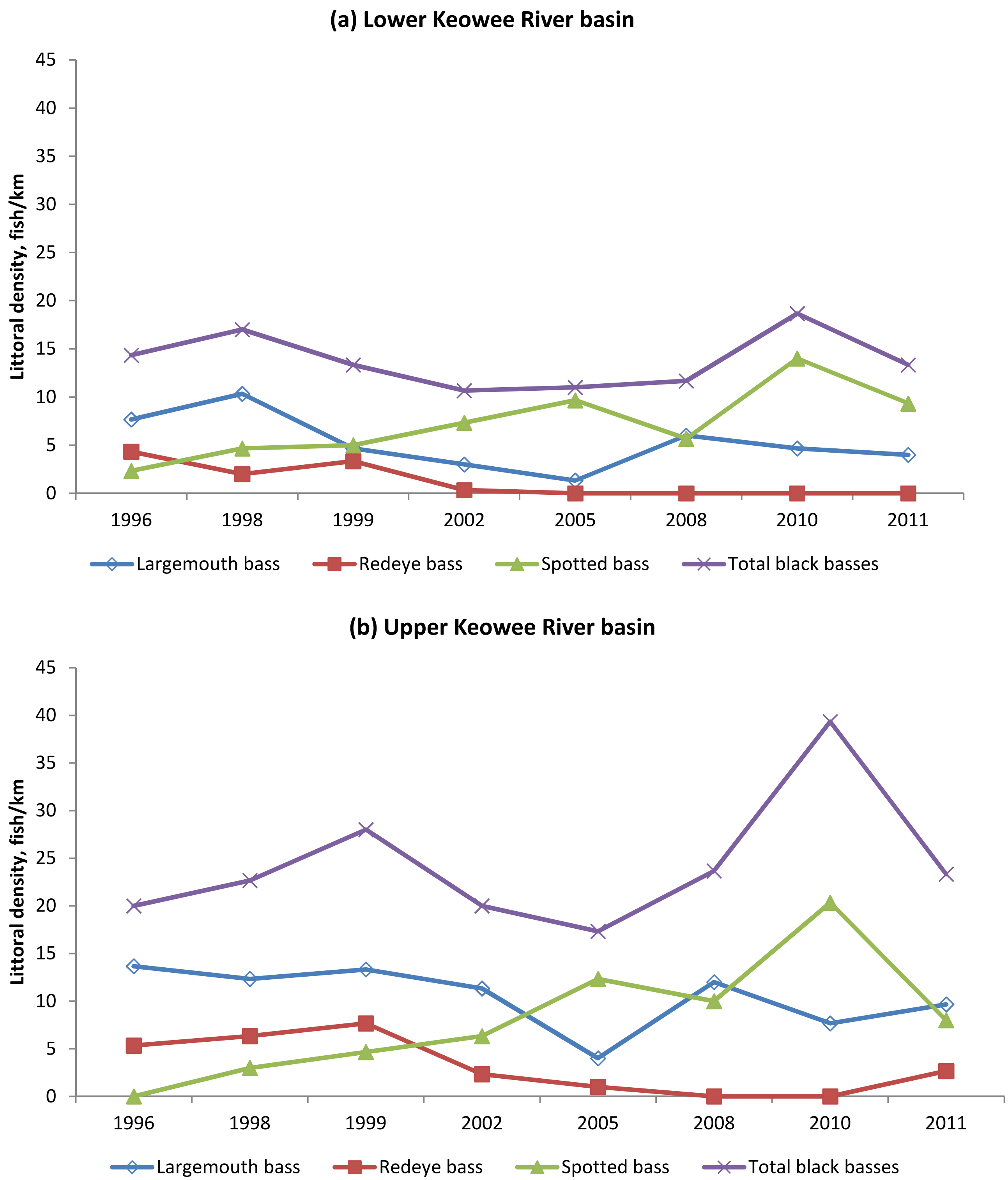


Figure 3-47 (page 1 of 2). Littoral density (no/km) of largemouth bass, redeye bass, spotted bass, and total black basses in the (a) Lower Keowee River basin; (b) Upper Keowee River basin; and (c) Little River basin of Lake Keowee, based on spring shoreline electrofishing carried out 1996, 1998, 1999, 2002, 2005, 2008, 2010, and 2011 (note scale of x-axis is discontinuous).

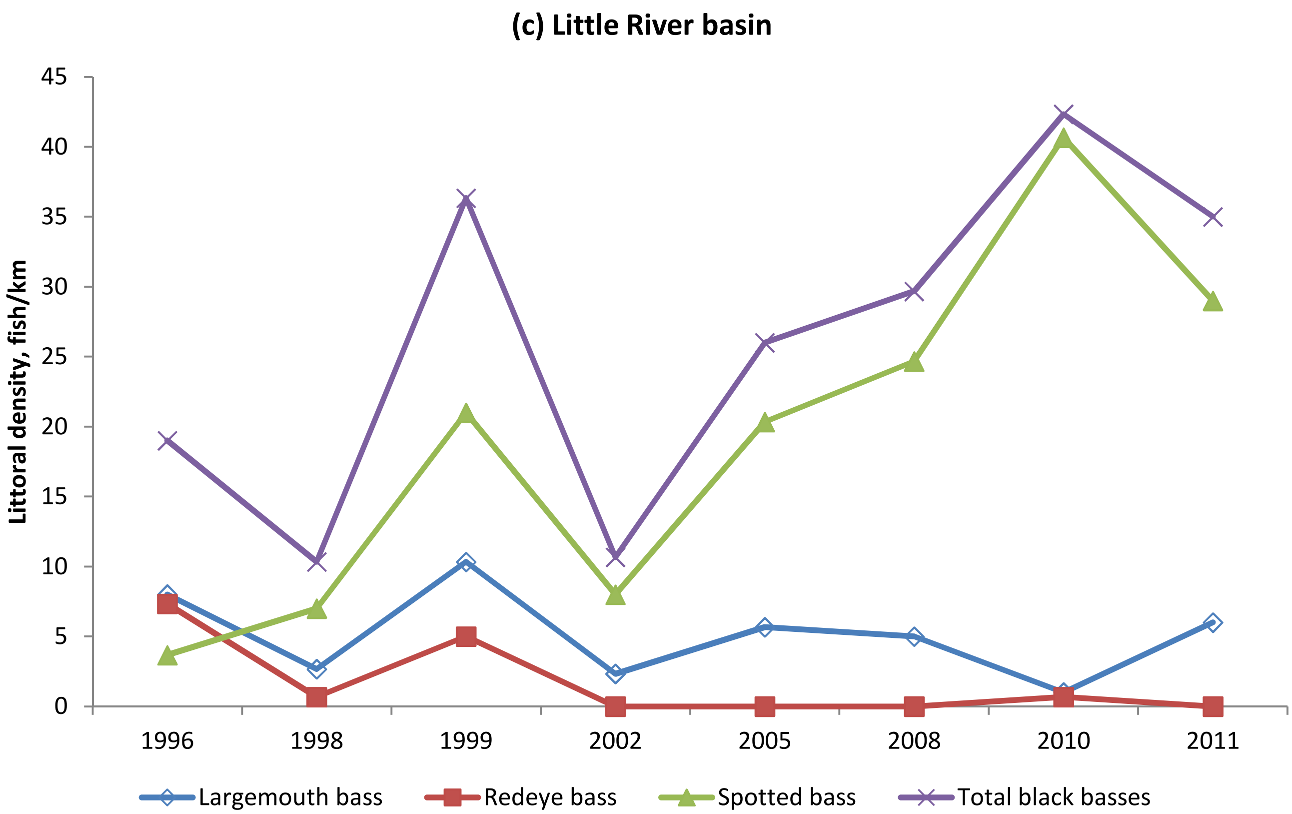


Figure 3-47 (page 2 of 2). Littoral density (no/km) of largemouth bass, redeye bass, spotted bass, and total black basses in the (a) Lower Keowee River basin; (b) Upper Keowee River basin; and (c) Little River basin of Lake Keowee, based on spring shoreline electrofishing carried out 1996, 1998, 1999, 2002, 2005, 2008, 2010, and 2011 (note scale of x-axis is discontinuous).

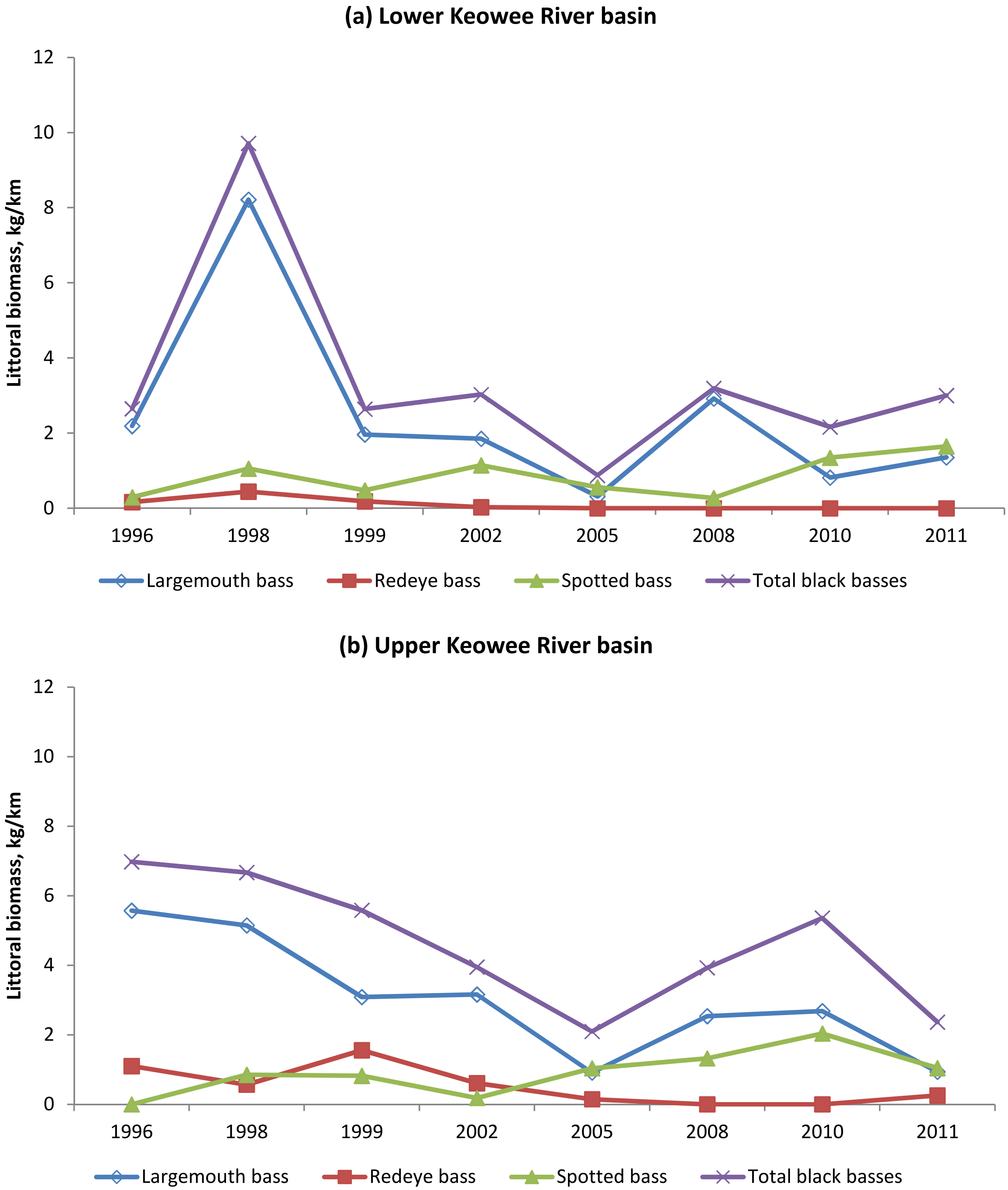


Figure 3-48 (page 1 of 2). Littoral biomass (kg/km) of largemouth bass, redeye bass, spotted bass, and total black basses in the (a) Lower Keowee River basin; (b) Upper Keowee River basin; and (c) Little River basin of Lake Keowee, based on spring shoreline electrofishing carried out 1996, 1998, 1999, 2002, 2005, 2008, 2010, and 2011 (note scale of x-axis is discontinuous).

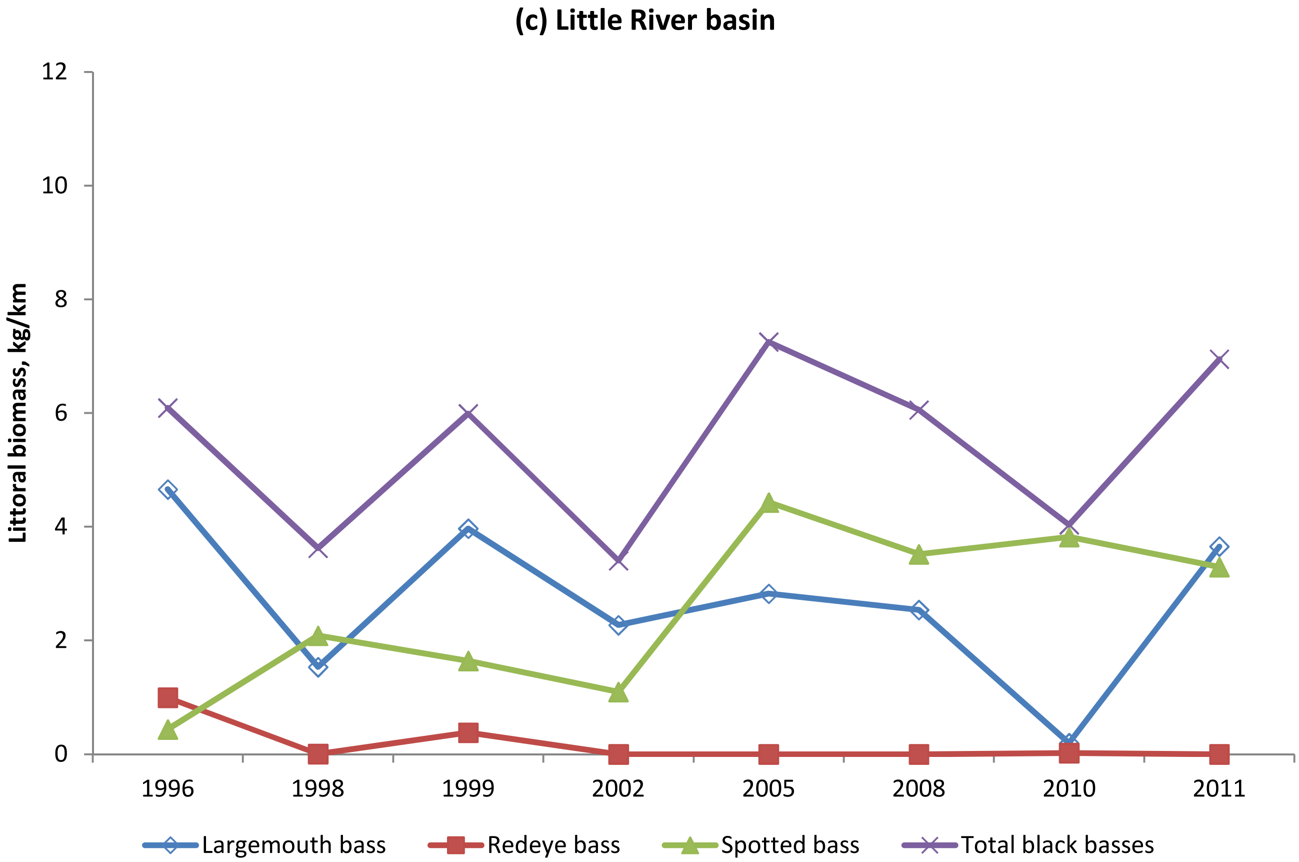
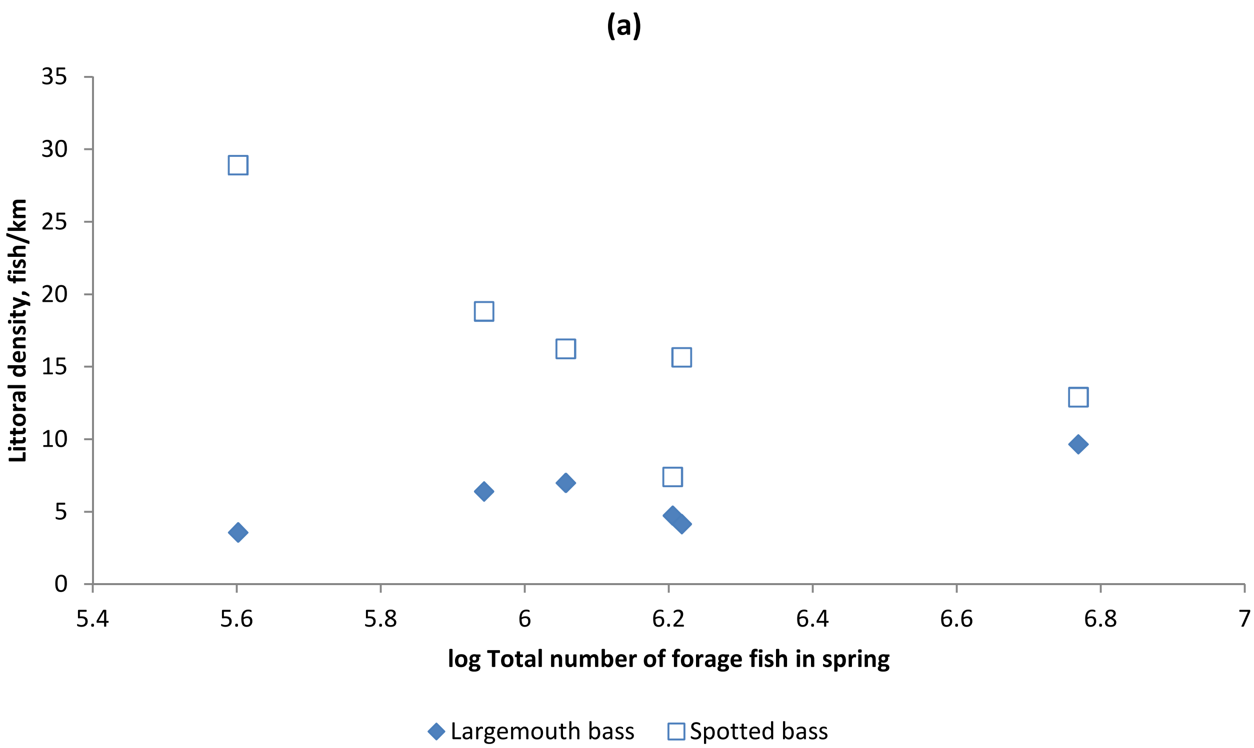


Figure 3-48 (page 2 of 2). Littoral biomass (kg/km) of largemouth bass, redeye bass, spotted bass, and total black basses in the (a) Lower Keowee River basin; (b) Upper Keowee River basin; and (c) Little River basin of Lake Keowee, based on spring shoreline electrofishing carried out 1996, 1998, 1999, 2002, 2005, 2008, 2010, and 2011 (note scale of x-axis is discontinuous).



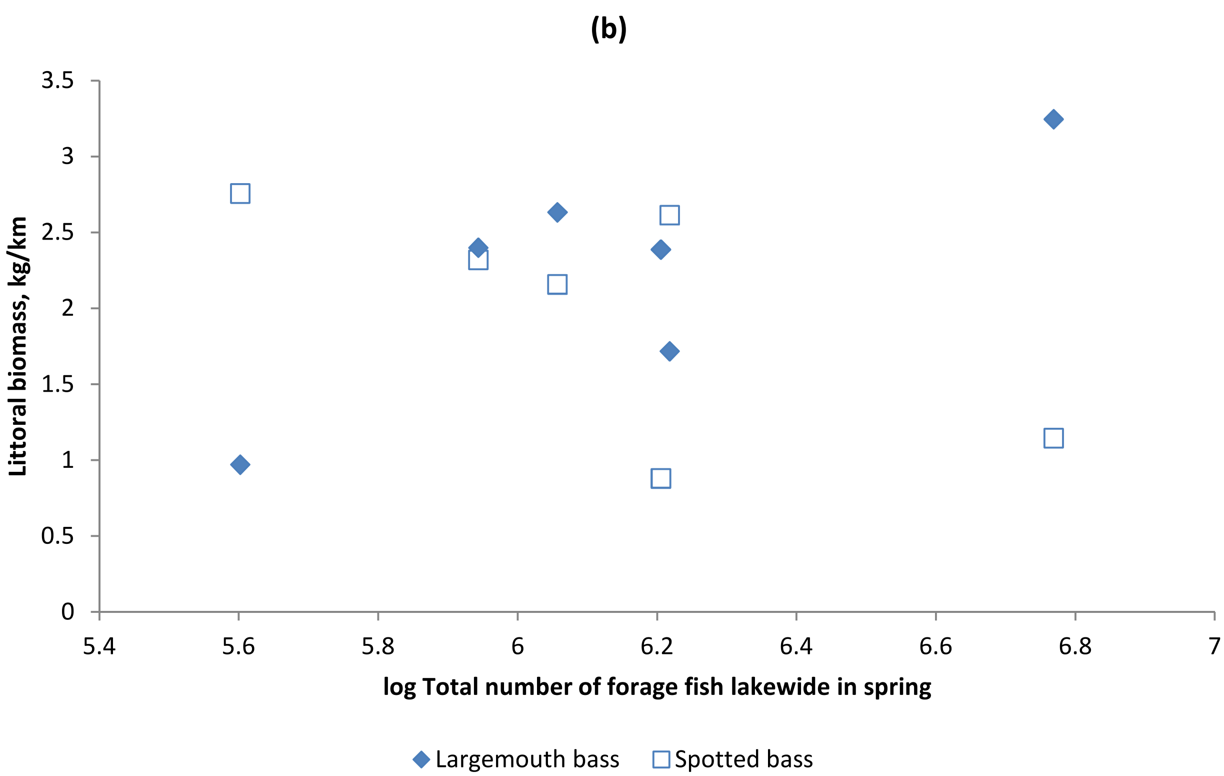
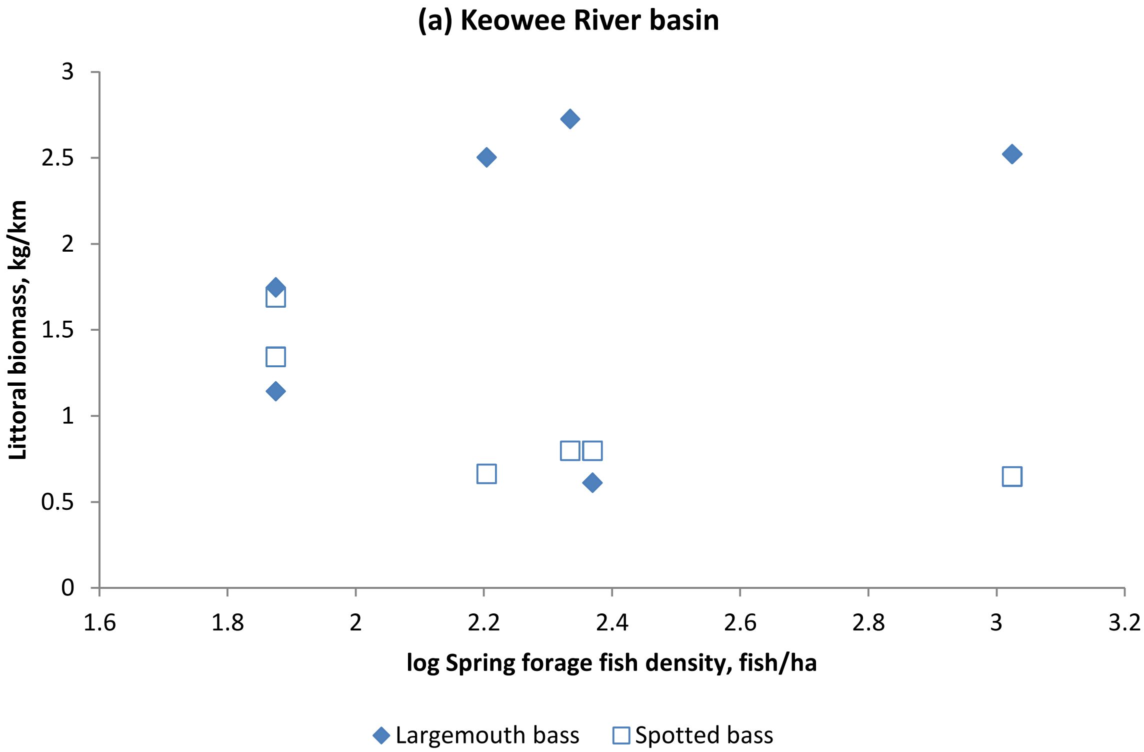


Figure 3-49. Littoral (a) density and (b) biomass of largemouth bass and spotted bass on Lake Keowee as measured in spring shoreline electrofishing, vs. total number of forage fish lakewide in spring, based on data collected 1999, 2002, 2005, 2008, 2010, and 2011.



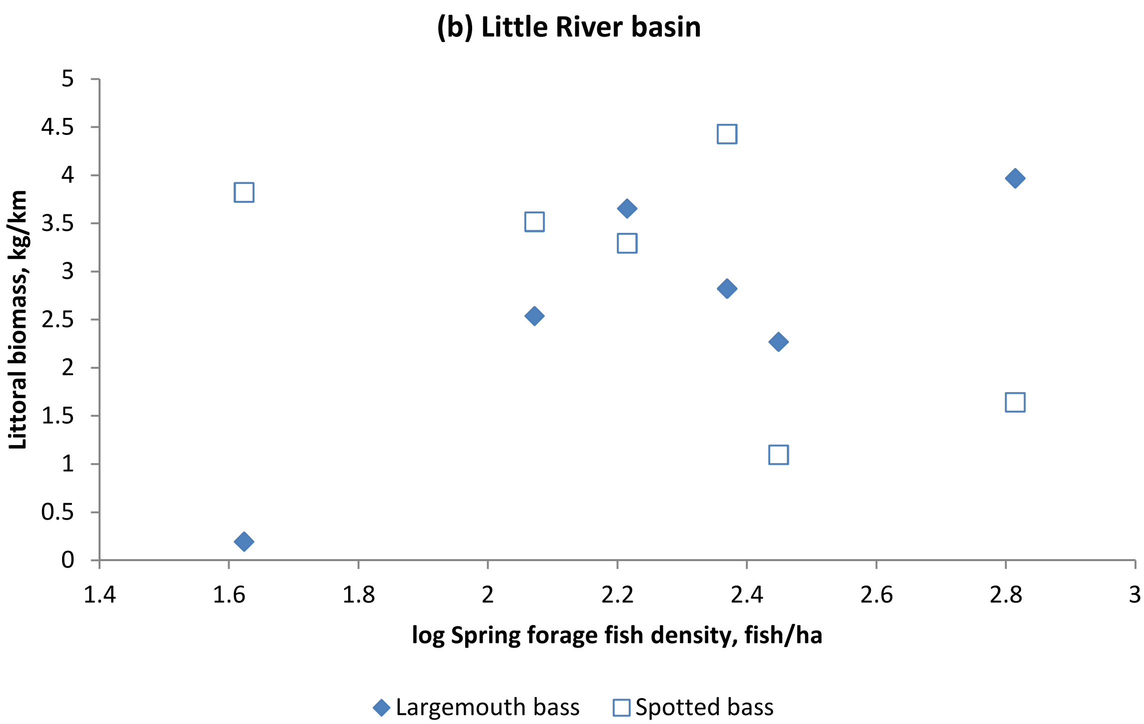


Figure 3-50. Littoral biomass of largemouth bass and spotted bass as measured in spring shoreline electrofishing, vs. spring forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, based on data collected 1999, 2002, 2005, 2008, 2010, and 2011.

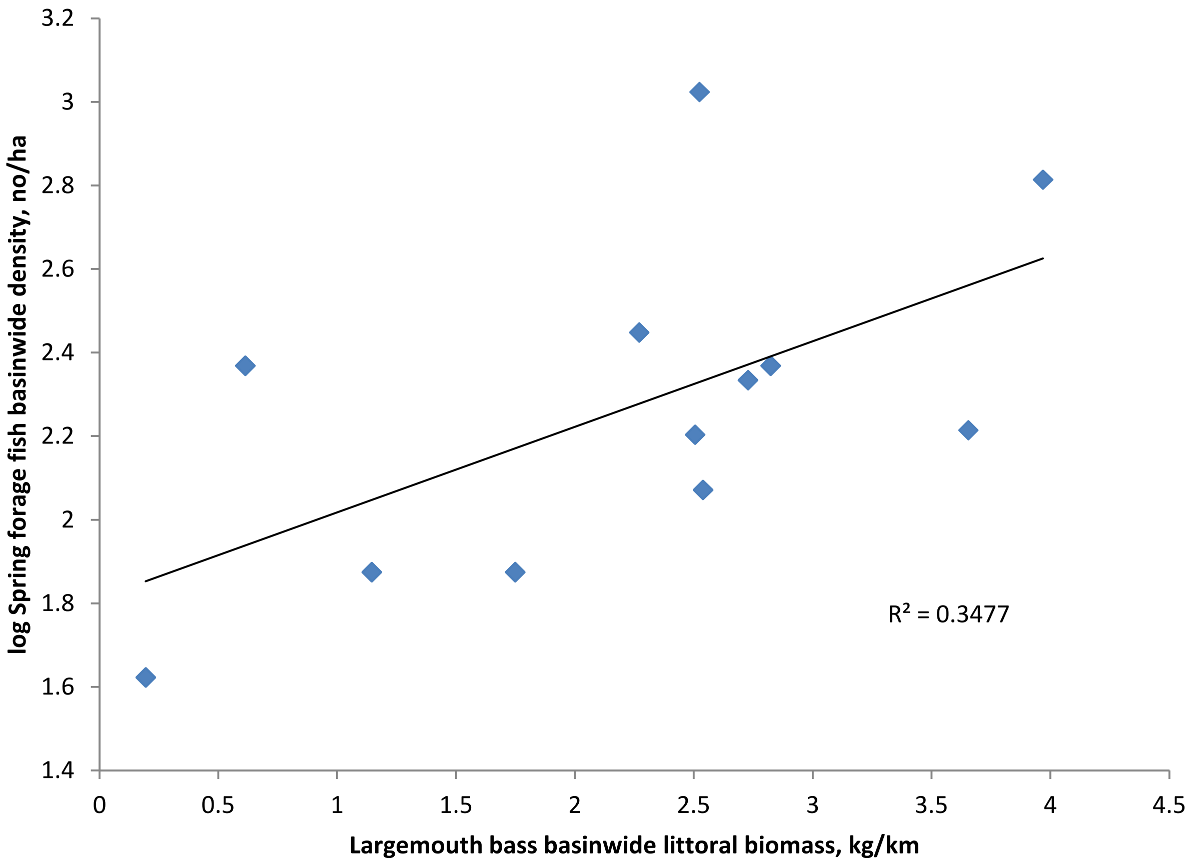


Figure 3-51. Spring forage fish densities in the Keowee River and Little River basins of Lake Keowee vs. basinwide mean littoral biomass of largemouth bass, based on hydroacoustics and electrofishing data collected 1999, 2002, 2005, 2008, 2010, and 2011.

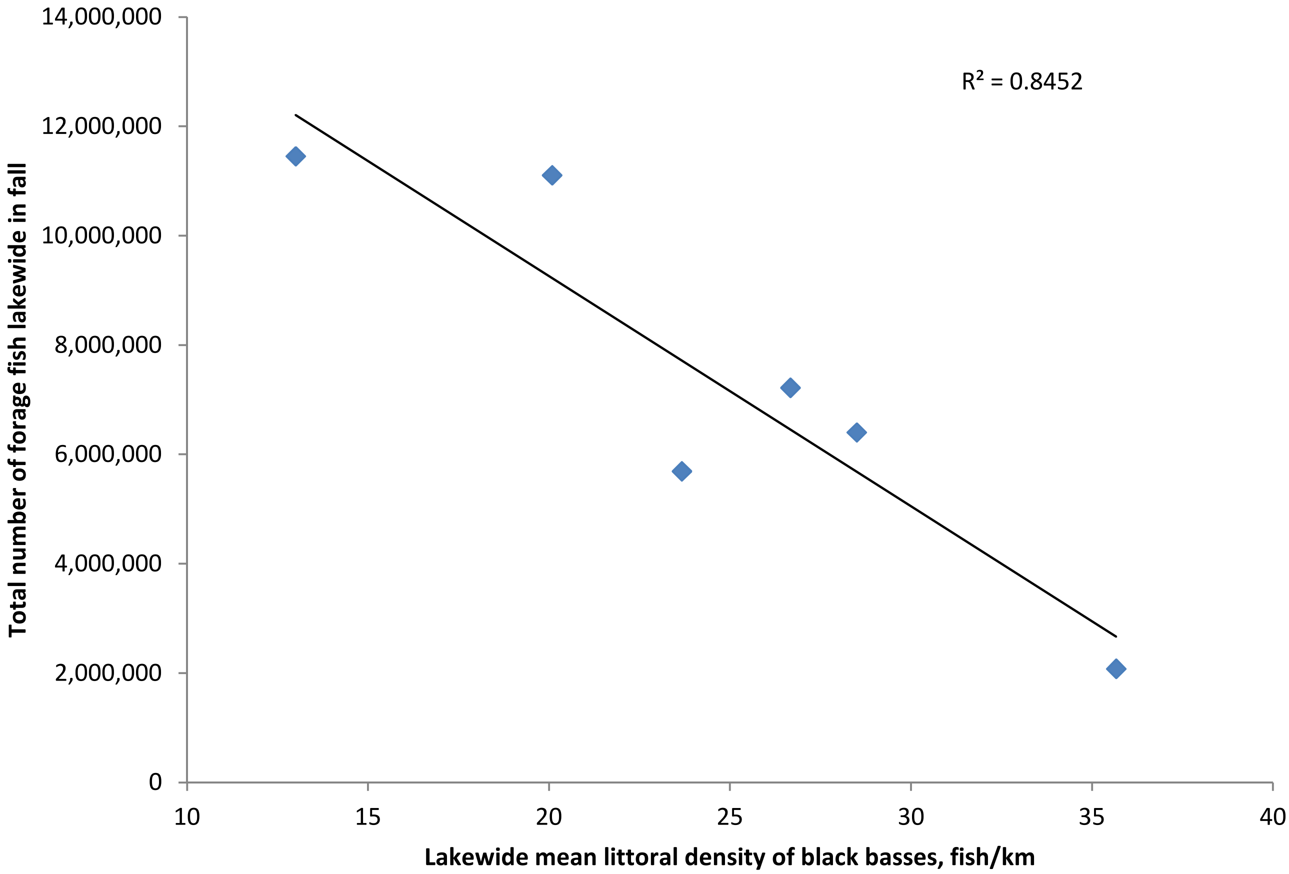
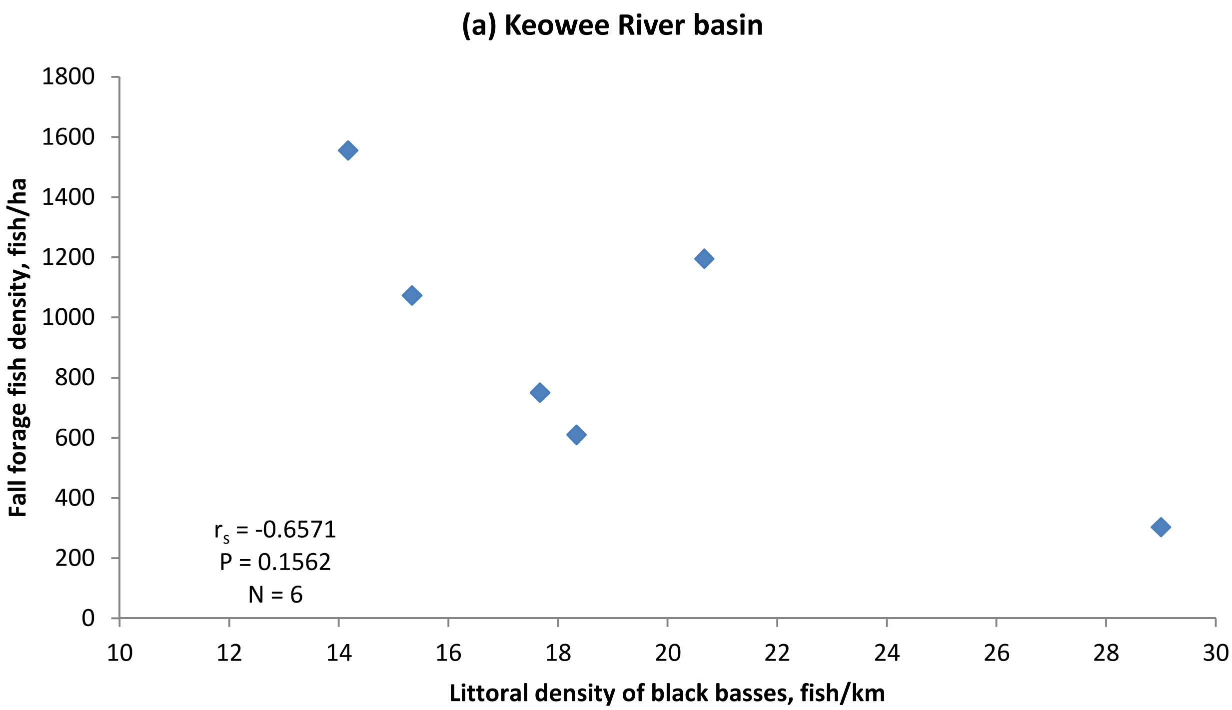


Figure 3-52. Total number of forage fish lakewide in fall on Lake Keowee vs. lakewide mean littoral density of black basses, based on spring shoreline electrofishing in the upper and lower Keowee River basin and the Little River basin, 1999, 2002, 2005, 2008, 2010, and 2011.



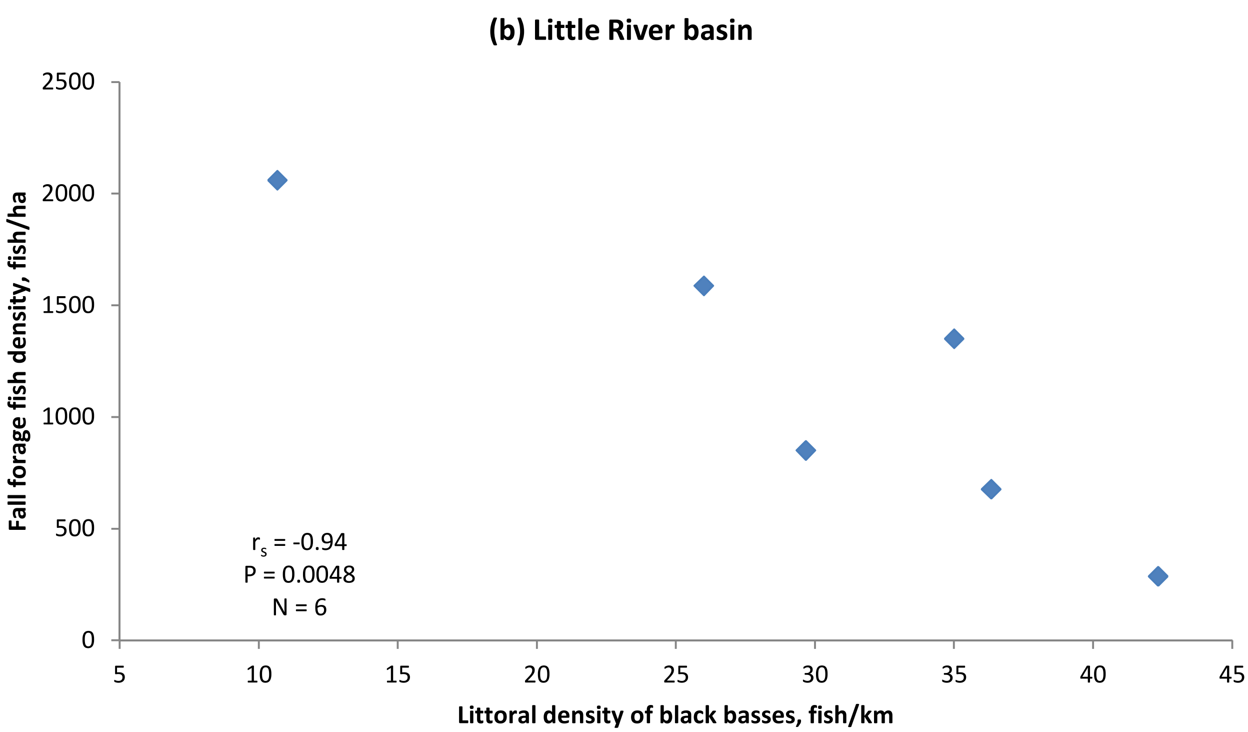


Figure 3-53. Fall forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee vs. basin mean littoral density of black basses measured in spring shoreline electrofishing carried out on Lake Keowee in 1999, 2002, 2005, 2008, 2010, and 2011.

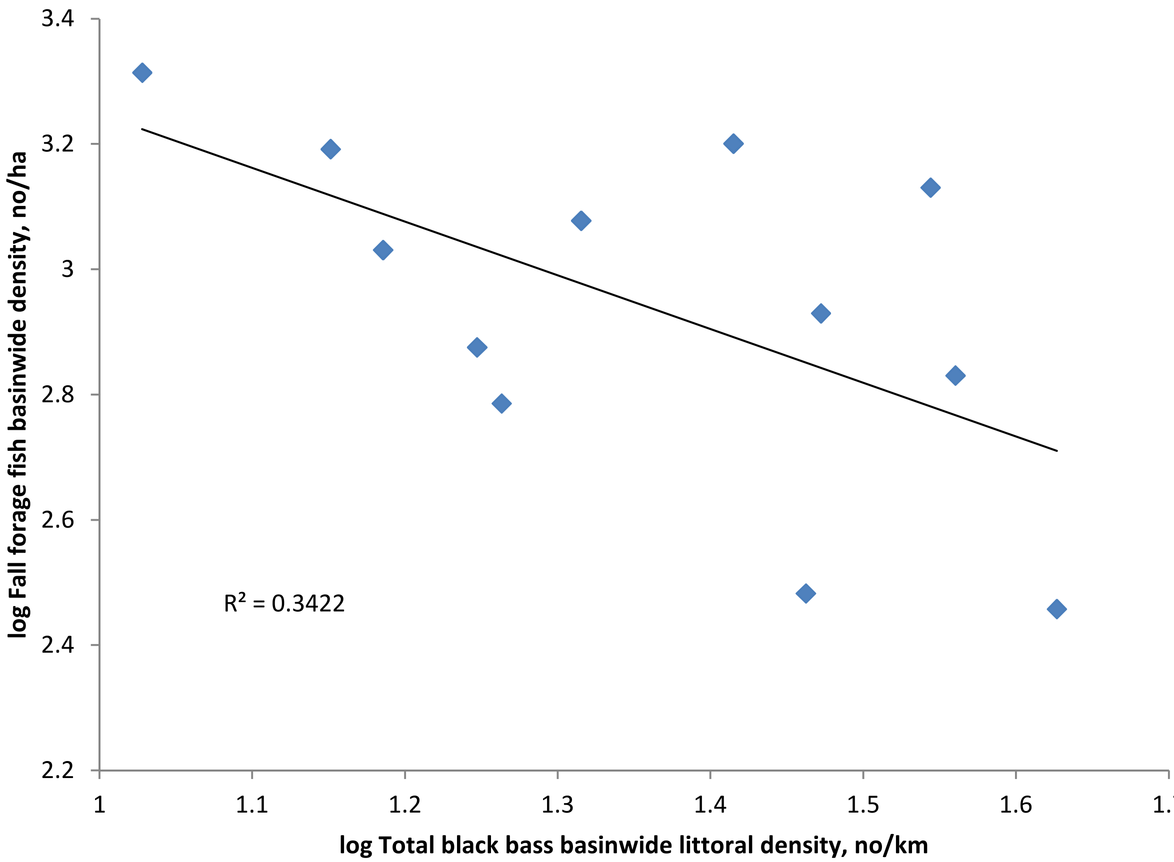


Figure 3-54. Fall forage fish densities in the Keowee River and Little River basins of Lake Keowee vs. basinwide mean littoral biomass of total black basses, based on hydroacoustics and electrofishing data collected 1999, 2002, 2005, 2008, 2010, and 2011.

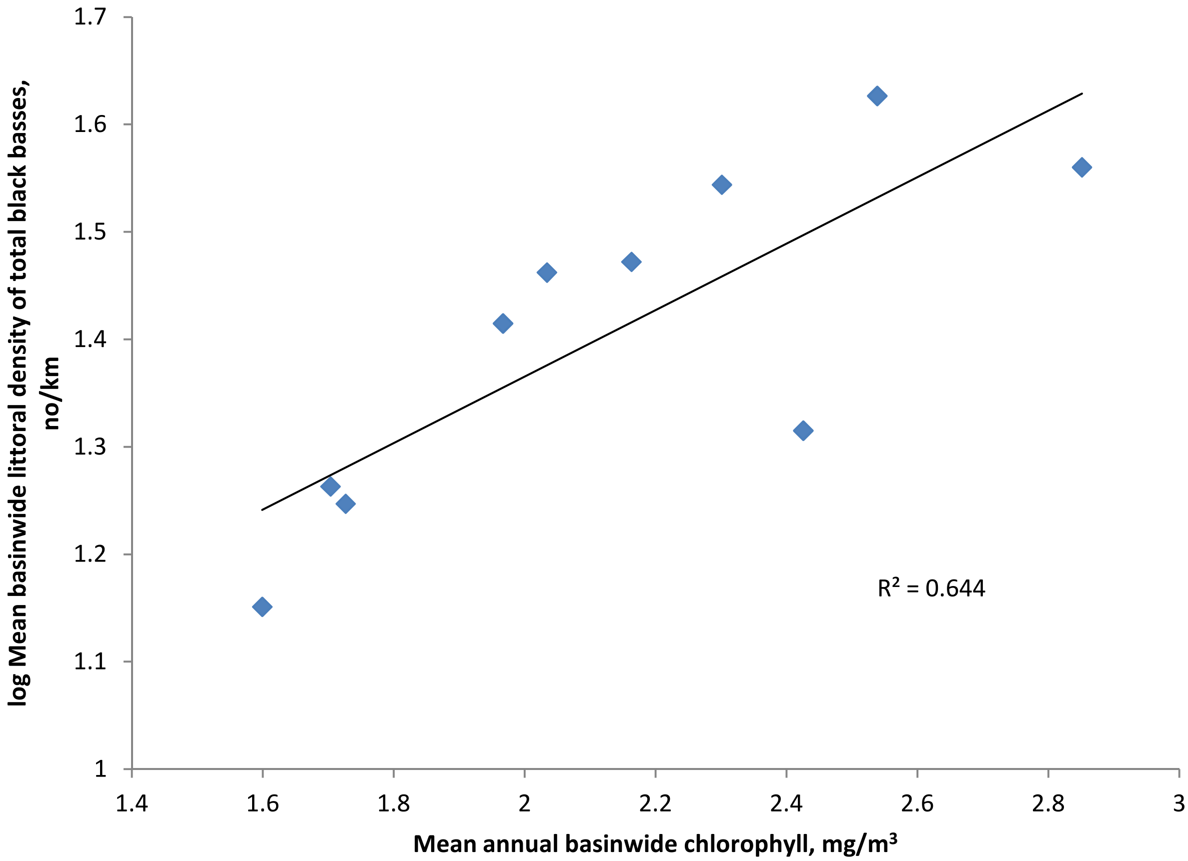


Figure 3-55. Mean basinwide littoral density of total black basses in spring shoreline electrofishing in the Keowee River and Little River basins of Lake Keowee vs. mean annual basinwide surface (0-10 m) chlorophyll concentration, for years with both electrofishing and mean annual chlorophyll data (1999, 2005, 2008, 2010, 2011).

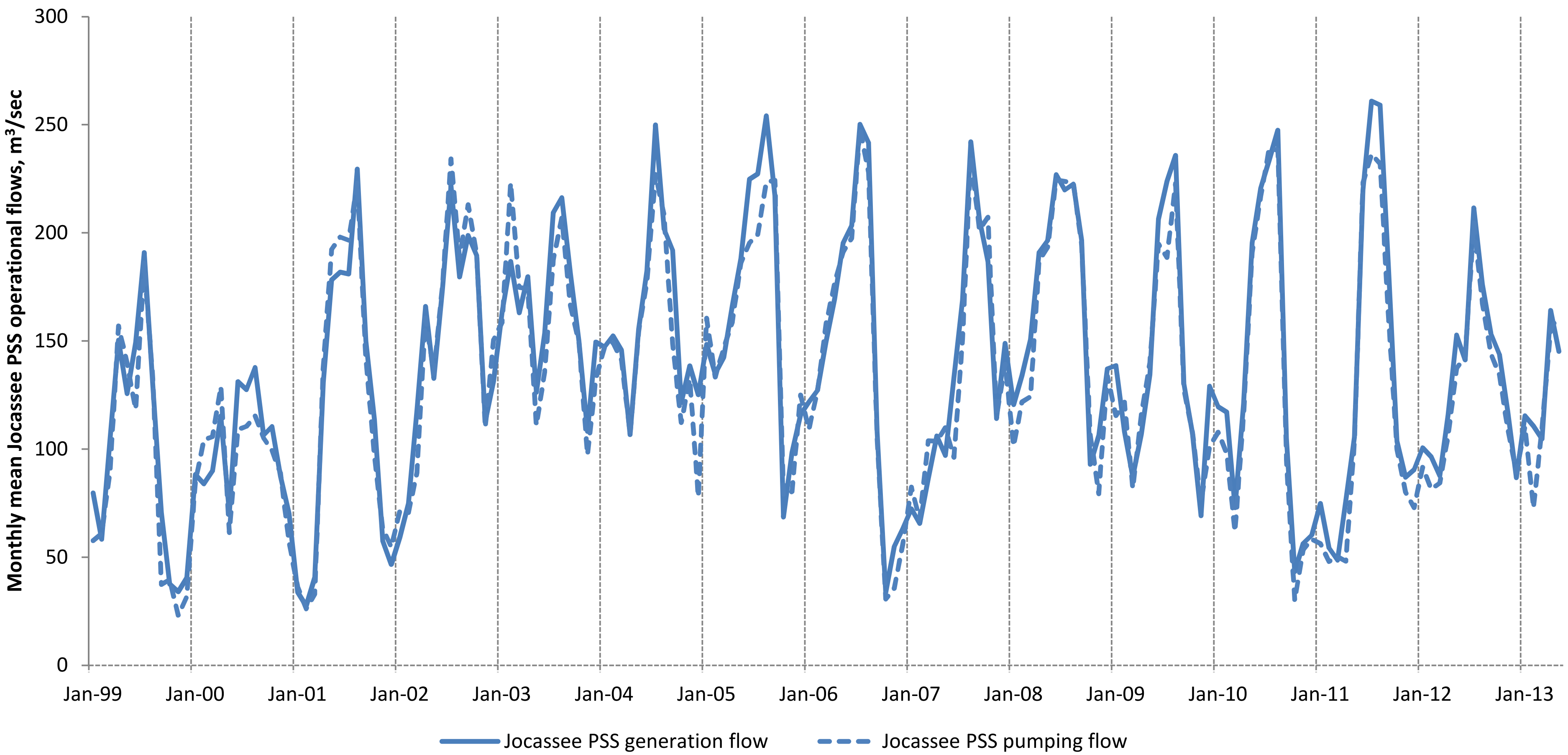


Figure 3-56. Monthly mean generation and pumping flows at Jocassee Pumped Storage Station, January 1999 through May 2013.

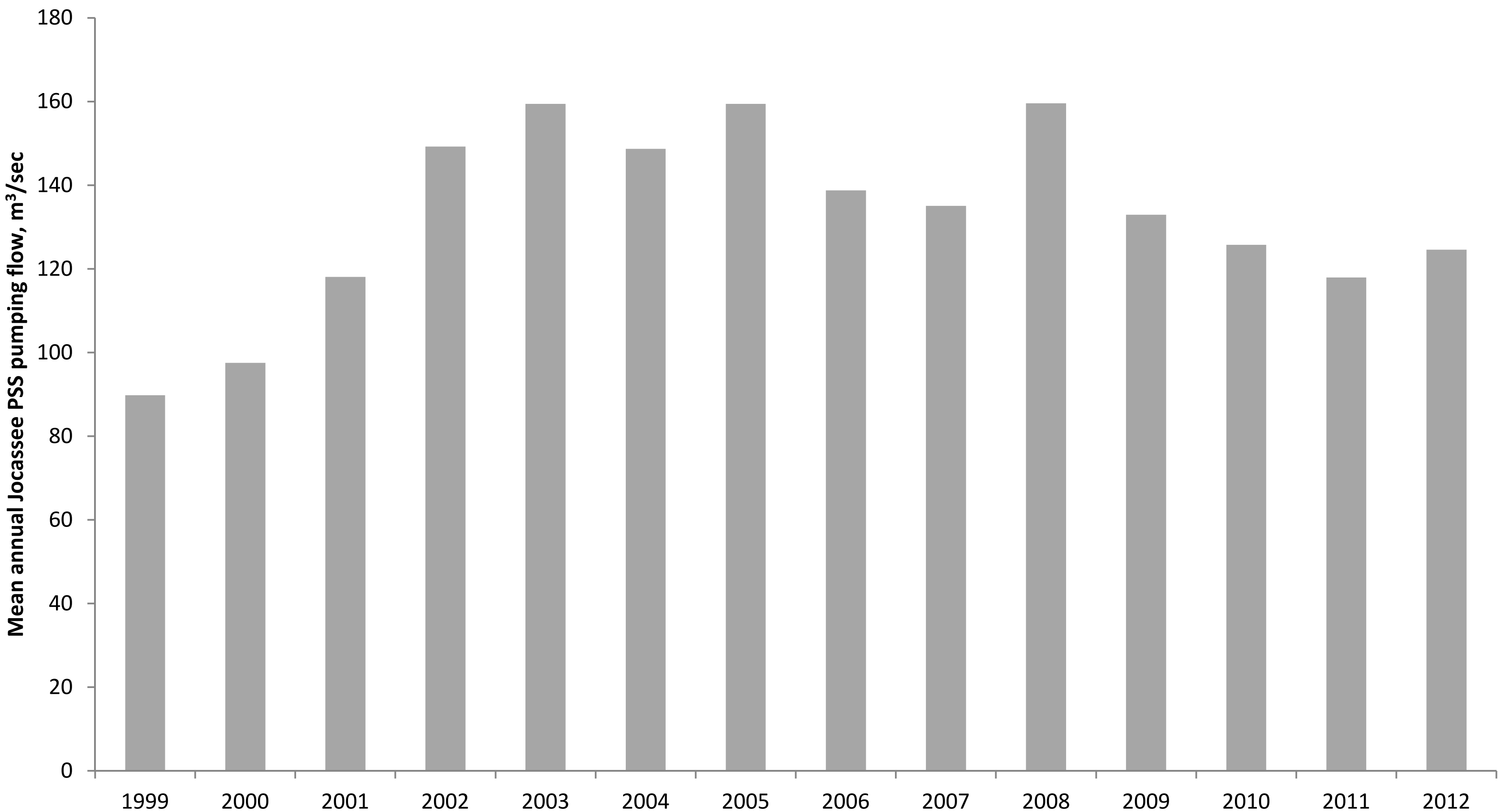


Figure 3-57. Mean annual pumping flow at Jocassee Pumped Storage Station, 1999-2012.

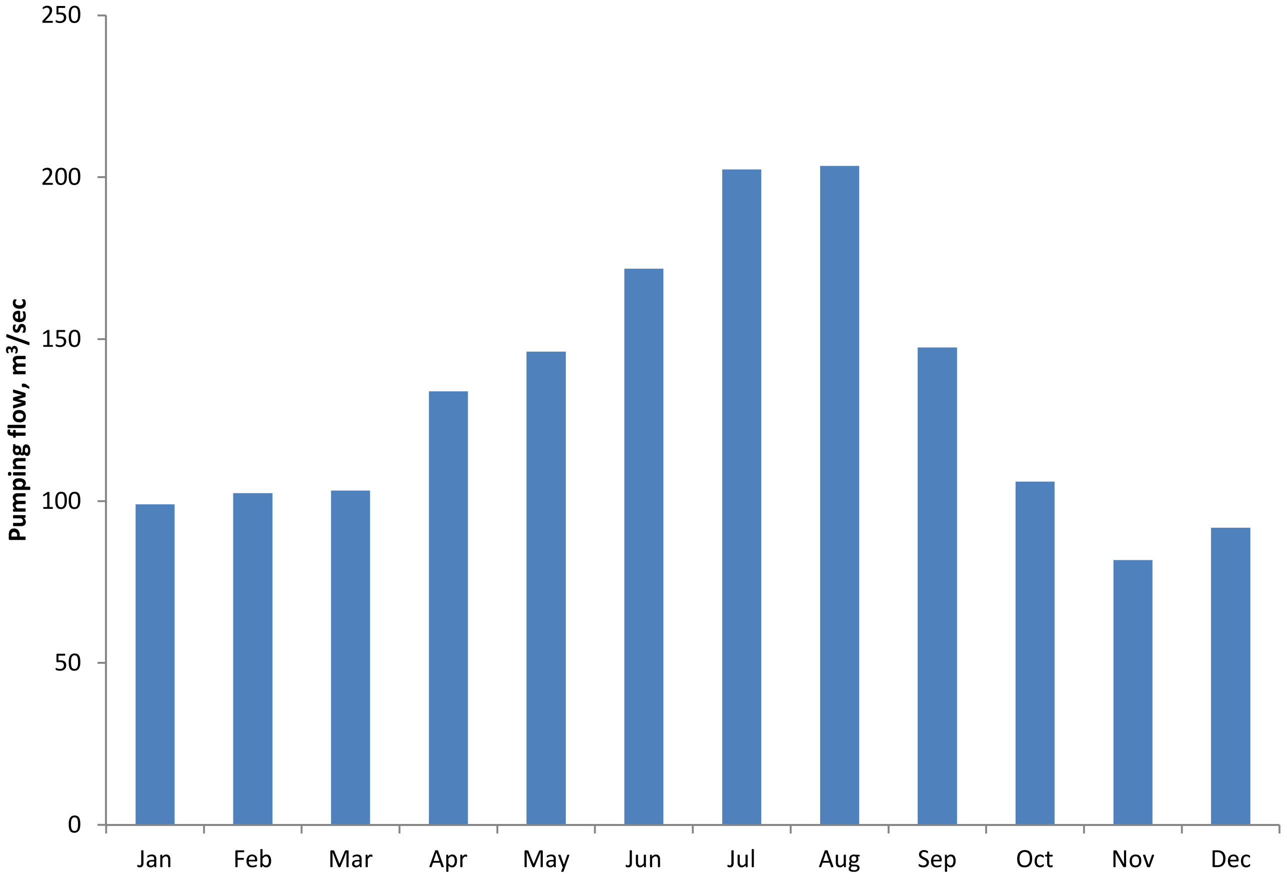


Figure 3-58. Mean seasonal variation in Jocassee pumping flows. Values represent means of daily mean pumping flows for each month of the year based on daily data from 1999-2012.

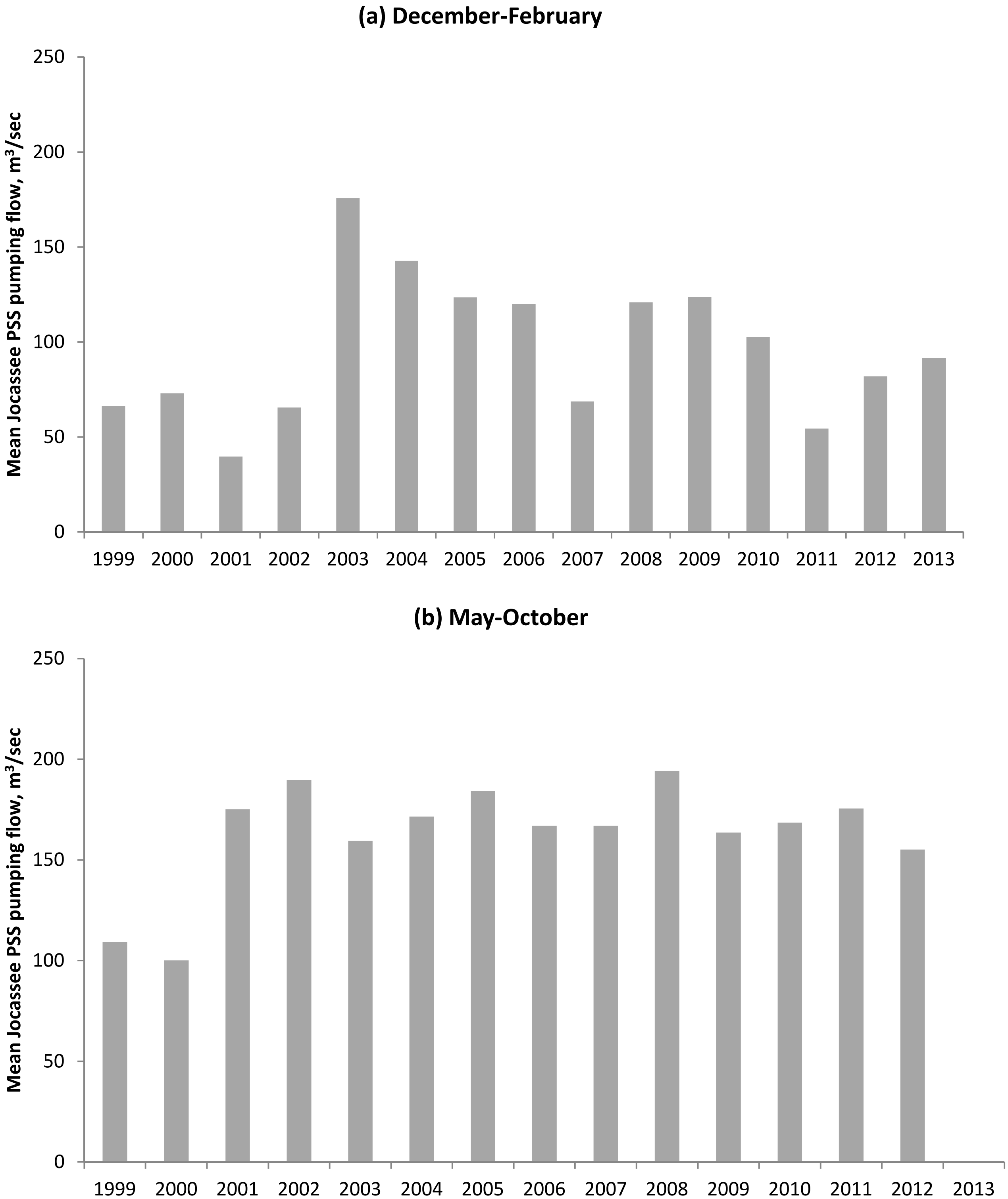


Figure 3-59. Mean Jocassee Pumped Storage Station pumping flows observed (a) December-February and (b) May-October, 1999-2013. Year for December-February data is year in which January and February data were collected.

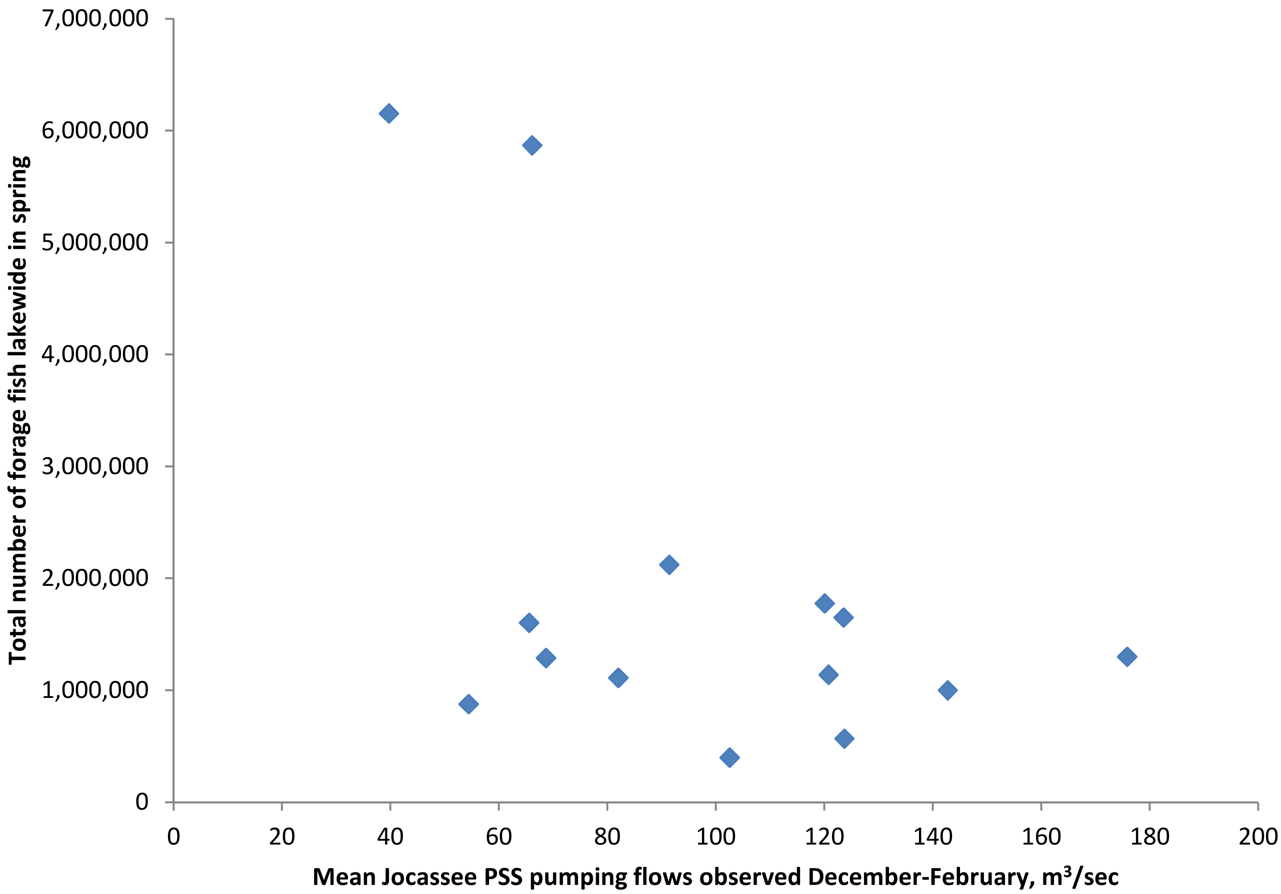
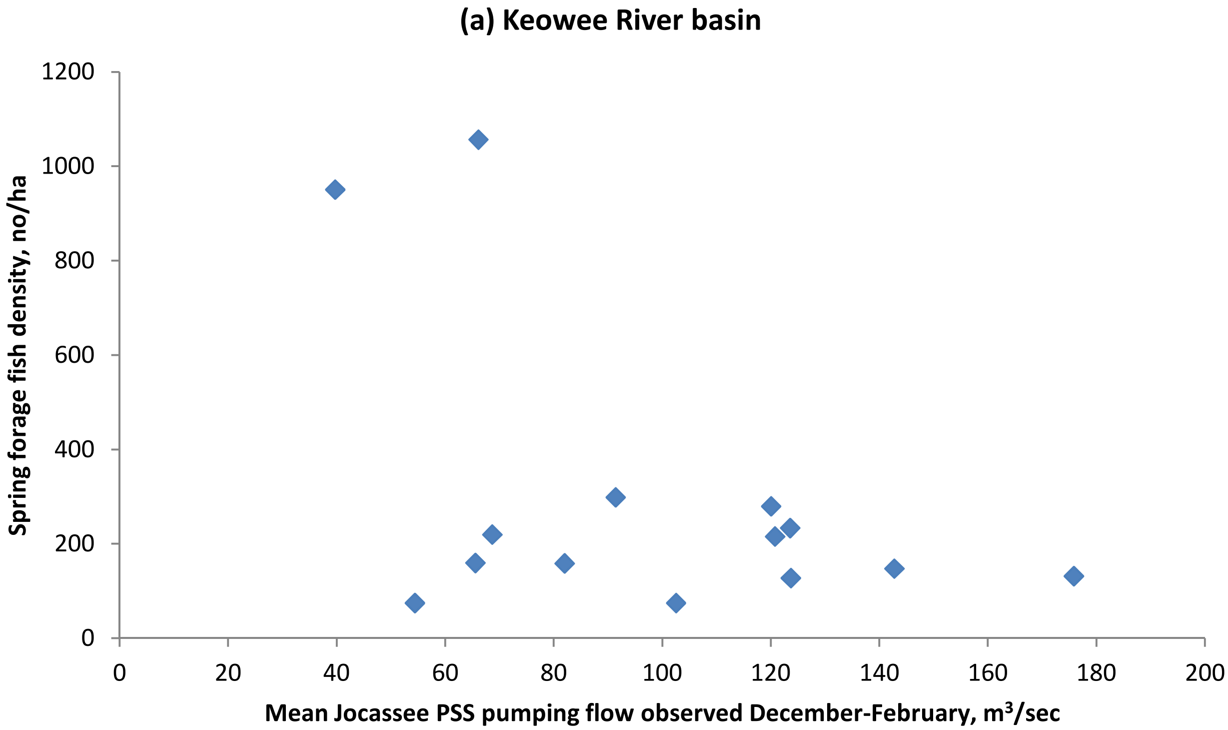


Figure 3-60. Total number of forage fish lakewide in Lake Keowee in spring, vs. mean pumping flow at Jocassee Pumped Storage Station observed December-February, 1999-2013.



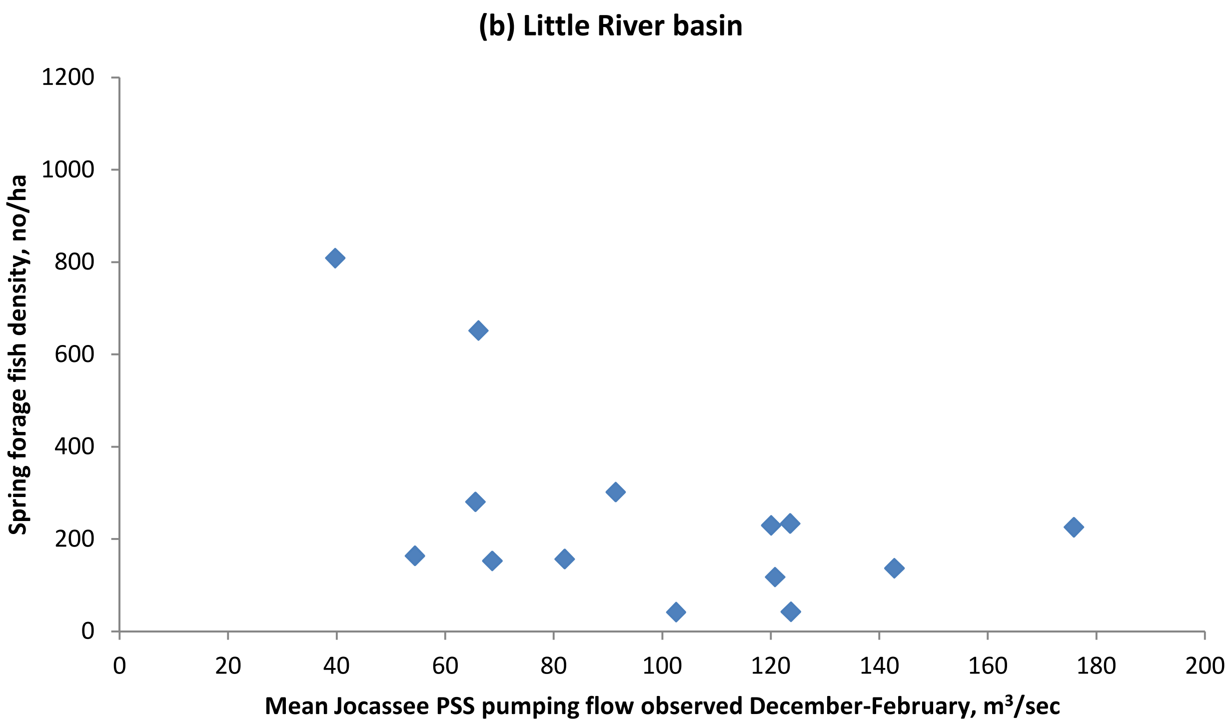


Figure 3-61. Spring forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. mean pumping flow at Jocassee Pumped Storage Station observed December-February, 1999-2013.

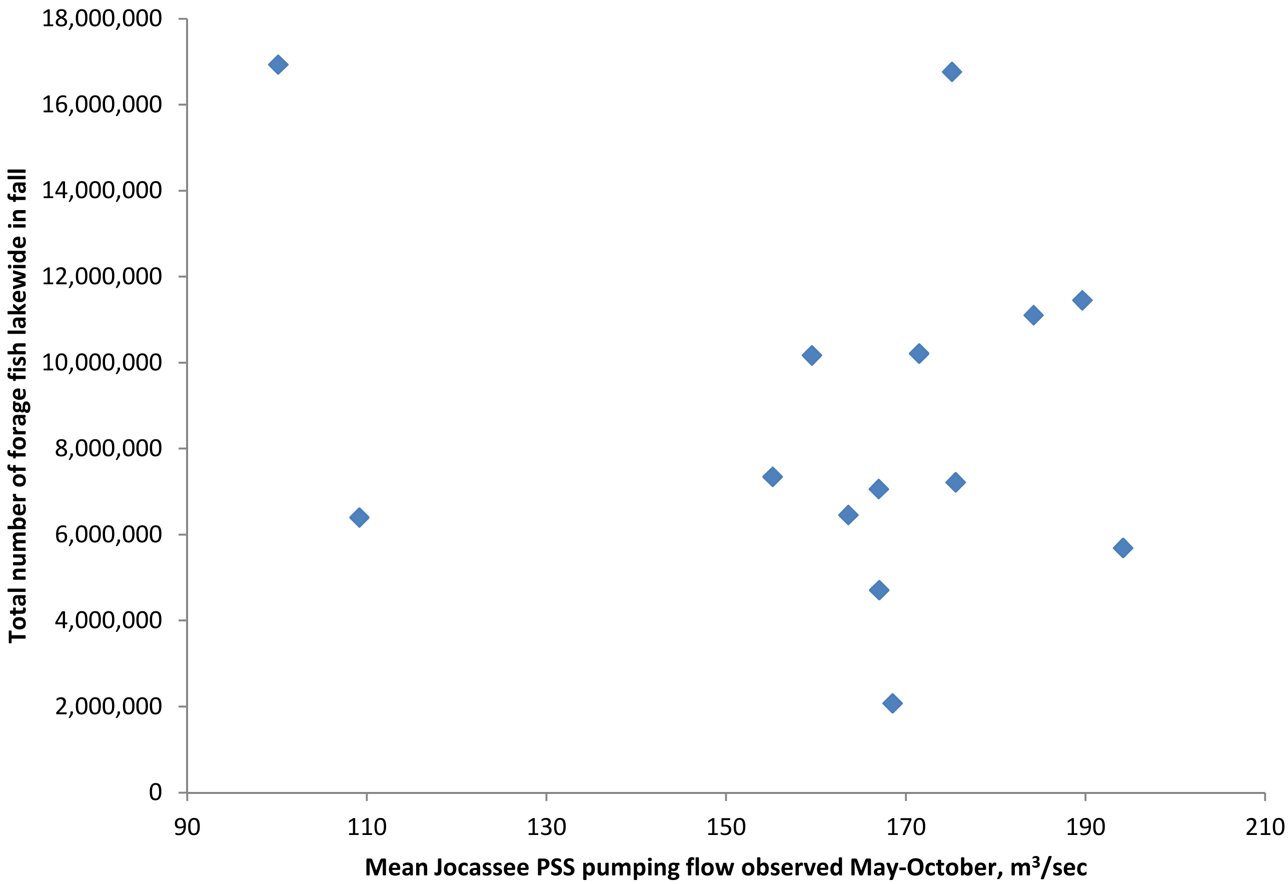
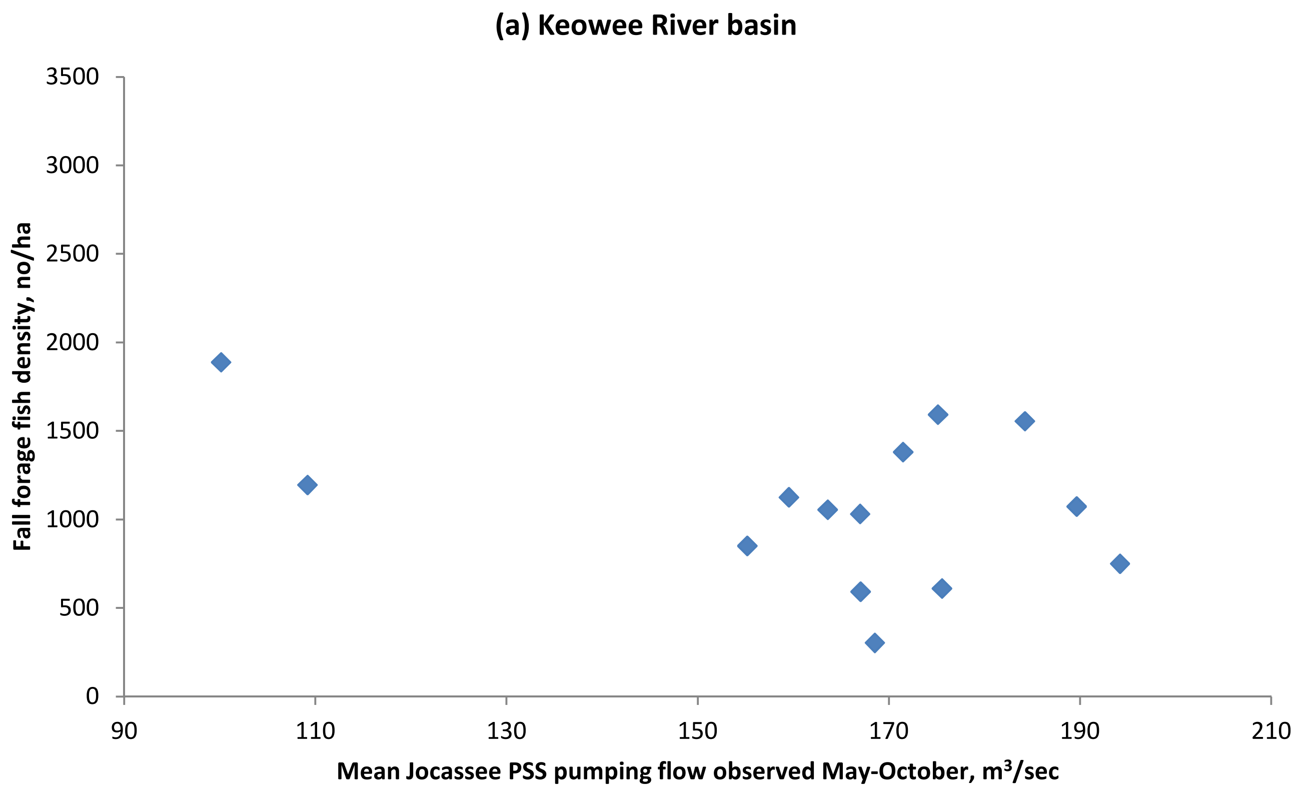


Figure 3-62. Total number of forage fish lakewide in Lake Keowee in fall, vs. mean pumping flow at Jocassee Pumped Storage Station observed May-October, 1999-2012.



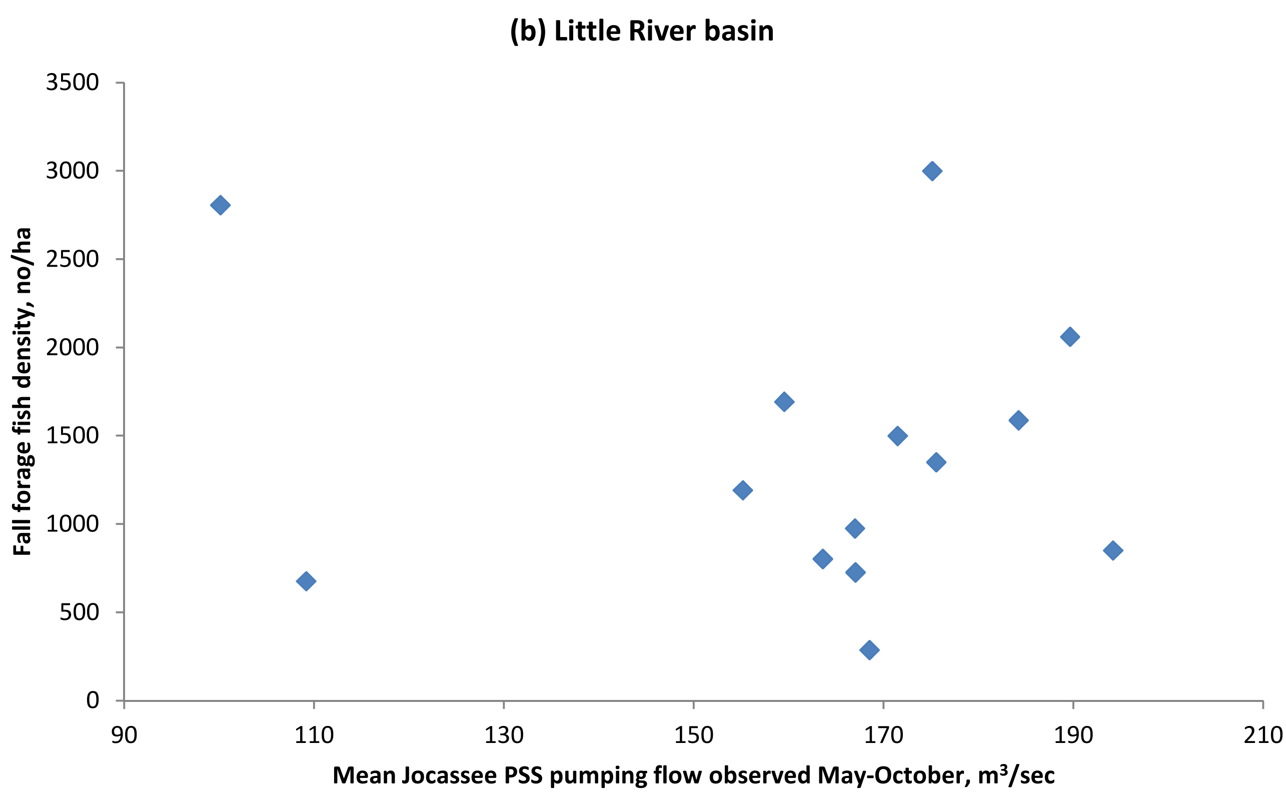


Figure 3-63. Fall forage fish densities in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. mean Jocassee Pumped Storage Station pumping flow observed May-October, 1999-2012.

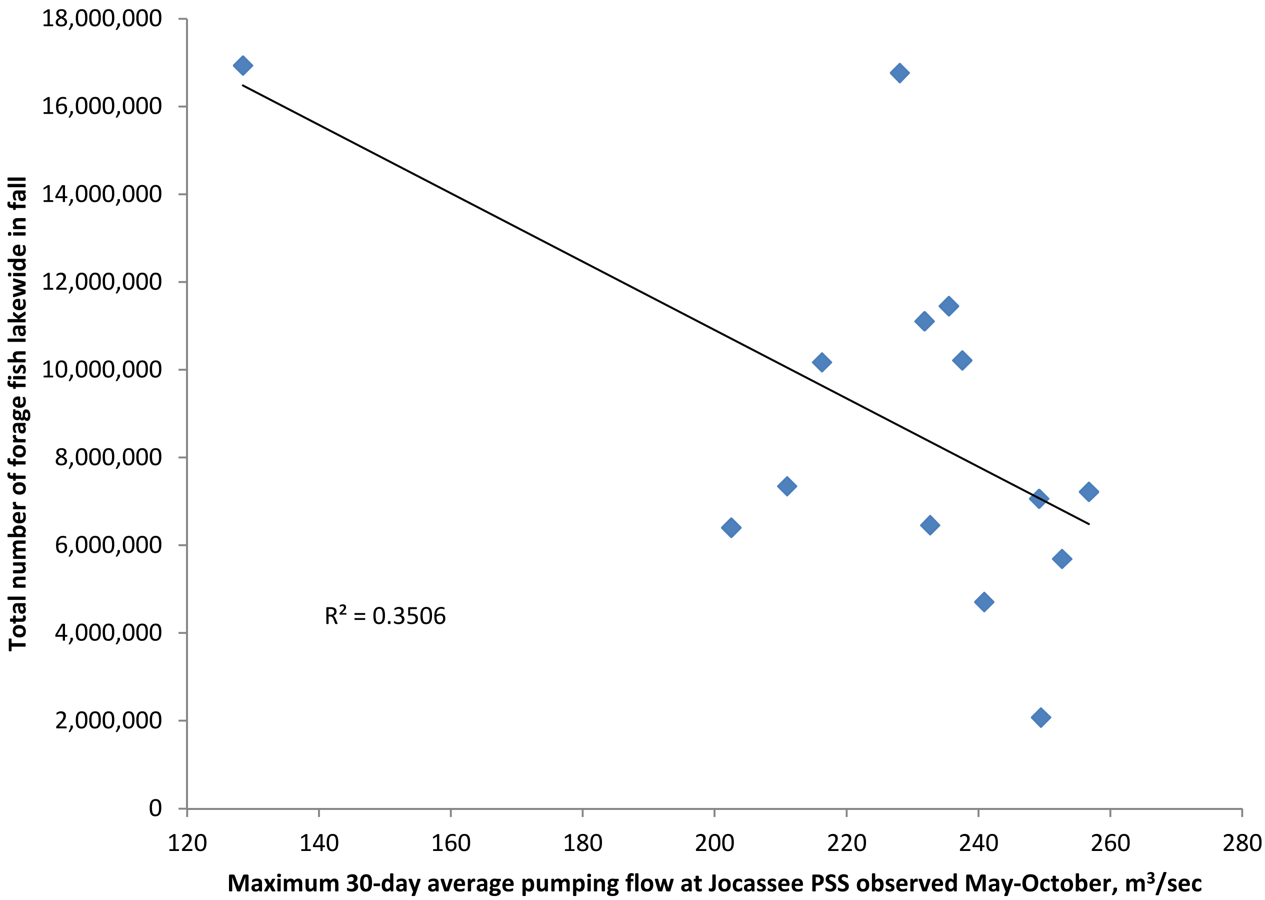


Figure 3-64. Total number of forage fish lakewide in Lake Keowee in fall, vs. maximum 30-day average pumping flow at Jocassee Pumped Storage Station observed May-October, 1999-2012.

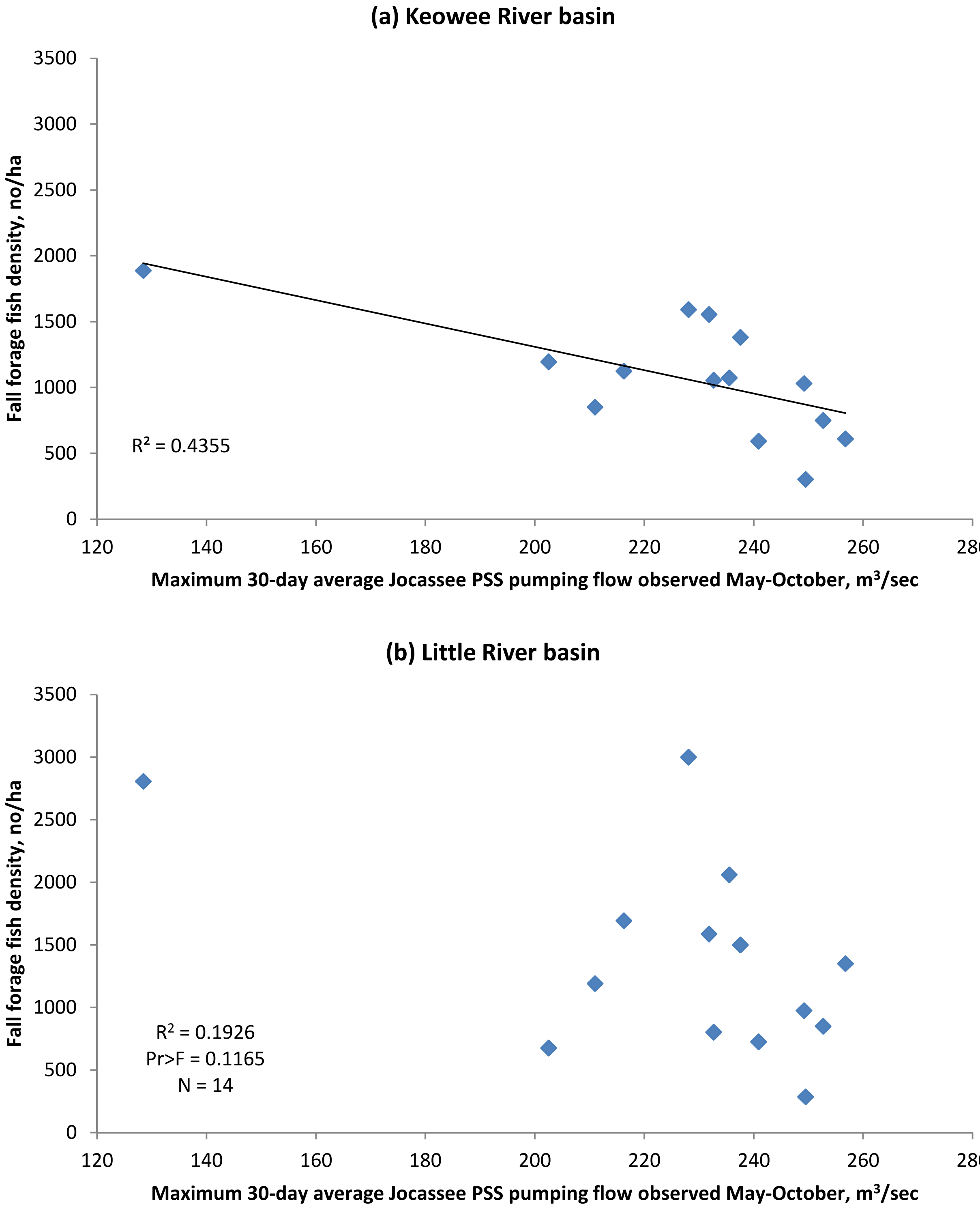


Figure 3-65. Fall forage fish densities in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. maximum 30-day average Jocassee Pumped Storage Station pumping flow observed May-October, 1999-2012.

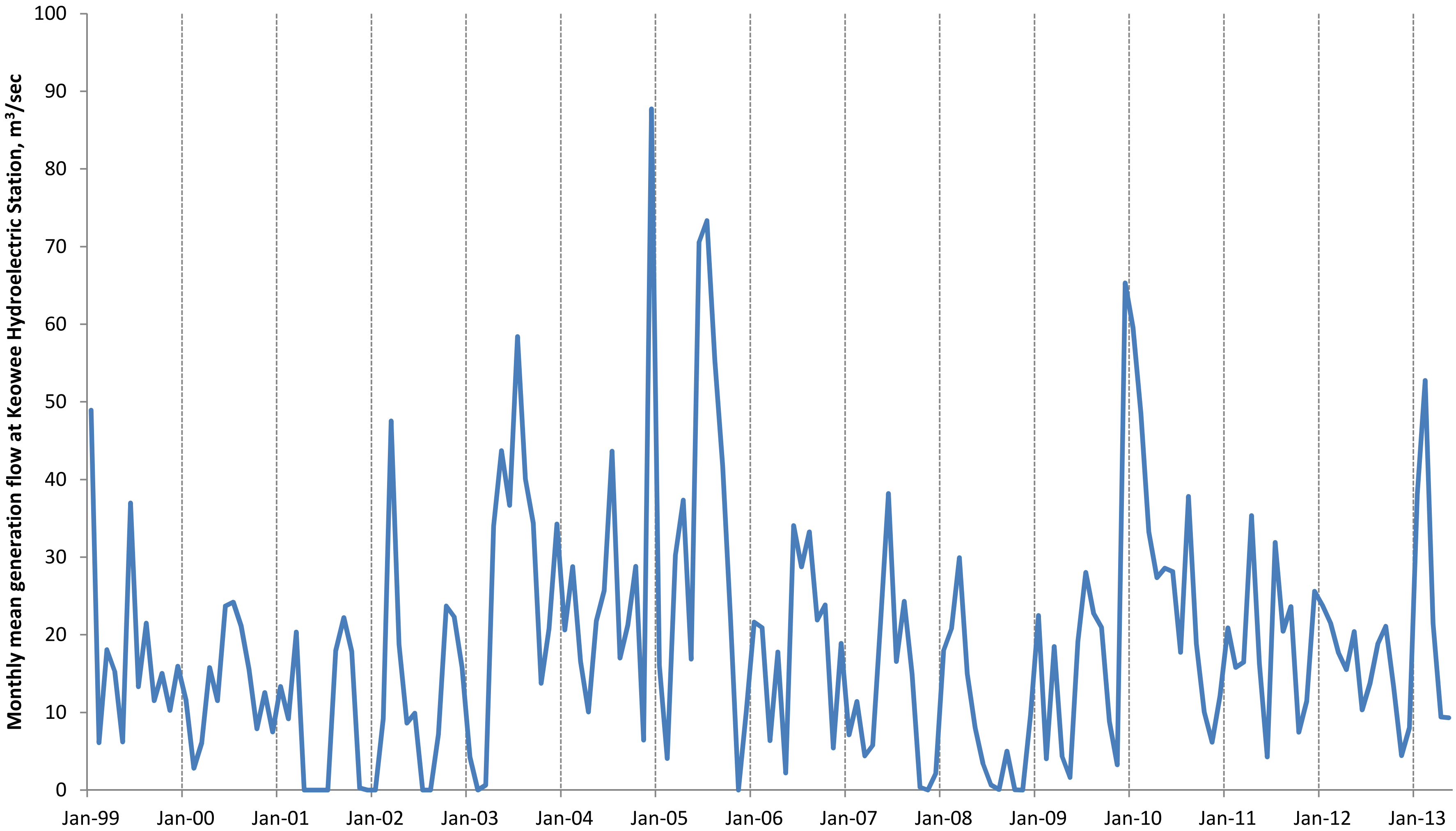


Figure 3-66. Monthly mean generation flows at Keowee Hydroelectric Station, January 1999 through May 2013.

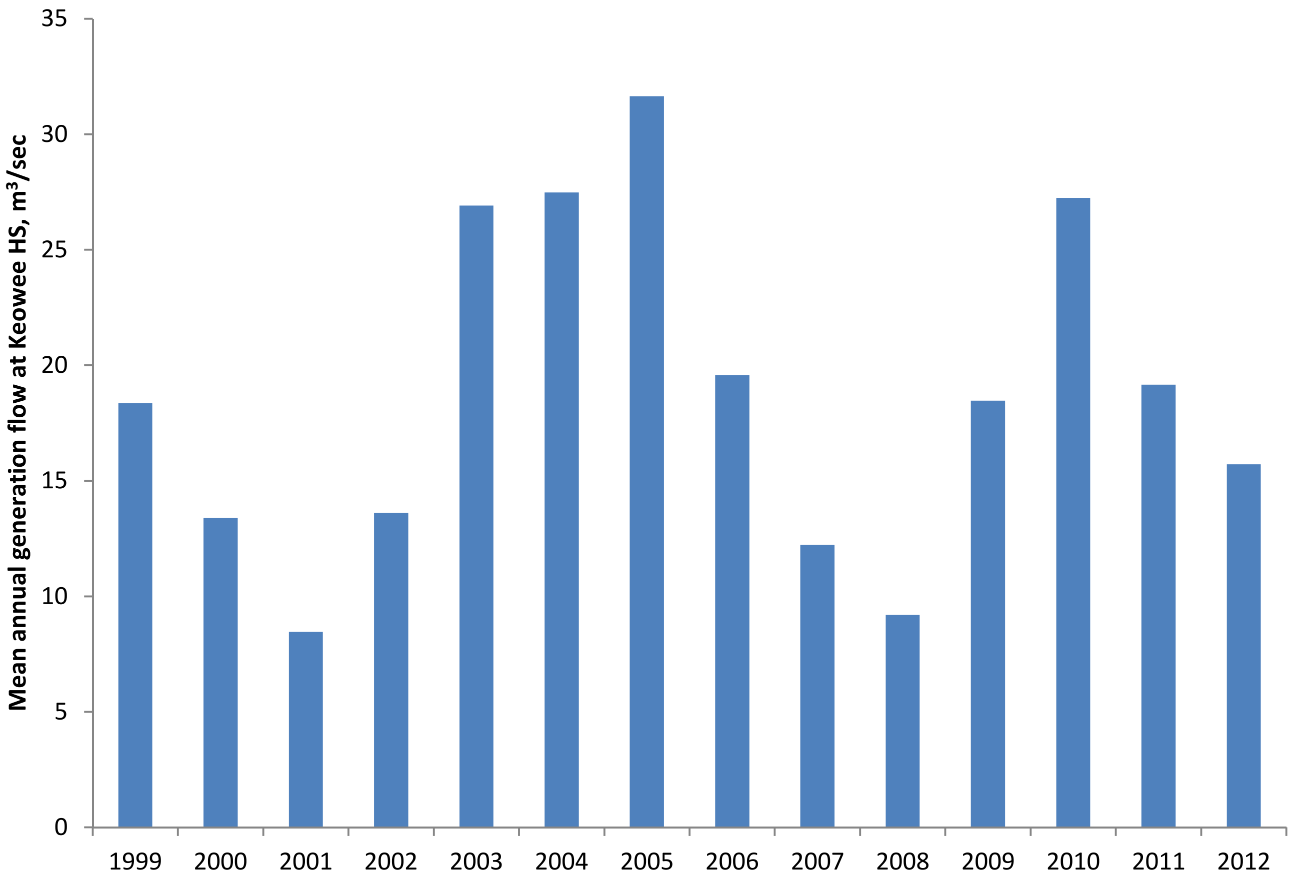


Figure 3-67. Mean annual generation flow at Keowee Hydroelectric Station, 1999-2012.

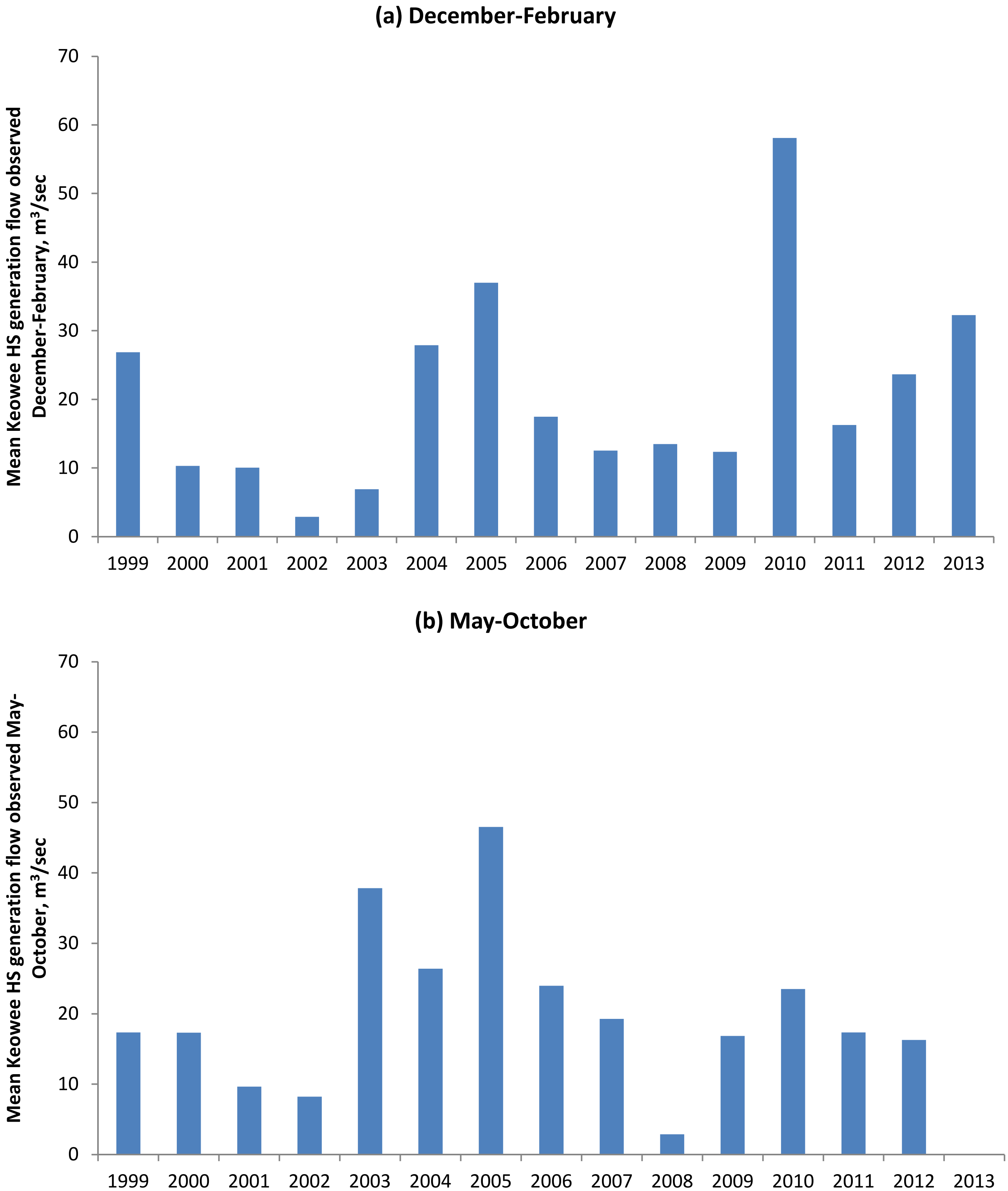


Figure 3-68. Mean generation flow at Keowee Hydroelectric Station observed (a) December-February 1999-2013 and (b) May-October 1999-2012. Mean December-February data are plotted with January-February year.

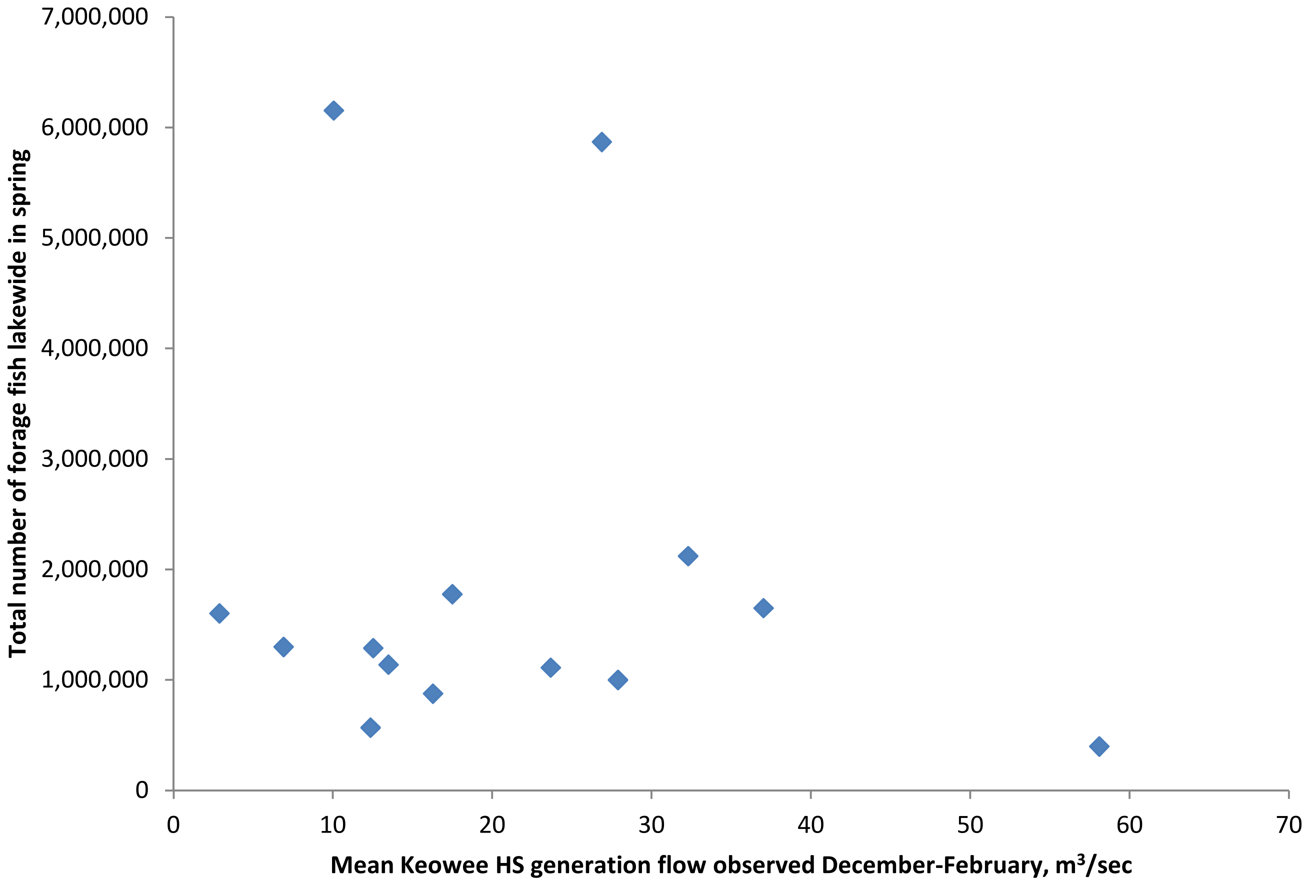


Figure 3-69. Total number of forage fish lakewide on Lake Keowee in spring, vs. mean generation flow observed December-February at Keowee Hydroelectric Station, 1999-2013.

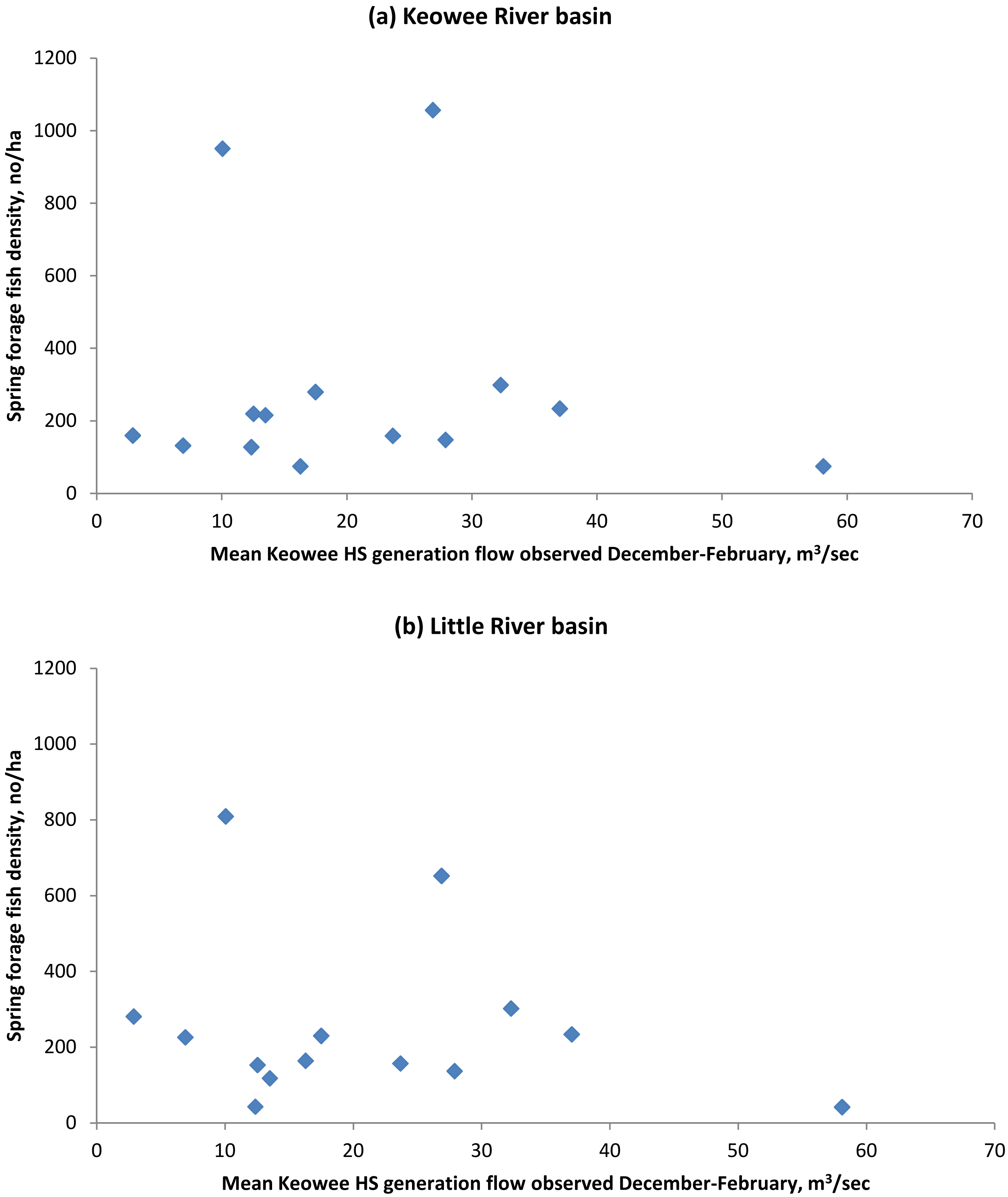


Figure 3-70. Spring forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. mean generation flow observed December-February at Keowee Hydroelectric Station, 1999-2013.

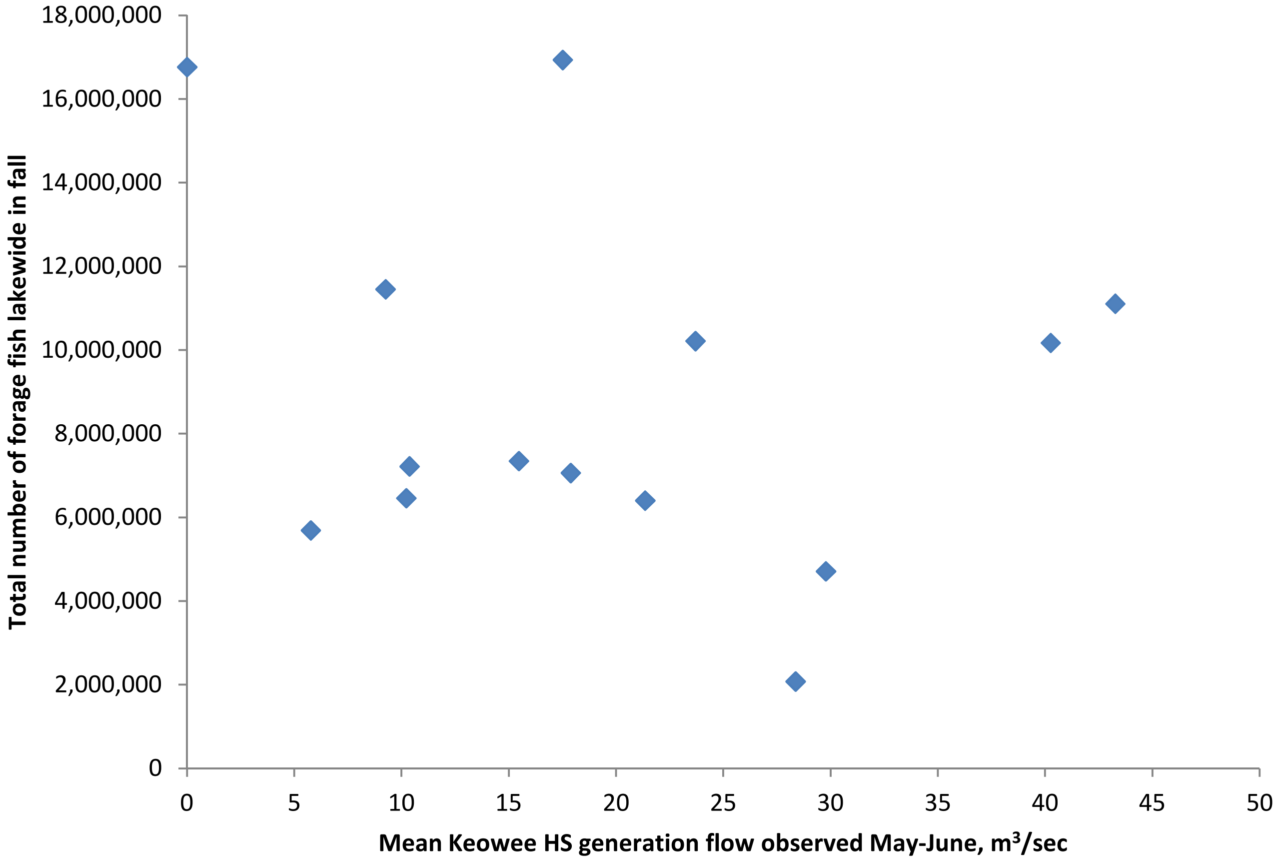
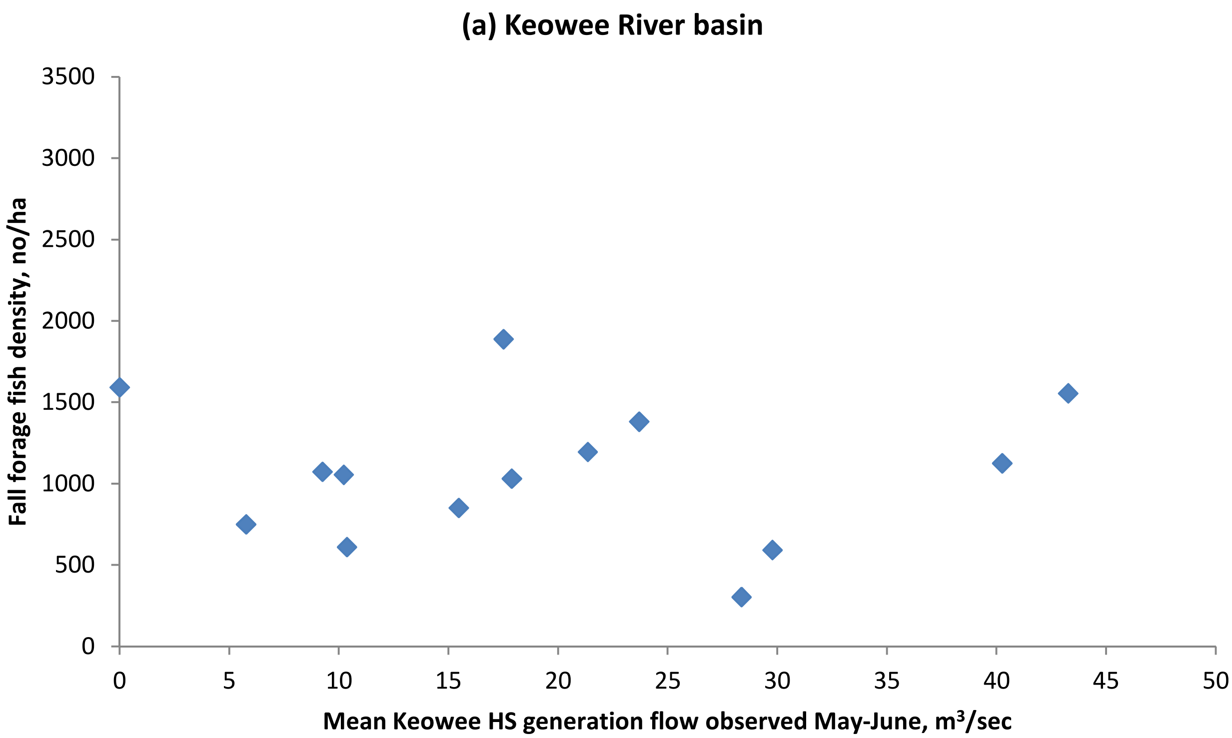


Figure 3-71. Total number of forage fish lakewide in fall on Lake Keowee vs. mean Keowee Hydroelectric Station generation flow observed May-June, 1999-2012.



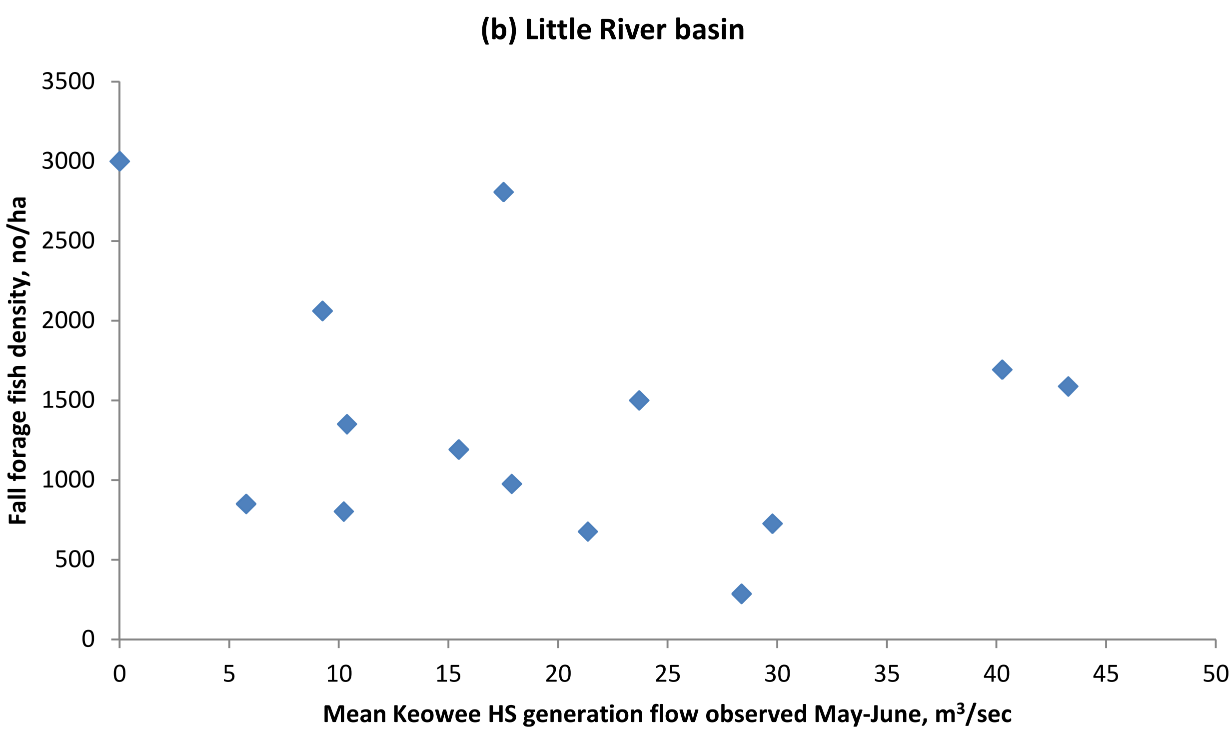


Figure 3-72. Fall forage fish densities in the (a) Keowee River basin and (b) Little River basin of Lake Keowee vs. mean Keowee Hydroelectric Station generation flow observed May-June, 1999-2012.

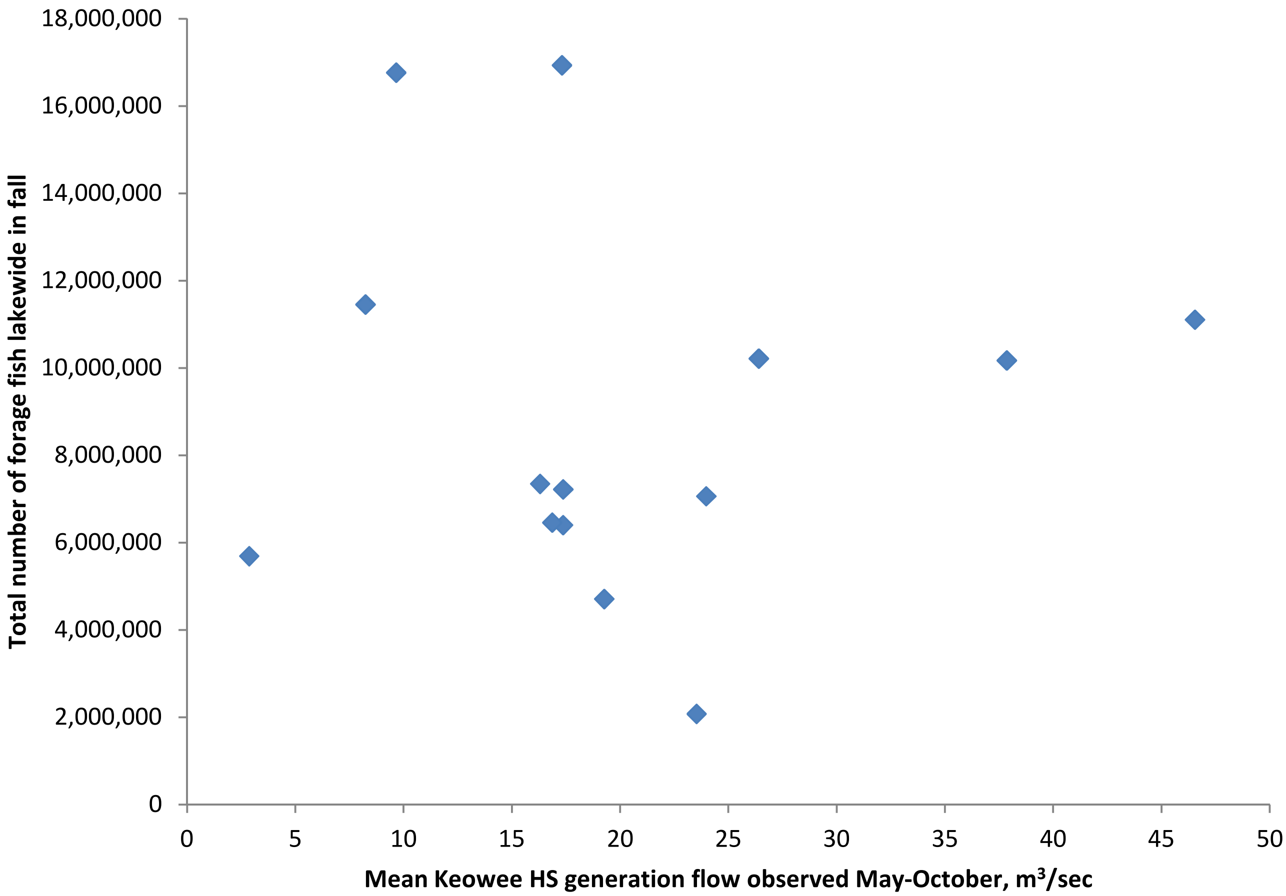


Figure 3-73. Total number of forage fish lakewide in fall on Lake Keowee, vs. mean generation observed May-October at Keowee Hydroelectric Station, 1999-2012.

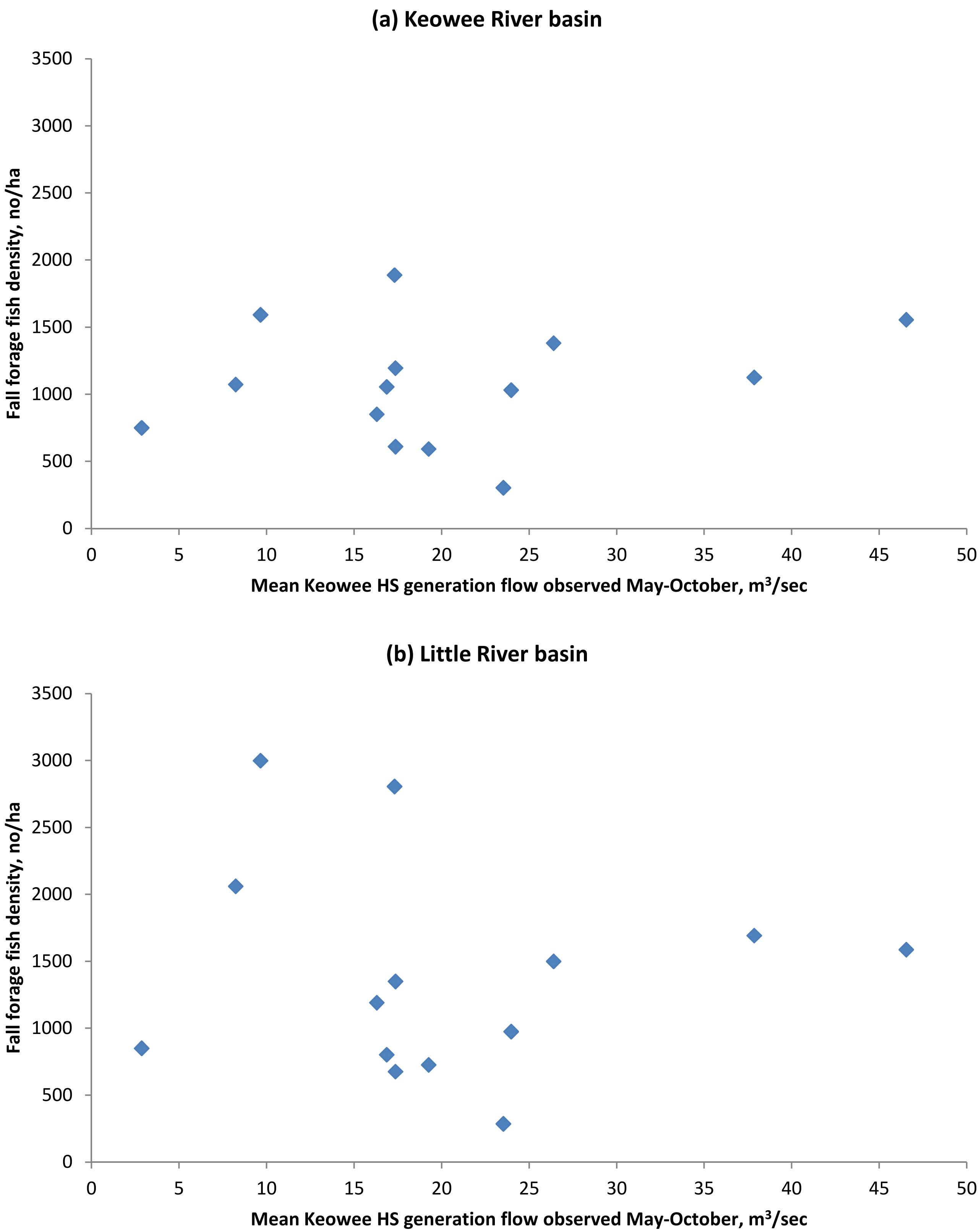


Figure 3-74. Fall forage fish density in the (a) Keowee River basin and (b) Little River basin of Lake Keowee, vs. mean generation flow observed May-October at Keowee Hydroelectric Station, 1999-2012.

Abbreviations used in Appendix Tables

Abs: absolute value
BLBkgkm: littoral biomass of total black basses, kg/km
BLBnumkm: littoral density of total black basses, no/km
Cms: m^3/sec
FallDensKeo: fall forage fish density in the Keowee River basin, no/ha
FallDensLit: fall forage fish density in the Little River basin, no/ha
FallFish: total number of forage fish lakewide in fall
FebClad: February density of cladocerans, organisms/m^3
FebCop: February density of copepods, organisms/m^3
FebCrust: February density of total crustacean zooplankton (copepods plus cladocerans), organisms/m^3
FebRot: February density of rotifers, organisms/m^3
FebTotalZoo: February total zooplankton density, organisms/m^3
JanFebChl: Mean January-February 0-10 m mean chlorophyll concentration, mg/m^3
JanFebLWChl: Mean January-February 0-10 mean lakewide chlorophyll concentration, mg/m^3
LMBkgkm: Largemouth bass littoral biomass, kg/km
LMBnumkm: Largemouth bass littoral density, no/km
Log: $\log_{10}$-transformed
LW: lakewide
Max30dayDecFebJocPump: Maximum 30-day average JPSS pumping flow observed December-February, m^3/sec
Max30dayDecFebKeoGen: Maximum 30-day average Keowee HS generation flow observed December-February, m^3/sec
Max30dayDecFebKeoLL: Lowest 30-day average Lake Keowee lake level observed December-February, meters below full pool
Max30dayMayOctJocPump: Maximum 30-day average JPSS pumping flow observed May-October, m^3/sec
Max30dayMayOctKeoGen: Maximum 30-day average Keowee HS generation flow observed May-October, m^3/sec
Max30dayMayOctKeoLL: Lowest 30-day average Lake Keowee lake level observed May-October, meters below full pool
Max3dayLLDeclineMayJun: Maximum 3-day decline in lake level observed May-June, meters
Max3dayLLIncreaseMayJun: Maximum 3-day increase in lake level observed May-June, meters
MaxDailyDecFebJocPump: Maximum daily JPSS pumping flow observed December-February, m^3/sec
MaxDailyDecFebKeoGen: Maximum daily Keowee HS generation flow observed December-February, m^3/sec
MaxDailyDecFebKeoLL: Lowest daily Lake Keowee lake level observed December-February, meters below full pool
MaxDailyMayJunKeoGen: Maximum daily Keowee HS generation flow observed May-June, m^3/sec
MaxDailyMayOctJocPump: Maximum daily JPSS pumping flow observed May-October, m^3/sec
MaxDailyMayOctKeoGen: Maximum daily Keowee HS generation flow observed May-October, m^3/sec
MaxDailyMayOctKeoLL: Lowest daily Lake Keowee lake level observed May-October, meters below full pool
MaxTempLit: Mean maximum annual surface (0-5 m) temperature in the Little River basin, C
MaxTempLowerKeo: Mean maximum annual surface (0-5 m) temperature in the lower Keowee River basin, C
MaxTempMiddleKeo: Mean maximum annual surface (0-5 m) temperature in the middle Keowee River basin, C
MaxTempUpperKeo: Maximum annual surface (0-5 m) temperature at Location 507 in the upper Keowee River basin, C
MayAugClad: Mean of cladoceran density observed in May and August, organisms/m^3
MayAugCop: Mean of copepod density observed in May and August, organisms/m^3
MayAugCrust: Mean of total crustacean zooplankton density observed in May and August, organisms/m^3
MayAugRot: Mean of rotifer density observed in May and August, organisms/m^3
MayAugTotalZoo: Mean of total zooplankton density observed in May and August, organisms/m^3
MayChl: May surface (0-10 m) chlorophyll concentration, mg/m^3
MayClad: May cladoceran density, organisms/m^3
MayCop: May copepod density, organisms/m^3
MayCrust: May total crustacean zooplankton density, organisms/m^3
MayJunChl: Mean May-June surface (0-10 m) chlorophyll concentration, mg/m^3
MayJunLWChl: Mean May-June lakewide surface (0-10 m) chlorophyll concentration, mg/m3

MayLWChl: May mean lakewide surface (0-10 m) chlorophyll concentration, mg/m3
MayOctChl: Mean May-October surface (0-10 m) chlorophyll concentration, mg/m3
MayOctLWChl: Mean May-October lakewide surface (0-10 m) chlorophyll concentration, mg/m3
MayRot: May rotifer density, organisms/m3
MayTotalZoo: May total zooplankton density, organisms/m3
MeanAnnChl: Mean annual chlorophyll concentration, mg/m3
MeanAnnLWChl: Mean annual lakewide chlorophyll concentration, mg/m3
MeanDecFebJocPump: Mean JPSS pumping flow observed December-February, m3/sec
MeanDecFebKeoGen: Mean Keowee HS generation flow observed December-February, m3/sec
MeanDecFebKeoLL: Mean Lake Keowee lake level observed December-February, meters below full pool
MeanMayJunKeoGen: Mean Keowee HS generation flow observed May-June, m3/sec
MeanMayJunKeoLL: Mean Lake Keowee lake level observed May-June, meters below full pool
MeanMayOctJocPump: Mean JPSS pumping flows observed May-October, m3/sec
MeanMayOctKeoGen: Mean Keowee HS generation flow observed May-October, m3/sec
MeanMayOctKeoLL: Mean Lake Keowee lake level observed May-October, meters below full pool
MinTempLowerKeo: Minimum annual surface (0-5 m) temperature in the lower Keowee River basin, C
MinTempLowerLit: Minimum annual surface (0-5 m) temperature in the lower Little River basin, C
MinTempMidKeo: Minimum annual surface (0-5 m) temperature in the middle Keowee River basin, C
MinTempUpperKeo: Minimum annual surface (0-5 m) temperature in the upper Keowee River basin, C
MinTempUpperLit: Minimum annual surface (0-5 m) temperature in the upper Little River basin, C
RangeMayJunLL: Range over which lake level varied in May and June, m
SPBkgkm: Spotted bass littoral biomass, kg/km
SPBnumkm: Spotted bass littoral density, no/km
SprDensKeo: Spring forage fish density in the Keowee River basin, no/ha
SprDensLit: Spring forage fish density in the Little River basin, no/ha
SprFish: Total number of forage fish lakewide in spring

Appendix Table 1. Linear regression analysis relating total number of forage fish lakewide on Lake Keowee in spring and spring forage fish densities (no/ha) in the Keowee River and Little River basins of Lake Keowee to minimum winter surface (0-5 m) temperatures (C) observed in the lower, middle, and upper Keowee River basin and the lower and upper Little River basin. Temperature data from the following locations were utilized to characterize sub-basins: lower Keowee River basin (Locations 504, 508); middle Keowee River basin (Locations 505, 506); upper Keowee River basin (Location 507); lower Little River basin (Location 502); and upper Little River basin (Locations 500, 502).

Years	**Basin (fish)**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**SPEC**	**Outliers: |SR|≥2.5**	**Sig. Cook's D**
1999-2013	Lakewide	Dep: logSprFish Indep: MinTempLowerKeo	0.0040	0.8445	12	Intercept: 0.0013 MinTemp: 0.8445	0.6469	(none)	(none)
1999-2013	Lakewide	Dep: logSprFish Indep: MinTempMidKeo	0.1226	0.2408	13	Intercept: 0.0004 MinTemp: 0.2408	0.5825	(none)	(none)
1999-2013	Lakewide	Dep: logSprFish Indep: MinTempUpperKeo	0.3192	0.0888	10	Intercept: 0.0064 MinTemp: 0.0888	0.1607	(none)	(none)
1999-2013	Keowee	Dep: logSprDensKeo Indep: MinTempLowerKeo	0.0071	0.7946	12	Intercept: 0.1843 MinTemp: 0.7946	0.7221	(none)	(none)
1999-2013	Keowee	Dep: logSprDensKeo Indep: MinTempMidKeo	0.1128	0.2619	13	Intercept: 0.3075 MinTemp: 0.2619	0.6229	(none)	(none)
1999-2013	Keowee	Dep: logSprDensKeo Indep: MinTempUpperKeo	0.2835	0.1131	10	Intercept: 0.8625 MinTemp: 0.1131	0.1652	(none)	(none)
1999-2013	Lakewide	Dep: logSprFish Indep: MinTempLowerLit	0.1232	0.2395	13	Intercept: 0.0003 MinTemp: 0.2395	0.3050	(none)	(none)
1999-2013	Lakewide	Dep: logSprFish Indep: MinTempUpperLit	0.1192	0.2717	12	Intercept: 0.0002 MinTemp: 0.2717	0.6246	(none)	(none)
1999-2013	Little	Dep: logSprDensLit Indep: MinTempLowerLit	0.1076	0.2740	13	Intercept: 0.3372 MinTemp: 0.2740	0.4849	(none)	(none)
1999-2013	Little	Dep: logSprDensLit Indep: MinTempUpperLit	0.1353	0.2394	12	Intercept: 0.3103 MinTemp: 0.2394	0.3263	(none)	(none)

Appendix Table 2. Linear regression analysis relating total number of forage fish lakewide on Lake Keowee in fall and fall forage fish densities (no/ha) in the Keowee River and Little River basins of Lake Keowee to maximum summer surface (0-5 m) temperatures (C) observed in the lower, middle, and upper Keowee River basin and in the Little River basin. Temperature data from the following locations were utilized to characterize sub-basins: lower Keowee River basin (Locations 504, 508); middle Keowee River basin (Locations 505, 506); upper Keowee River basin (Location 507); Little River basin (Locations 500, 501, 502).

Years	Basin (fish)	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	Dep: FallFish Indep: MaxTempLowerKeo	0.0598	0.3996	14	Intercept: 0.3146 MaxTemp: 0.3996	0.2119	(none)	(none)
1999-2012	Lakewide	Dep: FallFish Indep: MaxTempMiddleKeo	0.1907	0.1185	14	Intercept: 0.0884 MaxTemp: 0.1185	0.4800	(none)	(none)
1999-2012	Lakewide	Dep: FallFish Indep: MaxTempUpperKeo	0.1408	0.2064	13	Intercept: 0.3016 MaxTemp: 0.2064	0.2054	(none)	(none)
1999-2012	Keowee	Dep: FallDensKeo Indep: MaxTempLowerKeo	0.2226	0.0885	14	Intercept: 0.0592 MaxTemp: 0.0885	0.1893	(none)	(none)
1999-2012	Keowee	FallDensKeo = 13,841 – 406.90853 MaxTempMiddleKeo	0.4051	**0.0144**	14	Intercept: 0.0092 MaxTemp: **0.0144**	0.4430	(none)	(none)
1999-2012	Keowee	Dep: FallDensKeo Indep: MaxTempUpperKeo	0.0844	0.3356	13	Intercept: 0.0.4921 MaxTemp: 0.3356	0.5291	(none)	(none)
1999-2012	Lakewide	FallFish = 139,547,156 – 4,308,293 MaxTempLit	0.3174	**0.0359**	14	Intercept: 0.0268 MaxTemp: **0.0359**	0.2333	(none)	(none)
1999-2012	Little	logFallDensLit = 11.47181 – 0.27681 MaxTempLit	0.3244	**0.0335**	14	Intercept: 0.0066 MaxTemp: **0.0335**	0.3484	(none)	(none)

Appendix Table 3. Linear regression analyses relating spring forage fish numbers lakewide in Lake Keowee (SprFish) and spring forage fish densities (no/ha) (SprDens) in the Keowee River and Little River basins of Lake Keowee to mean, lowest daily, and lowest 30-day average Lake Keowee lake levels (meters below full pool, positive number) observed December-February, utilizing lake level data from December 1998 through February 2013 and forage fish data from spring 1999 through spring 2013. Variable name for lowest daily lake level: MaxDailyDecFebKeoLL; variable name for lowest 30-day average lake level: Max30dayDecFebKeoLL.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2013	Lakewide	logSprFish MeanDecFebKeoLL	0.0645	0.3811	14	Intercept: <0.0001 KeoLL: 0.3811	0.2634	(none)	(none)
1999-2013	Lakewide	logSprFish MaxDailyDecFebKeoLL	0.1592	0.1576	14	Intercept: <0.0001 KeoLL: 0.1576	0.7578	(none)	(none)
1999-2013	Lakewide	logSprFish Max30dayDecFebKeoLL	0.0998	0.2712	14	Intercept: <0.0001 KeoLL: 0.2712	0.3174	(none)	(none)
1999-2013	Keowee	logSprDensKeo MeanDecFebKeoLL	0.0178	0.6497	14	Intercept: <0.0001 KeoLL: 0.6497	0.2580	(none)	(none)
1999-2013	Keowee	logSprDensKeo MaxDailyDecFebKeoLL	0.1030	0.2633	14	Intercept: <0.0001 KeoLL: 0.2633	0.5078	(none)	(none)
1999-2013	Keowee	logSprDensKeo Max30dayDecFebKeoLL	0.0322	0.5391	14	Intercept: <0.0001 KeoLL: 0.5391	0.3254	(none)	(none)
1999-2013	Little	logSprDensLit MeanDecFebKeoLL	0.0884	0.3018	14	Intercept: <0.0001 KeoLL: 0.3018	0.7018	(none)	(none)
1999-2013	Little	logSprDensLit MaxDailyDecFebKeoLL	0.1566	0.1614	14	Intercept: <0.0001 KeoLL: 0.1614	0.6854	(none)	(none)
1999-2013	Little	logSprDensLit Max30dayDecFebKeoLL	0.1348	0.1966	14	Intercept: <0.0001 KeoLL: 0.1966	0.7410	(none)	(none)

Appendix Table 4. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean lake level (meters below full pool) observed May-June on Lake Keowee, and to the range over which lake level varied during May-June (m) (maximum daily lake level minus minimum daily lake level), utilizing data from 1999 through 2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	FallFish MeanMayJunKeoLL	0.1658	0.1484	14	Intercept: 0.0220 KeoLL: 0.1484	0.6779	(none)	(none)
1999-2012	Lakewide	FallFish RangeMayJunLL	0.1475	0.1752	14	Intercept: 0.0010 KeoLL: 0.1752	0.1709	(none)	(none)
1999-2012	Keowee	FallDensKeo MeanMayJunKeoLL	0.0331	0.5335	14	Intercept: 0.0024 KeoLL: 0.5335	0.9433	(none)	(none)
1999-2012	Keowee	FallDensKeo RangeMayJunLL	0.0739	0.3470	14	Intercept: 0.0010 KeoLL: 0.3470	0.2549	(none)	(none)
1999-2012	Little	logFallDensLit MeanMayJunKeoLL	0.1973	0.1115	14	Intercept: <0.0001 KeoLL: 0.1115	0.2582	(none)	(none)
1999-2012	Little	logFallDensLit = 3.24867 – 0.24885 RangeMayJunLL	0.0715	0.3553	14	Intercept: <0.0001 KeoLL: 0.3553	0.3828	**2010** **(SR=-2.731)**	(none)

Appendix Table 5. Repeat of analysis in Appendix Table 4 in which observation for 2010 was identified as outlying, excluding outlying observation.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012 (excl 2010)	Little	logFallDensLit = 3.45215 – 0.45621 RangeMayJunLL	0.3865	**0.0233**	13	Intercept: <0.0001 KeoLL: **0.0233**	0.3017	(none)	(none)

Appendix Table 6. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to the maximum 3-day increase (m) and the maximum 3-day decline (m) in lake level observed during the May-June forage fish spawning period on Lake Keowee. Both maximum 3-day increase and maximum 3-day decline in lake level are expressed as positive numbers in these analyses. Analyses are based on data collected 1999-2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	FallFish logMax3dayLLIncreaseMayJun	0.0061	0.7911	14	Intercept: 0.0279 LLChange: 0.7911	0.3946	(none)	(none)
1999-2012	Lakewide	FallFish logAbsMax3dayLLDeclineMayJun	0.1486	0.1735	14	Intercept: 0.3384 LLChange: 0.1735	0.4649	(none)	(none)
1999-2012	Keowee	FallDensKeo logMax3dayLLIncreaseMayJun	0.0358	0.5172	14	Intercept: 0.0020 LLChange: 0.5172	0.2554	(none)	(none)
1999-2012	Keowee	FallDensKeo logAbsMax3dayLLDeclineMayJun	0.1649	0.1497	14	Intercept: 0.1922 LLChange: 0.1497	0.5703	(none)	(none)
1999-2012	Little	logFallDensLit logMax3dayLLIncreaseMayJun	0.0081	0.7593	14	Intercept: <0.0001 LLChange: 0.7593	0.4608	**2010 (SR=-2.559)**	(none)
1999-2012	Little	logFallDensLit logAbsMax3dayLLDeclineMayJun	0.1142	0.2373	14	Intercept: <0.0001 LLChange: 0.2373	0.3118	(none)	(none)

Appendix Table 7. Repeat of analysis in Appendix Table 6 where observation for 2010 was identified as outlying, excluding the outlying observation.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012 (excl 2010)	Little	logFallDensLit logMax3dayLLIncreaseMayJun	0.2129	0.1125	13	Intercept: <0.0001 LLChange: 0.1125	0.3140	(none)	(none)

Appendix Table 8. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean, lowest daily, and lowest 30-day average Lake Keowee lake levels (meters below full pool, positive number) observed May-October, utilizing data from 1999 through 2012. Variable name for lowest daily lake level: MaxDailyMayOctKeoLL; variable name for lowest 30-day average lake level: Max30dayMayOctKeoLL.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	FallFish MeanMayOctKeoLL	0.0918	0.2924	14	Intercept: 0.1426 KeoLL: 0.2924	0.7511	(none)	(none)
1999-2012	Lakewide	FallFish MaxDailyMayOctKeoLL	0.0005	0.9366	14	Intercept: 0.1512 KeoLL: 0.9366	0.3221	(none)	(none)
1999-2012	Lakewide	FallFish Max30dayMayOctKeoLL	0.0212	0.6197	14	Intercept: 0.2725 KeoLL: 0.6197	0.3827	(none)	(none)
1999-2012	Keowee	FallDensKeo MeanMayOctKeoLL	0.0063	0.7868	14	Intercept: 0.0194 KeoLL: 0.7868	0.7129	(none)	(none)
1999-2012	Keowee	FallDensKeo MaxDailyMayOctKeoLL	0.0024	0.8676	14	Intercept: 0.1057 KeoLL: 0.8676	0.3802	(none)	(none)
1999-2012	Keowee	FallDensKeo Max30dayMayOctKeoLL	0.0351	0.5213	14	Intercept: 0.2099 KeoLL: 0.5213	0.3542	(none)	(none)
1999-2012	Little	logFallDensLit MeanMayOctKeoLL	0.0956	0.2820	14	Intercept: <0.0001 KeoLL: 0.2820	0.2075	(none)	(none)
1999-2012	Little	logFallDensLit MaxDailyMayOctKeoLL	0.0000	0.9857	14	Intercept: <0.0001 KeoLL: 0.9857	0.3326	(none)	(none)
1999-2012	Little	logFallDensLit Max30dayMayOctKeoLL	0.0091	0.7452	14	Intercept: <0.0001 KeoLL: 0.7452	0.4867	(none)	(none)

Appendix Table 9. Linear regression analyses relating spring forage fish lakewide total numbers (SprFish) to mean lakewide surface (0-10 m) chlorophyll concentrations (mg/m^3) measured in January and February; and linear regression analyses relating spring forage fish densities (no/ha) (SprDens) in the Keowee River and Little River basins of Lake Keowee to basinwide mean surface (0-10 m) chlorophyll concentrations (mg/m^3) measured in January and February, utilizing data collected 1999-2013.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2013	Lakewide	logSprFish = 5.83773 + 1.46950 logJanFebLWChl	0.3467	**0.0267**	14	Intercept: <0.0001 Chl: **0.0267**	0.3879	(none)	(none)
1999-2013	Keowee	logSprDens = 2.05979 + 1.64355 logJanFebChl	0.4210	**0.0121**	14	Intercept: <0.0001 Chl: **0.0121**	0.1953	(none)	(none)
1999-2013	Little	logSprDens = 1.87039 + 1.51066 logJanFebChl	0.3106	**0.0384**	14	Intercept: <0.0001 Chl: **0.0384**	0.8258	(none)	(none)
1999-2013	Both basins	logSprDens = 2.02425 + 1.28267 logJanFebChl	0.2772	**0.0040**	28	Intercept: <0.0001 Chl: **0.0040**	0.4842	(none)	(none)

Appendix Table 10. Linear regression analyses relating fall forage fish lakewide total numbers (FallFish) and fall forage fish densities in the Keowee River and Little River basins of Lake Keowee (FallDens) to surface (0-10 m) chlorophyll concentrations (mg/m^3) measured during the following periods: January-December (mean annual); May; May-June; and May-October, utilizing data collected 1999-2012.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	FallFish MeanAnnLWChl	0.0399	0.5129	13	Intercept: 0.7560 Chl: 0.5129	0.0979	(none)	(none)
1999-2012	Lakewide	FallFish MayLWChl	0.0010	0.9144	14	Intercept: 0.2714 Chl: 0.9144	0.8229	(none)	(none)
1999-2012	Lakewide	FallFish MayJunLWChl	0.0272	0.5730	14	Intercept: 0.1217 Chl: 0.5730	0.9853	(none)	(none)
1999-2012	Lakewide	FallFish MayOctLWChl	0.0042	0.8262	14	Intercept: 0.4464 Chl: 0.8262	0.2687	(none)	(none)
1999-2012	Keowee	FallDensKeo MeanAnnChl	0.0731	0.3716	13	Intercept: 0.5858 Chl: 0.3716	0.3989	(none)	(none)
1999-2012	Keowee	FallDensKeo MayChl	0.0000	0.9859	14	Intercept: 0.1939 Chl: 0.9859	**0.0440**	(none)	(none)
1999-2012	Keowee	FallDensKeo MayJunChl	0.0001	0.9700	14	Intercept: 0.1438 Chl: 0.9700	0.5168	(none)	(none)
1999-2012	Keowee	FallDensKeo MayOctChl	0.0080	0.7610	14	Intercept: 0.2812 Chl: 0.7610	0.6186	(none)	(none)
1999-2012	Little	FallDensLit MeanAnnChl	0.0097	0.7490	13	Intercept: 0.0003 Chl: 0.7490	0.2389	(none)	(none)
1999-2012	Little	FallDensLit MayChl	0.0568	0.4121	14	Intercept: <0.0001 Chl: 0.4121	0.5802	(none)	(none)
1999-2012	Little	FallDensLit	0.2021	0.1068	14	Intercept: <0.0001	0.8366	(none)	(none)

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
		MayJunChl				Chl: 0.1068			
1999-2012	Little	FallDensLit MayOctChl	0.0419	0.4828	14	Intercept: <0.0001 Chl: 0.4828	0.4076	(none)	(none)
1999-2012	Both basins	FallDens MeanAnnChl	0.0116	0.6012	26	Intercept: <0.0001 Chl: 0.6012	0.2400	**Lit-2010 (SR=-2.531)**	(none)
1999-2012	Both basins	FallDens MayChl	0.0000	0.9912	28	Intercept: <0.0001 Chl: 0.9912	0.2078	(none)	(none)
1999-2012	Both basins	FallDens MayJunChl	0.0118	0.5816	28	Intercept: <0.0001 Chl: 0.5816	0.4763	(none)	(none)
1999-2012	Both basins	FallDens MayOctChl	0.0014	0.8519	28	Intercept: <0.0001 Chl: 0.8519	0.1980	(none)	(none)

Appendix Table 11. Linear regression analyses relating spring forage fish lakewide total numbers (SprFish) to mean densities of copepods, cladocerans, total crustacean zooplankton (sum of copepods and cladocerans), rotifers, and total zooplankton (organisms/m^3) measured in 20-m-to-surface net tows in February, averaged over Locations 502 and 508, utilizing data collected 1999-2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	logSprFish = 2.04175 + 1.09938 logFebCop	0.4120	**0.0180**	13	Intercept: 0.1949 Zoo: **0.0180**	0.1434	(none)	(none)
1999-2012	Lakewide	logSprFish = 2.94956 + 0.87008 logFebClad	0.3588	**0.0305**	13	Intercept: 0.0430 Zoo: **0.0305**	0.7474	(none)	(none)
1999-2012	Lakewide	logSprFish = 1.35534 + 1.19369 logFebCrust	0.4849	**0.0082**	13	Intercept: 0.3824 Zoo: **0.0082**	0.0741	(none)	(none)
1999-2012	Lakewide	logSprFish FebRot	0.0296	0.5741	13	Intercept: <0.0001 Zoo: 0.5741	**0.0377**	(none)	(none)
1999-2012	Lakewide	logSprFish FebTotalZoo	0.2766	0.0649	13	Intercept: <0.0001 Zoo: 0.0649	0.7746	**1999 (SR=2.665)**	(none)

Appendix Table 12. Repeat of analysis in Appendix Table 11 where observation for 1999 was identified as outlying, excluding data for outlying observation.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012 (excl 1999)	Lakewide	logSprFish = 5.29528 + 0.00004 FebTotalZoo	0.6267	**0.0022**	12	Intercept: <0.0001 Zoo: **0.0022**	0.0926	(none)	(none)

Appendix Table 13. Linear regression analyses relating spring forage fish densities (no/ha) (SprDens) in the Keowee River and Little River basins of Lake Keowee to mean densities of copepods, cladocerans, total crustacean zooplankton (sum of copepods and cladocerans), rotifers, and total zooplankton (organisms/m^3) measured in 20-m-to-surface net tows in February. Spring forage fish densities in the Keowee River basin were regressed on zooplankton densities measured at Location 508 in the Keowee River basin; spring forage fish densities in the Little River basin were regressed on zooplankton densities measured at Location 502 in the Little River basin. Analyses utilized data collected 1999-2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Keowee	logSprDens logFebCop	0.2835	0.0610	13	Intercept: 0.6231 Zoo: 0.0610	0.0989	(none)	(none)
1999-2012	Keowee	logSprDens = -1.25355 + 0.96936 logFebClad	0.4531	**0.0117**	13	Intercept: 0.3122 Zoo: **0.0117**	0.6055	**1999 (SR=3.066)**	(none)
1999-2012	Keowee	logSprDens = -2.31141 + 1.15444 logFebCrust	0.4994	**0.0069**	13	Intercept: 0.1263 Zoo: **0.0069**	**0.0420**	(none)	(none)
1999-2012	Keowee	logSprDens FebRot	0.0912	0.3159	13	Intercept: <0.0001 Zoo: 0.3159	0.0580	(none)	(none)
1999-2012	Keowee	logSprDens FebTotalZoo	0.2070	0.1183	13	Intercept: <0.0001 Zoo: 0.1183	0.5706	**1999 (SR=2.769)**	(none)
1999-2012	Little	logSprDens = -2.00730 + 0.42275 logFebCop	0.3973	**0.0209**	13	Intercept: 0.2315 Zoo: **0.0209**	0.5501	(none)	(none)
1999-2012	Little	logSprDens logFebClad	0.2792	0.0634	13	Intercept: 0.8309 Zoo: 0.0634	0.5298	(none)	(none)
1999-2012	Little	logSprDens = -2.04271 + 1.07335 logFebCrust	0.3924	**0.0220**	13	Intercept: 0.2320 Zoo: **0.0220**	0.8311	(none)	(none)
1999-2012	Little	logSprDens FebRot	0.0001	0.9723	13	Intercept: <0.0001 Zoo: 0.9723	0.1804	(none)	(none)
1999-2012	Little	logSprDens FebTotalZoo	0.2870	0.0592	13	Intercept: 0.0005 Zoo: 0.0592	0.6624	(none)	(none)

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Both	logSprDens = -1.22646 + 0.94270 logFebCop	0.3200	**0.0026**	26	Intercept: 0.2525 Zoo: **0.0026**	0.3299	(none)	(none)
1999-2012	Both	logSprDens = -0.69681 + 0.81537 logFebClad	0.3549	**0.0013**	26	Intercept: 0.4051 Zoo: **0.0013**	0.5097	**Keo-1999 (SR=2.774)**	(none)
1999-2012	Both	logSprDens = -2.17609 + 1.11366 logFebCrust	0.4395	**0.0002**	26	Intercept: 0.0451 Zoo: **0.0002**	0.3239	(none)	(none)
1999-2012	Both	logSprDens FebRot	0.0265	0.4265	26	Intercept: <0.0001 Zoo: 0.4265	0.0774	(none)	(none)
1999-2012	Both	logSprDens = 1.77320 + 0.00003 FebTotalZoo	0.2062	**0.0198**	26	Intercept: <0.0001 Zoo: **0.0198**	0.8254	**Keo-1999 (SR=2.931)**	(none)

Appendix Table 14. Repeat of analyses in Appendix Table 13 for regressions where observations for 1999 were identified as outlying, excluding outlying observations.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012 (excl 1999)	Keowee	logSprFish = -1.69834 + 1.07211 logFebClad	0.8732	**<0.0001**	12	Intercept: 0.0052 Zoo: **<0.0001**	0.1636	(none)	(none)
1999-2012 (excl 1999)	Keowee	logSprFish = 1.53984 + 0.00004 FebTotalZoo	0.6171	**0.0025**	12	Intercept: <0.0001 Zoo: **0.0025**	0.2525	**2001 (SR=2.568)**	(none)
1999-2012 (excl 1999)	Both	logSprFish = -0.81690 + 0.83351 logFebClad	0.5169	**<0.0001**	24	Intercept: 0.2079 Zoo: **<0.0001**	0.7959	**Lit-2010 (SR=-2.760)**	(none)
1999-2012 (excl 1999)	Both	logSprFish = 1.55836 + 0.00003 FebTotalZoo	0.4615	**0.0003**	24	Intercept: <0.0001 Zoo: **0.0003**	0.2947	**Lit-2010 (SR=-2.670)**	(none)

Appendix Table 15. Linear regression analyses relating fall forage fish lakewide total numbers (FallFish) to densities of copepods, cladocerans, total crustacean zooplankton (sum of copepods and cladocerans), rotifers, and total zooplankton (organisms/m^3) measured in 20-m-to-surface net tows in May, averaged over Locations 502 and 508, utilizing data collected 1999-2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	FallFish logMayCop	0.0949	0.3058	13	Intercept: 0.4625 Zoo: 0.3058	0.3295	(none)	(none)
1999-2012	Lakewide	FallFish logMayClad	0.0005	0.9446	13	Intercept: 0.6328 Zoo: 0.9446	0.2025	(none)	(none)
1999-2012	Lakewide	FallFish logMayCrust	0.0514	0.4566	13	Intercept: 0.6161 Zoo: 0.4566	0.6989	(none)	(none)
1999-2012	Lakewide	FallFish = 38,309,740 + 11,041,707 logMayRot	0.4354	**0.0141**	13	Intercept: 0.0393 Zoo: **0.0141**	0.4306	(none)	(none)
1999-2012	Lakewide	FallFish = -63,481,192 + 15,634,163 logMayTotalZoo	0.3610	**0.0299**	13	Intercept: 0.0526 Zoo: **0.0299**	0.2430	(none)	(none)

Appendix Table 16. Linear regression analyses relating fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to densities of copepods, cladocerans, total crustacean zooplankton (sum of copepods and cladocerans), rotifers, and total zooplankton (organisms/m^3) measured in 20-m-to-surface net tows in May. Fall forage fish densities in the Keowee River basin were regressed on zooplankton densities measured at Location 508 in the Keowee River basin; fall forage fish densities in the Little River basin were regressed on zooplankton densities measured at Location 502 in the Little River basin. Analyses utilized data collected 1999-2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Keowee	FallDensKeo logMayCop	0.0141	0.6990	13	Intercept: 0.9603 MayZoo: 0.6990	0.7943	(none)	(none)
1999-2012	Keowee	FallDensKeo MayClad	0.0787	0.3531	13	Intercept: 0.0008 MayZoo: 0.3531	0.3482	(none)	(none)
1999-2012	Keowee	FallDensKeo MayCrust	0.0050	0.8187	13	Intercept: 0.0728 MayZoo: 0.8187	0.6123	(none)	(none)
1999-2012	Keowee	FallDensKeo = -4832.69439 + 1426.82994 logMayRot	0.5823	**0.0024**	13	Intercept: 0.0089 MayZoo: **0.0024**	0.5118	**2011 (SR=-2.633)**	(none)
1999-2012	Keowee	FallDensKeo = -8414.47817 + 2096.53960 logMayTotalZoo	0.4118	**0.0181**	13	Intercept: 0.0325 MayZoo: **0.0181**	0.4417	(none)	(none)
1999-2012	Little	logFallDensLit logMayCop	0.0210	0.6366	13	Intercept: 0.0815 MayZoo: 0.6366	0.0802	(none)	(none)
1999-2012	Little	logFallDensLit logMayClad	0.0067	0.7910	13	Intercept: 0.0135 MayZoo: 0.7910	0.7211	(none)	(none)
1999-2012	Little	logFallDensLit logMayCrust	0.0164	0.6769	13	Intercept: 0.1276 MayZoo: 0.6769	0.2424	(none)	(none)
1999-2012	Little	logFallDensLit logMayRot	0.0924	0.3127	13	Intercept: 0.0310 MayZoo: 0.3127	0.4111	(none)	(none)
1999-2012	Little	logFallDensLit logMayTotalZoo	0.0609	0.4164	13	Intercept: 0.1879 MayZoo: 0.4164	0.2889	(none)	(none)

Appendix Table 17. Repeat of analysis in Appendix Table 16 where observation for 2011 was identified as outlying, excluding the outlying observation.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012 (excl 2011)	Keowee	FallDensKeo = -5350.54367 + 1564.16943 logMayRot	0.8162	**<0.0001**	12	Intercept: 0.0003 MayZoo: **<0.0001**	0.4186	(none)	(none)

Appendix Table 18. Linear regression analyses relating fall forage fish lakewide total numbers (FallFish) to mean densities of copepods, cladocerans, total crustacean zooplankton (sum of copepods and cladocerans), rotifers, and total zooplankton (organisms/m^3) measured in 20-m-to-surface net tows in May and August, averaged over Locations 502 and 508, utilizing data collected 1999-2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	FallFish MayAugCop	0.0104	0.7408	13	Intercept: 0.0877 Zoo: 0.7408	0.3033	(none)	(none)
1999-2012	Lakewide	FallFish MayAugClad	0.0020	0.8857	13	Intercept: 0.0653 Zoo: 0.8857	0.4186	(none)	(none)
1999-2012	Lakewide	FallFish MayAugCrust	0.0086	0.7638	13	Intercept: 0.1296 Zoo: 0.7638	0.7632	(none)	(none)
1999-2012	Lakewide	FallFish logMayAugRot	0.0933	0.3101	13	Intercept: 0.5900 Zoo: 0.3101	0.0940	(none)	(none)
1999-2012	Lakewide	FallFish logMayAugTotalZoo	0.0421	0.5012	13	Intercept: 0.6961 Zoo: 0.5012	0.0729	(none)	(none)

Appendix Table 19. Linear regression analyses relating fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean densities of copepods, cladocerans, total crustacean zooplankton (sum of copepods and cladocerans), rotifers, and total zooplankton (organisms/m^3) measured in 20-m-to-surface net tows in May and August. Fall forage fish densities in the Keowee River basin were regressed on zooplankton densities measured at Location 508 in the Keowee River basin; fall forage fish densities in the Little River basin were regressed on zooplankton densities measured at Location 502 in the Little River basin. Analyses utilized data collected 1999-2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Keowee	FallDensKeo MayAugCop	0.0109	0.7342	13	Intercept: 0.0130 MayAugZoo: 0.7342	0.3437	(none)	(none)
1999-2012	Keowee	FallDensKeo MayAugClad	0.0143	0.6976	13	Intercept: 0.0033 MayAugZoo: 0.6976	0.5034	(none)	(none)
1999-2012	Keowee	FallDensKeo MayAugCrust	0.0220	0.6286	13	Intercept: 0.0203 MayAugZoo: 0.6286	0.5010	(none)	(none)
1999-2012	Keowee	FallDensKeo logMayAugRot	0.1495	0.1918	13	Intercept: 0.4404 MayAugZoo: 0.1918	0.4644	(none)	(none)
1999-2012	Keowee	FallDensKeo logMayAugTotal	0.0442	0.4907	13	Intercept: 0.7075 MayAugZoo: 0.4907	0.9627	(none)	(none)
1999-2012	Little	logFallDensLit MayAugCop	0.0022	0.8794	13	Intercept: <0.0001 MayAugZoo: 0.8794	0.1107	(none)	(none)
1999-2012	Little	logFallDensLit MayAugClad	0.1167	0.2534	13	Intercept: <0.0001 MayAugZoo: 0.2534	0.4177	(none)	(none)
1999-2012	Little	logFallDensLit MayAugCrust	0.0312	0.5636	13	Intercept: <0.0001 MayAugZoo: 0.5636	0.3635	(none)	(none)
1999-2012	Little	logFallDensLit logMayAugRot	0.0191	0.6526	13	Intercept: 0.0180 MayAugZoo: 0.6526	0.2228	(none)	**1999 (CD=3.737)**
1999-2012	Little	logFallDensLit logMayAugTotalZoo	0.0026	0.8679	13	Intercept: 0.1014 MayAugZoo: 0.8679	0.1532	(none)	**1999 (CD=3.684)**

Appendix Table 20. Repeat of analysis in Appendix Table 19 for analyses where observation for the year 1999 was identified as highly influential, excluding the highly influential observation.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012 (excl 1999)	Little	logFallDensLit = 0.29814 + 0.63436 logMayAugRot	0.4644	**0.0147**	12	Intercept: 0.7643 MayAugZoo: **0.0147**	0.3431	(none)	(none)
1999-2012 (excl 1999)	Little	logFallDensLit = -1.12546 + 0.88826 logMayAugTotalZoo	0.3489	**0.0431**	12	Intercept: 0.5555 MayAugZoo: **0.0431**	0.3281	(none)	(none)

Appendix Table 21. Linear regression analyses relating spring forage fish densities (no/ha) in the Keowee River and Little River basins of Lake Keowee to littoral density (no/km) and biomass (kg/km) of largemouth bass (LMB); spotted bass (SPB); and total black basses (BLB) measured in spring shoreline electrofishing carried out in 1999, 2002, 2005, 2008, 2010, and 2011.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logSprDens Indep: LMBnumkm	0.3003	0.0651	12	Intercept: <0.0001 Pred: 0.0651	0.8849	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logSprDens Indep: logSPBnumkm	0.2325	0.1124	12	Intercept: <0.0001 Pred: 0.1124	0.9603	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logSprDens Indep: logBLBnumkm	0.0635	0.4293	12	Intercept: 0.0070 Pred: 0.4293	0.3455	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	logSprDens = 1.81285 + 0.20478 LMBkgkm	0.3477	**0.0436**	12	Intercept: <0.0001 Pred: **0.0436**	0.8047	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logSprDens Indep: logSPBkgkm	0.2042	0.1402	12	Intercept: <0.0001 Pred: 0.1402	0.8984	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logSprDens Indep: BLBkgkm	0.0232	0.6364	12	Intercept: <0.0001 Pred: 0.6364	0.2313	(none)	(none)

Appendix Table 22. Linear regression analyses relating fall forage fish total lakewide numbers on Lake Keowee to mean lakewide littoral density (no/km) and biomass (kg/km) of largemouth bass (LMB); spotted bass (SPB); and total black basses (BLB) measured in spring shoreline electrofishing carried out in 1999, 2002, 2005, 2008, 2010, and 2011.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999, 2002, 2005, 2008, 2010, 2011	Lakewide	FallFish LWLMBnumkm	0.0127	0.8319	6	Intercept: 0.1621 Pred: 0.8319	0.2156	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Lakewide	FallFish = 14,000,339 – 400,407 LWSPBnumkm	0.6566	0.0505	6	Intercept: 0.0057 Pred: 0.0505	0.3386	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Lakewide	FallFish = 17,678,109 – 420,830 LWBLBnumkm	0.8452	**0.0095**	6	Intercept: 0.0016 Pred: **0.0095**	0.2944	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Lakewide	FallFish LWLMBkgkm	0.0711	0.6096	6	Intercept: 0.4091 Pred: 0.6096	0.1495	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Lakewide	FallFish LWSPBkgkm	0.1748	0.4095	6	Intercept: 0.0625 Pred: 0.4095	0.1454	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Lakewide	FallFish LWBLBkgkm	0.0624	0.6332	6	Intercept: 0.3290 Pred: 0.6332	0.2619	(none)	(none)

Appendix Table 23. Linear regression analyses relating fall forage fish densities (no/ha) in the Keowee River and Little River basins of Lake Keowee to littoral density (no/km) and biomass (kg/km) of largemouth bass (LMB); spotted bass (SPB); and total black basses (BLB) measured in spring shoreline electrofishing carried out in 1999, 2002, 2005, 2008, 2010, and 2011.

Years	Zone	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logFallDens Indep: LMBnumkm	0.0007	0.9343	12	Intercept: <0.0001 Pred: 0.9343	0.1587	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logFallDens Indep: logSPBnumkm	0.1561	0.2036	12	Intercept: <0.0001 Pred: 0.2036	0.2533	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	logFallDens = 4.10610 – 0.85820 logBLBnumkm	0.3422	**0.0457**	12	Intercept: <0.0001 Pred: **0.0457**	0.1721	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	logFallDens LMBkgkm	0.1344	0.2412	12	Intercept: <0.0001 Pred: 0.2412	0.2243	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logFallDens Indep: logSPBkgkm	0.0543	0.4659	12	Intercept: <0.0001 Pred: 0.4659	0.1786	(none)	(none)
1999, 2002, 2005, 2008, 2010, 2011	Both basins	Dep: logFallDens Indep: BLBkgkm	0.0126	0.7284	12	Intercept: <0.0001 Pred: 0.7284	0.2317	(none)	(none)

Appendix Table 24. Linear regression analyses relating spring forage fish numbers lakewide in Lake Keowee (SprFish) and spring forage fish densities (no/ha) in the Keowee River and Little River basins of Lake Keowee to mean, maximum daily, and maximum 30-day average pumping flows (m^3/sec) observed December-February at Jocassee Pumped Storage Station, utilizing pumping data from December 1998 through February 2013 and forage fish data from spring 1999 through spring 2013.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2013	Lakewide	logSprFish MeanDecFebJocPump	0.1789	0.1318	14	Intercept: <0.0001 JocPump: 0.1318	0.2492	(none)	(none)
1999-2013	Lakewide	logSprFish MaxDailyDecFebJocPump	0.0138	0.6891	14	Intercept: <0.0001 JocPump: 0.6891	0.1935	(none)	(none)
1999-2013	Lakewide	logSprFish Max30dayDecFebJocPump	0.0917	0.2926	14	Intercept: <0.0001 JocPump: 0.2926	0.1812	(none)	(none)
1999-2013	Keowee	logSprDensKeo MeanDecFebJocPump	0.1385	0.1900	14	Intercept: <0.0001 JocPump: 0.1900	0.1006	(none)	(none)
1999-2013	Keowee	logSprDensKeo MaxDailyDecFebJocPump	0.0096	0.7384	14	Intercept: <0.0001 JocPump: 0.7384	0.1304	(none)	(none)
1999-2013	Keowee	logSprDensKeo Max30dayDecFebJocPump	0.0687	0.3653	14	Intercept: <0.0001 JocPump: 0.3653	0.0894	(none)	(none)
1999-2013	Little	logSprDensLit MeanDecFebJocPump	0.1715	0.1410	14	Intercept: <0.0001 JocPump: 0.1410	0.9176	(none)	(none)
1999-2013	Little	logSprDensLit MaxDailyDecFebJocPump	0.0092	0.7442	14	Intercept: <0.0001 JocPump: 0.7442	0.2032	(none)	(none)
1999-2013	Little	logSprDensLit Max30dayDecFebJocPump	0.0855	0.3103	14	Intercept: <0.0001 JocPump: 0.3103	0.5235	(none)	(none)

Appendix Table 25. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean pumping flows (m^3/sec) observed May-June at Jocassee Pumped Storage Station, utilizing data from 1999 through 2012.

Years	**Basin**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**SPEC**	**Outliers: |SR|≥2.5**	**Sig. Cook's D**
1999-2012	Lakewide	FallFish MeanMayJunJocPump	0.0550	0.4195	14	Intercept: 0.0252 JocPump: 0.4195	0.0935	(none)	(none)
1999-2012	Keowee	FallDensKeo MeanMayJunJocPump	0.0569	0.4113	14	Intercept: 0.0133 JocPump: 0.4113	0.1188	(none)	(none)
1999-2012	Little	logFallDensLit MeanMayJunJocPump	0.0647	0.3801	14	Intercept: <0.0001 JocPump: 0.3801	0.1856	(none)	(none)

Appendix Table 26. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean, maximum daily, and maximum 30-day average pumping flows (m^3/sec) observed May-October at Jocassee Pumped Storage Station, utilizing data from 1999 through 2012.

Years	**Basin**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**SPEC**	**Outliers: |SR|≥2.5**	**Sig. Cook's D**
1999-2012	Lakewide	FallFish MeanMayOctJocPump	0.0474	0.4546	14	Intercept: 0.0726 JocPump: 0.4546	0.6372	(none)	(none)
1999-2012	Lakewide	FallFish MaxDailyMayOctJocPump	0.0495	0.4447	14	Intercept: 0.1369 JocPump: 0.4447	0.3305	(none)	(none)
1999-2012	Lakewide	FallFish = 26,482,038 – 77,886 Max30dayMayOctJocPump	0.3506	**0.0257**	14	Intercept: 0.0026 JocPump: **0.0257**	0.4016	(none)	(none)
1999-2012	Keowee	FallDensKeo MeanMayOctJocPump	0.1501	0.1711	14	Intercept: 0.0121 JocPump: 0.1711	0.7736	(none)	(none)
1999-2012	Keowee	FallDensKeo MaxDailyMayOctJocPump	0.1556	0.1627	14	Intercept: 0.0281 JocPump: 0.1627	0.6524	(none)	(none)
1999-2012	Keowee	FallDensKeo = 3084.97707 – 8.88036 Max30dayMayOctJocPump	0.4355	**0.0102**	14	Intercept: 0.0006 JocPump: **0.0102**	0.5148	(none)	(none)
1999-2012	Little	logFallDensLit MeanMayOctJocPump	0.0023	0.8693	14	Intercept: <0.0001 JocPump: 0.8693	0.5973	(none)	(none)
1999-2012	Little	logFallDensLit MaxDailyMayOctJocPump	0.0028	0.8563	14	Intercept: 0.0007 JocPump: 0.8563	0.5720	(none)	(none)
1999-2012	Little	logFallDensLit Max30dayMayOctJocPump	0.1926	0.1165	14	Intercept: <0.0001 JocPump: 0.1165	0.6206	(none)	(none)

Appendix Table 27. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean, maximum daily, and maximum 30-day average pumping flows (m^3/sec) observed May-October at Jocassee Pumped Storage Station, utilizing data from 1999 through 2012. JPSS pumping variables have been power-transformed by raising variables to a power of 3 to account for negative skew in the original distribution and allow assumption of a normal distribution.

Years	**Basin**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**SPEC**	**Outliers: |SR|≥2.5**	**Sig. Cook's D**
1999-2012	Lakewide	FallFish $MeanMayOctJocPump^3$	0.0235	0.6005	14	Intercept: 0.0087 JocPump: 0.6005	0.6818	(none)	(none)
1999-2012	Lakewide	FallFish $MaxDailyMayOctJocPump^3$	0.0214	0.6178	14	Intercept: 0.0268 JocPump: 0.6178	0.3583	(none)	(none)
1999-2012	Lakewide	FallFish = 16,737347 – 0.64601 $Max30dayMayOctJocPump^3$	0.3430	**0.0278**	14	Intercept: 0.0003 JocPump: **0.0278**	0.3551	(none)	(none)
1999-2012	Keowee	FallDensKeo $MeanMayOctJocPump^3$	0.1038	0.2614	14	Intercept: 0.0009 JocPump: 0.2614	0.9027	(none)	(none)
1999-2012	Keowee	FallDensKeo $MaxDailyMayOctJocPump^3$	0.1095	0.2479	14	Intercept: 0.0031 JocPump: 0.2479	0.8590	(none)	(none)
1999-2012	Keowee	FallDensKeo = 2009.49863 – 0.00008 $Max30dayMayOctJocPump^3$	0.4604	**0.0076**	14	Intercept: <0.0001 JocPump: **0.0076**	0.3838	(none)	(none)
1999-2012	Little	logFallDensLit $MeanMayOctJocPump^3$	0.0000	0.9870	14	Intercept: <0.0001 JocPump: 0.9870	0.5602	(none)	(none)
1999-2012	Little	logFallDensLit $MaxDailyMayOctJocPump^3$	0.0001	0.9751	14	Intercept: <0.0001 JocPump: 0.9751	0.5335	(none)	(none)
1999-2012	Little	logFallDensLit $Max30dayMayOctJocPump^3$	0.1938	0.1151	14	Intercept: <0.0001 JocPump: 0.1151	0.6894	(none)	(none)

Appendix Table 28. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean, maximum daily, and maximum 30-day average pumping flows (m^3/sec) observed May-October at Jocassee Pumped Storage Station, utilizing data from 1999 through 2012, excluding data for the year 2000 (see text).

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012 (excl 2000)	Lakewide	FallFish MeanMayOctJocPump	0.0565	0.4344	13	Intercept: 0.8994 JocPump: 0.4344	0.4748	(none)	(none)
1999-2012 (excl 2000)	Lakewide	FallFish MaxDailyMayOctJocPump	0.0845	0.3352	13	Intercept: 0.6929 JocPump: 0.3352	0.4347	(none)	(none)
1999-2012 (excl 2000)	Lakewide	FallFish = 22,978,878 – 63,077 Max30dayMayOctJocPump	0.0787	0.3531	13	Intercept: 0.1605 JocPump: 0.3531	0.6452	(none)	(none)
1999-2012 (excl 2000)	Keowee	FallDensKeo MeanMayOctJocPump	0.0019	0.8875	13	Intercept: 0.2444 JocPump: 0.8875	0.4433	(none)	(none)
1999-2012 (excl 2000)	Keowee	FallDensKeo MaxDailyMayOctJocPump	0.0002	0.9633	13	Intercept: 0.4792 JocPump: 0.9633	0.4414	(none)	(none)
1999-2012 (excl 2000)	Keowee	FallDensKeo = 3507.26307 – 10.66551 Max30dayMayOctJocPump	0.2123	0.1130	13	Intercept: 0.0344 JocPump: 0.1130	0.4072	(none)	(none)
1999-2012 (excl 2000)	Little	logFallDensLit MeanMayOctJocPump	0.1018	0.2880	13	Intercept: 0.0021 JocPump: 0.2880	0.5681	(none)	(none)
1999-2012 (excl 2000)	Little	logFallDensLit MaxDailyMayOctJocPump	0.1316	0.2231	13	Intercept: 0.7318 JocPump: 0.2231	0.7318	(none)	(none)
1999-2012 (excl 2000)	Little	logFallDensLit Max30dayMayOctJocPump	0.0416	0.5041	13	Intercept: 0.0050 JocPump: 0.5041	0.9814	(none)	(none)

Appendix Table 29. Linear regression analyses relating spring forage fish numbers lakewide in Lake Keowee (SprFish) and spring forage fish densities (no/ha) (SprDens) in the Keowee River and Little River basins of Lake Keowee to mean, maximum daily, and maximum 30-day average generation flows (m^3/sec) observed December-February at Keowee Hydroelectric Station, utilizing generation data from December 1998 through February 2013 and forage fish data from spring 1999 through spring 2013.

Years	**Basin**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**SPEC**	**Outliers: |SR|≥2.5**	**Sig. Cook's D**
1999-2013	Lakewide	logSprFish logMeanDecFebKeoGen	0.0301	0.5532	14	Intercept: <0.0001 KeoGen: 0.5532	0.7204	(none)	(none)
1999-2013	Lakewide	logSprFish logMaxDailyDecFebKeoGen	0.0008	0.9246	14	Intercept: 0.0015 KeoGen: 0.9246	0.1233	(none)	(none)
1999-2013	Lakewide	logSprFish logMax30dayDecFebKeoGen	0.0068	0.7795	14	Intercept: <0.0001 KeoGen: 0.7795	0.6055	(none)	(none)
1999-2013	Keowee	logSprDensKeo logMeanDecFebKeoGen	0.0005	0.9372	14	Intercept: <0.0001 KeoGen: 0.9372	0.7786	(none)	(none)
1999-2013	Keowee	logSprDensKeo logMaxDailyDecFebKeoGen	0.0286	0.5630	14	Intercept: 0.3672 KeoGen: 0.5630	0.1746	(none)	(none)
1999-2013	Keowee	logSprDensKeo logMax30dayDecFebKeoGen	0.0043	0.8240	14	Intercept: 0.0010 KeoGen: 0.8240	0.8092	(none)	(none)
1999-2013	Little	logSprDensLit logMeanDecFebKeoGen	0.0590	0.4027	14	Intercept: <0.0001 KeoGen: 0.4027	0.7375	(none)	(none)
1999-2013	Little	logSprDensLit logMaxDailyDecFebKeoGen	0.0055	0.8012	14	Intercept: 0.1254 KeoGen: 0.8012	0.1013	(none)	(none)
1999-2013	Little	logSprDensLit logMax30dayDecFebKeoGen	0.0286	0.5632	14	Intercept: 0.0004 KeoGen: 0.5632	0.4414	(none)	(none)

Appendix Table 30. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean and maximum daily generation flows (m^3/sec) observed May-June at Keowee Hydroelectric Station, utilizing data from 1999 through 2012.

Years	Basin	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	SPEC	Outliers: |SR|≥2.5	Sig. Cook's D
1999-2012	Lakewide	FallFish MeanMayJunKeoGen	0.0336	0.5308	14	Intercept: 0.0007 KeoGen: 0.5308	0.7954	(none)	(none)
1999-2012	Lakewide	FallFish MaxDailyMayJunKeoGen	0.0297	0.5559	14	Intercept: 0.0034 KeoGen: 0.5559	0.0668	(none)	(none)
1999-2012	Keowee	FallDensKeo MeanMayJunKeoGen	0.0000	0.9872	14	Intercept: 0.0006 KeoGen: 0.9872	0.8358	(none)	(none)
1999-2012	Keowee	FallDensKeo MaxDailyMayJunKeoGen	0.0019	0.8832	14	Intercept: 0.0046 KeoGen: 0.8832	**0.0277**	(none)	(none)
1999-2012	Little	logFallDensLit MeanMayJunKeoGen	0.0443	0.4701	14	Intercept: <0.0001 KeoGen: 0.4701	0.4087	(none)	(none)
1999-2012	Little	logFallDensLit MaxDailyMayJunKeoGen	0.0401	0.4927	14	Intercept: <0.0001 KeoGen: 0.4927	0.0898	(none)	(none)

Appendix Table 31. Linear regression analyses relating fall forage fish numbers lakewide in Lake Keowee (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee to mean, maximum daily, and maximum 30-day average generation flows (m^3/sec) observed May-October at Keowee Hydroelectric Station, utilizing data from 1999 through 2012.

Years	**Basin**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**SPEC**	**Outliers: |SR|≥2.5**	**Sig. Cook's D**
1999-2012	Lakewide	FallFish MeanMayOctKeoGen	0.0002	0.9653	14	Intercept: 0.0044 KeoGen: 0.9653	0.3824	(none)	(none)
1999-2012	Lakewide	FallFish logMaxDailyMayOctKeoGen	0.0005	0.9367	14	Intercept: 0.5840 KeoGen: 0.9367	0.7534	(none)	(none)
1999-2012	Lakewide	FallFish Max30dayMayOctKeoGen	0.0027	0.8588	14	Intercept: 0.0191 KeoGen: 0.8588	0.3107	(none)	(none)
1999-2012	Keowee	FallDensKeo MeanMayOctKeoGen	0.0403	0.4914	14	Intercept: 0.0032 KeoGen: 0.4914	0.3430	(none)	(none)
1999-2012	Keowee	FallDensKeo logMaxDailyMayOctKeoGen	0.0036	0.8381	14	Intercept: 0.7219 KeoGen: 0.8381	0.4395	(none)	(none)
1999-2012	Keowee	FallDensKeo Max30dayMayOctKeoGen	0.0439	0.4720	14	Intercept: 0.0161 KeoGen: 0.4720	0.2871	(none)	(none)
1999-2012	Little	logFallDensLit MeanMayOctKeoGen	0.0000	0.9943	14	Intercept: <0.0001 KeoGen: 0.9943	0.4689	(none)	(none)
1999-2012	Little	logFallDensLit logMaxDailyMayOctKeoGen	0.0267	0.5769	14	Intercept: 0.0070 KeoGen: 0.5769	0.5660	(none)	(none)
1999-2012	Little	logFallDensLit Max30dayMayOctKeoGen	0.0029	0.8551	14	Intercept: <0.0001 KeoGen: 0.8551	0.3283	(none)	(none)

Appendix Table 32. Multiple regression analyses of total number of forage fish lakewide in spring in Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and Keowee Hydroelectric Station generation flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average), utilizing data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	Dep: logSprFish Indep: MeanDecFebJocPump Indep: logMeanDecFebKeoGen	0.1958	0.3016	14	Intercept: <0.0001 JocPump: 0.1603 KeoGen: 0.6403	1.011	0.3982	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MeanDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.1911	0.3115	14	Intercept: 0.0013 JocPump: 0.1360 KeoGen: 0.6920	1.037	0.2514	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MeanDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.1791	0.3377	14	Intercept: <0.0001 JocPump: 0.1568 KeoGen: 0.9624	1.028	0.3782	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MaxDailyDecFebJocPump Indep: logMeanDecFebKeoGen	0.0350	0.8219	14	Intercept: <0.0001 JocPump: 0.8165 KeoGen: 0.6324	1.091	0.5271	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MaxDailyDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.0188	0.9006	14	Intercept: 0.0026 JocPump: 0.6614 KeoGen: 0.8164	1.124	0.3127	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MaxDailyDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.0153	0.9187	14	Intercept: <0.0001 JocPump: 0.7635 KeoGen: 0.8993	1.189	0.4357	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: Max30dayDecFebJocPump Indep: logMeanDecFebKeoGen	0.1119	0.5208	14	Intercept: <0.0001 JocPump: 0.3359 KeoGen: 0.6273	1.012	0.4440	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	Dep: logSprFish Indep: Max30dayDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.0998	0.5607	14	Intercept: 0.0019 JocPump: 0.2947 KeoGen: 0.7584	1.042	0.3190	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: Max30dayDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.0925	0.5863	14	Intercept: <0.0001 JocPump: 0.3299 KeoGen: 0.9234	1.034	0.3636	(none)	(none)

Appendix Table 33. Multiple regression analyses of spring forage fish density (no/ha) in the Keowee River basin of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and Keowee Hydroelectric Station generation flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average), utilizing data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2013	Dep: logSprDensKeo Indep: MeanDecFebJocPump Indep: logMeanDecFebKeoGen	0.1388	0.4397	14	Intercept: <0.0001 JocPump: 0.2108 KeoGen: 0.9559	1.011	0.2331	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MeanDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.1983	0.2966	14	Intercept: 0.3636 JocPump: 0.1553 KeoGen: 0.3846	1.037	0.1782	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MeanDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.1550	0.3960	14	Intercept: 0.0007 JocPump: 0.1889 KeoGen: 0.6525	1.028	0.3300	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MaxDailyDecFebJocPump Indep: logMeanDecFebKeoGen	0.0097	0.9479	14	Intercept: 0.0004 JocPump: 0.7561 KeoGen: 0.9860	1.091	0.2241	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MaxDailyDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.0555	0.7305	14	Intercept: 0.4123 JocPump: 0.5873 KeoGen: 0.4802	1.124	0.2285	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MaxDailyDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.0227	0.8815	14	Intercept: 0.0018 JocPump: 0.6581 KeoGen: 0.7091	1.189	0.2681	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: Max30dayDecFebJocPump Indep: logMeanDecFebKeoGen	0.0687	0.6760	14	Intercept: 0.0001 JocPump: 0.3887 KeoGen: 0.9872	1.012	0.2511	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2013	Dep: logSprDensKeo Indep: Max30dayDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.1199	0.4955	14	Intercept: 0.3870 JocPump: 0.3085 KeoGen: 0.4409	1.042	0.2035	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: Max30dayDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.0818	0.6253	14	Intercept: 0.0011 JocPump: 0.3558 KeoGen: 0.6992	1.034	0.2929	(none)	(none)

Appendix Table 34. Multiple regression analyses of spring forage fish density (no/ha) in the Little River basin of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and Keowee Hydroelectric Station generation flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average), utilizing data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2013	Dep: logSprDensLit Indep: MeanDecFebJocPump Indep: logMeanDecFebKeoGen	0.2118	0.2702	14	Intercept: <0.0001 JocPump: 0.1722 KeoGen: 0.4692	1.011	0.6743	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MeanDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.1715	0.3553	14	Intercept: 0.1193 JocPump: 0.1657 KeoGen: 0.9867	1.037	0.3066	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MeanDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.1820	0.3312	14	Intercept: 0.0003 JocPump: 0.1787 KeoGen: 0.7139	1.028	0.6285	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MaxDailyDecFebJocPump Indep: logMeanDecFebKeoGen	0.0597	0.7127	14	Intercept: 0.0003 JocPump: 0.9283 KeoGen: 0.4582	1.091	0.6226	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MaxDailyDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.0112	0.9399	14	Intercept: 0.1493 JocPump: 0.8056 KeoGen: 0.8841	1.124	0.2853	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MaxDailyDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.0296	0.8478	14	Intercept: 0.0011 JocPump: 0.9186 KeoGen: 0.6403	1.189	0.5211	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: Max30dayDecFebJocPump Indep: logMeanDecFebKeoGen	0.1308	0.4624	14	Intercept: <0.0001 JocPump: 0.3608 KeoGen: 0.4647	1.012	0.7070	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2013	Dep: logSprDensLit Indep: Max30dayDecFebJocPump Indep: logMaxDailyDecFebKeoGen	0.0858	0.6106	14	Intercept: 0.1366 JocPump: 0.3468 KeoGen: 0.9567	1.042	0.3966	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: Max30dayDecFebJocPump Indep: logMax30dayDecFebKeoGen	0.0995	0.5618	14	Intercept: 0.0005 JocPump: 0.3719 KeoGen: 0.6870	1.034	0.6509	(none)	(none)

Appendix Table 35. Multiple regression analyses of total number of forage fish lakewide in spring on Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flow (m3/sec) December-February (mean, maximum daily, maximum 30-day average); and Lake Keowee lake level (meters below full pool) December-February (mean, lowest daily, lowest 30-day average), utilizing pumping and lake level data collected December 1998 through February 2013 and spring forage fish data collected 1999-2013. Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	Dep: logSprFish Indep: MeanDecFebJocPumpcms Indep: MeanDecFebLL	0.2081	0.2771	14	Intercept: <0.0001 JocPump: 0.1855 LakeLevel: 0.5374	1.044	0.5945	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MeanDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.2941	0.1472	14	Intercept: <0.0001 JocPump: 0.1749 LakeLevel: 0.2073	1.023	0.6153	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MeanDecFebJocPumpcms Indep: Max30dayDecFebLL	0.2331	0.2323	14	Intercept: <0.0001 JocPump: 0.1942 LakeLevel: 0.3970	1.046	0.5411	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MaxDailyDecFebJocPumpcms Indep: MeanDecFebLL	0.0713	0.6657	14	Intercept: <0.0001 JocPump: 0.7813 LakeLevel: 0.4268	1.020	0.5955	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MaxDailyDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.1695	0.3599	14	Intercept: <0.0001 JocPump: 0.7181 LakeLevel: 0.1787	1.002	0.4018	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: MaxDailyDecFebJocPumpcms Indep: Max30dayDecFebLL	0.1053	0.5422	14	Intercept: <0.0001 JocPump: 0.7991 LakeLevel: 0.3115	1.020	0.6002	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	Dep: logSprFish Indep: Max30dayDecFebJocPumpcms Indep: MeanDecFebLL	0.1371	0.4443	14	Intercept: <0.0001 JocPump: 0.3565 LakeLevel: 0.4626	1.020	0.5598	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: Max30dayDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.2363	0.2270	14	Intercept: <0.0001 JocPump: 0.3145 LakeLevel: 0.1768	1.004	0.6231	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: Max30dayDecFebJocPumpcms Indep: Max30dayDecFebLL	0.1672	0.3656	14	Intercept: <0.0001 JocPump: 0.3656 LakeLevel: 0.3395	1.022	0.5053	(none)	(none)

Appendix Table 36. Multiple regression analyses of spring forage fish density (no/ha) in the Keowee River basin of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flow (m3/sec) December-February (mean, maximum daily, maximum 30-day average); and Lake Keowee lake level (meters below full pool) December-February (mean, lowest daily, lowest 30-day average), utilizing pumping and lake level data collected December 1998 through February 2013 and spring forage fish data collected 1999-2013. Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2013	Dep: logSprDensKeo Indep: MeanDecFebJocPumpcms Indep: MeanDecFebLL	0.1419	0.4309	14	Intercept: <0.0001 JocPump: 0.2332 LakeLevel: 0.8387	1.044	0.2472	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MeanDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.2104	0.2727	14	Intercept: 0.0003 JocPump: 0.2467 LakeLevel: 0.3384	1.023	0.2702	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MeanDecFebJocPumpcms Indep: Max30dayDecFebLL	0.1494	0.4107	14	Intercept: <0.0001 JocPump: 0.2441 LakeLevel: 0.7152	1.046	0.1816	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MaxDailyDecFebJocPumpcms Indep: MeanDecFebLL	0.0242	0.8739	14	Intercept: 0.0006 JocPump: 0.7925 LakeLevel: 0.6931	1.020	0.3801	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MaxDailyDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.1103	0.5258	14	Intercept: 0.0022 JocPump: 0.7691 LakeLevel: 0.2884	1.002	0.4731	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: MaxDailyDecFebJocPumpcms Indep: Max30dayDecFebLL	0.0377	0.8094	14	Intercept: 0.0013 JocPump: 0.8070 LakeLevel: 0.5824	1.020	0.3456	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2013	Dep: logSprDensKeo Indep: Max30dayDecFebJocPumpcms Indep: MeanDecFebLL	0.0781	0.6392	14	Intercept: <0.0001 JocPump: 0.4141 LakeLevel: 0.7436	1.020	0.2789	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: Max30dayDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.1615	0.3795	14	Intercept: 0.0004 JocPump: 0.3996 LakeLevel: 0.2934	1.004	0.3197	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: Max30dayDecFebJocPumpcms Indep: Max30dayDecFebLL	0.0891	0.5984	14	Intercept: 0.0001 JocPump: 0.4248 LakeLevel: 0.6292	1.022	0.2363	(none)	(none)

Appendix Table 37. Multiple regression analyses of spring forage fish density (no/ha) in the Little River basin of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flow (m3/sec) December-February (mean, maximum daily, maximum 30-day average); and Lake Keowee lake level (meters below full pool) December-February (mean, lowest daily, lowest 30-day average), utilizing pumping and lake level data collected December 1998 through February 2013 and spring forage fish data collected 1999-2013. Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2013	Dep: logSprDensLit Indep: MeanDecFebJocPumpcms Indep: MeanDecFebLL	0.2186	0.2575	14	Intercept: <0.0001 JocPump: 0.2030 LakeLevel: 0.4327	1.044	0.3988	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MeanDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.2853	0.1576	14	Intercept: 0.0005 JocPump: 0.1868 LakeLevel: 0.2124	1.023	0.4504	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MeanDecFebJocPumpcms Indep: Max30dayDecFebLL	0.2539	0.1998	14	Intercept: 0.0002 JocPump: 0.2121 LakeLevel: 0.2940	1.046	0.5686	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MaxDailyDecFebJocPumpcms Indep: MeanDecFebLL	0.0914	0.5902	14	Intercept: 0.0017 JocPump: 0.8524 LakeLevel: 0.3399	1.020	0.4934	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MaxDailyDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.1630	0.3758	14	Intercept: 0.0048 JocPump: 0.7762 LakeLevel: 0.1828	1.002	0.3180	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MaxDailyDecFebJocPumpcms Indep: Max30dayDecFebLL	0.1369	0.4451	14	Intercept: 0.0035 JocPump: 0.8741 LakeLevel: 0.2284	1.020	0.5035	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2013	Dep: logSprDensLit Indep: Max30dayDecFebJocPumpcms Indep: MeanDecFebLL	0.1524	0.4029	14	Intercept: 0.0001 JocPump: 0.3819 LakeLevel: 0.3717	1.020	0.5567	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: Max30dayDecFebJocPumpcms Indep: MaxDailyDecFebLL	0.2281	0.2407	14	Intercept: 0.0007 JocPump: 0.3343 LakeLevel: 0.1818	1.004	0.3705	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: Max30dayDecFebJocPumpcms Indep: Max30dayDecFebLL	0.1932	0.3071	14	Intercept: 0.0003 JocPump: 0.3915 LakeLevel: 0.2511	1.022	0.4774	(none)	(none)

Appendix Table 38. Multiple regression analyses of total number of forage fish lakewide in spring in Lake Keowee on combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and Lake Keowee lake levels (meters below full pool, positive number) observed December-February (mean, lowest daily, lowest 30-day average). Variable names for lake level are MeanDecFebLL for mean lake level; MaxDailyDecFebLL for lowest daily lake level; and Max30dayDecFebLL for lowest 30-day average lake level observed December-February. These analyses utilize data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	Dep: logSprFish Indep: logMeanDecFebKeoGen Indep: MeanDecFebLL	0.0666	0.6845	14	Intercept: <0.0001 KeoGen: 0.8768 Lake level: 0.5253	2.704	0.3611	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: logMeanDecFebKeoGen Indep: MaxDailyDecFebLL	0.1801	0.3356	14	Intercept: <0.0001 KeoGen: 0.6071 Lake level: 0.1837	1.935	0.3874	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: logMeanDecFebKeoGen Indep: Max30dayDecFebLL	0.1214	0.4908	14	Intercept: 0.0002 KeoGen: 0.6134 Lake level: 0.3079	3.010	0.2845	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: logMaxDailyDecFebKeoGen Indep: MeanDecFebLL	0.0944	0.5797	14	Intercept: 0.0213 KeoGen: 0.5588 Lake level: 0.3091	1.309	0.3554	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: logMaxDailyDecFebKeoGen Indep: MaxDailyDecFebLL	0.2352	0.2288	14	Intercept: 0.0540 KeoGen: 0.3181 Lake level: 0.0935	0.371	0.1353	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: logMaxDailyDecFebKeoGen Indep: Max30dayDecFebLL	0.1578	0.3887	14	Intercept: 0.0459 KeoGen: 0.4025 Lake level: 0.1798	1.432	0.3175	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	Dep: logSprFish Indep: logMax30dayDecFebKeoGen Indep: MeanDecFebLL	0.0885	0.6007	14	Intercept: 0.0002 KeoGen: 0.6010 Lake level: 0.3421	2.189	0.3158	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: logMax30dayDecFebKeoGen Indep: MaxDailyDecFebLL	0.1999	0.2932	14	Intercept: 0.0001 KeoGen: 0.4699 Lake level: 0.1315	1.587	0.1270	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: logMax30dayDecFebKeoGen Indep: Max30dayDecFebLL	0.1530	0.4013	14	Intercept: 0.0005 KeoGen: 0.4237 Lake level: 0.1957	2.259	0.2831	(none)	(none)

Appendix Table 39. Multiple regression analyses of spring forage fish density (no/ha) in the Keowee River basin of Lake Keowee on combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and Lake Keowee lake levels (meters below full pool, positive number) observed December-February (mean, lowest daily, lowest 30-day average). Variable names for lake level are MeanDecFebLL for mean lake level; MaxDailyDecFebLL for lowest daily lake level; and Max30dayDecFebLL for lowest 30-day average lake level observed December-February. These analyses utilize data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMeanDecFebKeoGen Indep: MeanDecFebLL	0.0362	0.8164	14	Intercept: 0.0887 KeoGen: 0.6553 Lake level: 0.5365	2.704	0.4668	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMeanDecFebKeoGen Indep: MaxDailyDecFebLL	0.1803	0.3351	14	Intercept: 0.2154 KeoGen: 0.3304 Lake level: 0.1487	1.935	0.5518	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMeanDecFebKeoGen Indep: Max30dayDecFebLL	0.0782	0.6392	14	Intercept: 0.2264 KeoGen: 0.4747 Lake level: 0.3565	3.010	0.2227	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMaxDailyDecFebKeoGen Indep: MeanDecFebLL	0.0894	0.5974	14	Intercept: 0.8111 KeoGen: 0.3722 Lake level: 0.4099	1.309	0.4670	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMaxDailyDecFebKeoGen Indep: MaxDailyDecFebLL	0.2580	0.1937	14	Intercept: 0.6709 KeoGen: 0.1577 Lake level: 0.0923	1.371	0.5397	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMaxDailyDecFebKeoGen Indep: Max30dayDecFebLL	0.1350	0.4505	14	Intercept: 0.9598 KeoGen: 0.2773 Lake level: 0.2696	1.432	0.3639	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMax30dayDecFebKeoGen Indep: MeanDecFebLL	0.0764	0.6458	14	Intercept: 0.2114 KeoGen: 0.4210 Lake level: 0.3738	2.189	0.5324	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMax30dayDecFebKeoGen Indep: MaxDailyDecFebLL	0.2108	0.2720	14	Intercept: 0.3297 KeoGen: 0.2459 Lake level: 0.1179	1.587	0.5441	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: logMax30dayDecFebKeoGen Indep: Max30dayDecFebLL	0.1221	0.4884	14	Intercept: 0.3676 KeoGen: 0.3113 Lake level: 0.2497	2.259	0.5034	(none)	(none)

Appendix Table 40. Multiple regression analyses of spring forage fish density (no/ha) in the Little River basin of Lake Keowee on combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and Lake Keowee lake levels (meters below full pool, positive number) observed December-February (mean, lowest daily, lowest 30-day average). Variable names for lake level are MeanDecFebLL for mean lake level; MaxDailyDecFebLL for lowest daily lake level; and Max30dayDecFebLL for lowest 30-day average lake level observed December-February. These analyses utilize data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2013	Dep: logSprDensLit Indep: logMeanDecFebKeoGen Indep: MeanDecFebLL	0.0886	0.6005	14	Intercept: 0.0630 KeoGen: 0.9695 Lake level: 0.5625	2.704	0.2650	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: logMeanDecFebKeoGen Indep: MaxDailyDecFebLL	0.1586	0.3869	14	Intercept: 0.1069 KeoGen: 0.8745 Lake level: 0.2782	1.935	0.3476	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: logMeanDecFebKeoGen Indep: Max30dayDecFebLL	0.1446	0.4235	14	Intercept: 0.1987 KeoGen: 0.7289 Lake level: 0.3165	3.010	0.2916	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: logMaxDailyDecFebKeoGen Indep: MeanDecFebLL	0.0949	0.5779	14	Intercept: 0.4848 KeoGen: 0.7843 Lake level: 0.3196	1.309	0.3518	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: logMaxDailyDecFebKeoGen Indep: MaxDailyDecFebLL	0.1804	0.3349	14	Intercept: 0.7665 KeoGen: 0.5832 Lake level: 0.1538	1.371	0.2255	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: logMaxDailyDecFebKeoGen Indep: Max30dayDecFebLL	0.1581	0.3881	14	Intercept: 0.7269 KeoGen: 0.5923 Lake level: 0.1856	1.432	0.4189	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2013	Dep: logSprDensLit Indep: logMax30dayDecFebKeoGen Indep: MeanDecFebLL	0.0939	0.5814	14	Intercept: 0.1389 KeoGen: 0.8012 Lake level: 0.3923	2.189	0.1996	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: logMax30dayDecFebKeoGen Indep: MaxDailyDecFebLL	0.1647	0.3717	14	Intercept: 0.1631 KeoGen: 0.7500 Lake level: 0.2077	1.587	0.0995	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: logMax30dayDecFebKeoGen Indep: Max30dayDecFebLL	0.1597	0.3841	14	Intercept: 0.2917 KeoGen: 0.5797 Lake level: 0.2169	2.259	0.1523	(none)	(none)

Appendix Table 41. Multiple regression analysis of spring forage fish lakewide numbers and spring forage fish densities (no/ha) in the Keowee River and Little River basins of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average); and minimum winter surface (0-5 m) temperature observed at Location 507 on Lake Keowee, utilizing JPSS pumping data collected December 1998 through February 2013, and forage fish data collected spring 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	Dep: SprFish Indep: MeanDecFebJocPumpcms Indep: MinTempLoc507	0.3708	0.1976	10	Intercept: 0.0114 JocPump: 0.4738 Temp: 0.1871	1.164	0.2375	(none)	(none)
Lakewide	1999-2013	Dep: SprFish Indep: MaxDailyDecFebJocPumpcms Indep: MinTempLoc507	0.3235	0.2546	10	Intercept: 0.0217 JocPump: 0.8394 Temp: 0.1371	1.091	0.3803	(none)	(none)
Lakewide	1999-2013	Dep: SprFish Indep: Max30dayDecFebJocPumpcms Indep: MinTempLoc507	0.3327	0.2427	10	Intercept: 0.0166 JocPump: 0.7181 Temp: 0.1601	1.149	0.3587	(none)	(none)
Keowee	1999-2013	Dep: SprDensKeo Indep: MeanDecFebJocPumpcms Indep: MinTempLoc507	0.3229	0.2554	10	Intercept: 0.6388 JocPump: 0.5433 Temp: 0.2201	1.164	0.3474	(none)	(none)
Keowee	1999-2013	Dep: SprDensKeo Indep: MaxDailyDecFebJocPumpcms Indep: MinTempLoc507	0.2681	0.3074	10	Intercept: 0.8251 JocPump: 0.8767 Temp: 0.1652	1.091	0.4811	(none)	(none)
Keowee	1999-2013	Dep: SprDensKeo Indep: Max30dayDecFebJocPumpcms Indep: MinTempLoc507	0.2942	0.2954	10	Intercept: 0.7613 JocPump: 0.7538 Temp: 0.1913	1.149	0.3810	(none)	(none)
Little	1999-2013	Dep: SprDensLit Indep: MeanDecFebJocPumpcms	0.3478	0.2240	10	Intercept: 0.6802 JocPump: 0.4739	1.164	0.4936	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
		Indep: MinTempLoc507				Temp: 0.2151				
Little	1999-2013	Dep: SprDensLit Indep: MaxDailyDecFebJocPumpcms Indep: MinTempLoc507	0.2978	0.2901	10	Intercept: 0.9047 JocPump: 0.8593 Temp: 0.1566	1.091	0.5270	(none)	(none)
Little	1999-2013	Dep: SprDensLit Indep: Max30dayDecFebJocPumpcms Indep: MinTempLoc507	0.3078	0.2760	10	Intercept: 0.8363 JocPump: 0.7246 Temp: 0.1831	1.149	0.3518	(none)	(none)

Appendix Table 42. Multiple regression analyses relating total number of forage fish lakewide on Lake Keowee in spring to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average); and mean lakewide surface (0-10 m) chlorophyll concentration (mg/m^3) observed January-February, utilizing data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	Dep: logSprFish Indep: MeanDecFebJocPump Indep: logMeanJanFebLWChlor	0.3710	0.0781	14	Intercept: <0.0001 JocPump: 0.5280 Chlor: 0.0941	1.311	0.6389	(none)	(none)
Lakewide	1999-2013	logSprFish = 5.80743 + 0.00010 MaxDailyDecFebJocPump + 1.48255 logMeanJanFebLWChlor	0.3472	0.0958	14	Intercept: <0.0001 JocPump: 0.9309 Chlor: **0.0372**	1.059	0.5164	(none)	(none)
Lakewide	1999-2013	Dep: logSprFish Indep: Max30dayDecFebJocPump Indep: logMeanJanFebLWChlor	0.3495	0.0940	14	Intercept: <0.0001 JocPump: 0.8320 Chlor: 0.0609	1.231	0.6076	(none)	(none)

Appendix Table 43. Multiple regression analyses relating spring forage fish densities (no/ha) in the Keowee River and Little River basins of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average); and mean basinwide surface (0-10 m) chlorophyll concentrations (mg/m^3) observed January-February, utilizing data collected winter 1999 through spring 2013.

Basin	**Years**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**Maximum VIF**	**SPEC**	**Outliers |SR|≥2.5**	**Significant Cook's D**
Keowee	1999-2013	logSprDensKeo = 2.20328 – 0.00123 MeanDecFebJocPump + 1.50560 logMeanJanFebBasinChlor	0.4372	**0.0424**	14	Intercept: <0.0001 JocPump: 0.5848 Chlor: **0.0342**	1.183	0.3357	(none)	(none)
Keowee	1999-2013	logSprDensKeo = 2.05982 – 0.00000 MaxDailyDecFebJocPump + 1.64354 logMeanJanFebBasinChlor	0.4210	**0.0495**	14	Intercept: <0.0001 JocPump: 0.9999 Chlor: **0.0174**	1.023	0.3821	(none)	(none)
Keowee	1999-2013	Dep: logSprDensKeo Indep: Max30dayDecFebJocPump Indep: logMeanJanFebBasinChlor	0.4231	**0.0485**	14	Intercept: <0.0001 JocPump: 0.8441 Chlor: **0.0247**	1.128	0.2942	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MeanDecFebJocPump Indep: logMeanJanFebBasinChlor	0.3290	0.1115	14	Intercept: 0.0006 JocPump: 0.5944 Chlor: 0.1364	1.408	0.3757	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: MaxDailyDecFebJocPump Indep: logMeanJanFebBasinChlor	0.3150	0.1249	14	Intercept: 0.0026 JocPump: 0.7964 Chlor: **0.0487**	1.089	0.8380	(none)	(none)
Little	1999-2013	Dep: logSprDensLit Indep: Max30dayDecFebJocPump Indep: logMeanJanFebBasinChlor	0.3112	0.1287	14	Intercept: 0.0008 JocPump: 0.9258 Chlor: 0.0842	1.312	0.5632	(none)	(none)

Appendix Table 44. Multiple regression analyses of total number of forage fish lakewide in spring in Lake Keowee on combinations of variables for Keowee Hydroelectric Station generation flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and mean January-February surface (0-10 m) lakewide chlorophyll concentrations, utilizing data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2013	logSprFish = 6.05321 – 0.17663 logMeanDecFebKeoGen + 1.47430 logMeanJanFebLWChlor	0.3790	0.0728	14	Intercept: <0.0001 KeoGen: 0.4652 Chlor: **0.0302**	1.000	0.0998	(none)	(none)
Lakewide	1999-2013	logSprFish = 5.44918 + 0.17020 logMaxDailyDecFebKeoGen + 1.48455 logMeanJanFebLWChlor	0.3523	0.0917	14	Intercept: 0.0012 KeoGen: 0.7624 Chlor: **0.0326**	1.006	0.6060	(none)	(none)
Lakewide	1999-2013	logSprFish = 5.99062 – 0.10339 logMax30dayDecFebKeoGen + 1.47309 logMeanJanFebLWChlor	0.3551	0.0896	14	Intercept: <0.0001 KeoGen: 0.7122 Chlor: **0.0330**	1.000	0.3797	(none)	(none)

Appendix Table 45. Multiple regression analyses of spring forage fish densities (no/ha) in the Keowee River and Little River basins of Lake Keowee on combinations of variables for Keowee Hydroelectric Station generation flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and mean January-February basinwide (0-10 m) lakewide chlorophyll concentrations, utilizing data collected winter 1999 through spring 2013.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2013	logSprDensKeo = 2.10770 – 0.03938 logMeanDecFebKeoGen + 1.64583 logMeanJanFebChlor	0.4225	**0.0488**	14	Intercept: <0.0001 KeoGen: 0.8698 Chlor: **0.0162**	1.001	0.2188	(none)	(none)
Keowee	1999-2013	logSprDensKeo = 1.22015 + 0.37140 logMaxDailyDecFebKeoGen + 1.63653 logMeanJanFebChlor	0.4459	**0.0389**	14	Intercept: 0.3308 KeoGen: 0.4964 Chlor: **0.0150**	1.000	0.7131	(none)	(none)
Keowee	1999-2013	logSprDensKeo = 2.00745 + 0.03567 logMax30dayDecFebKeoGen + 1.63937 logMeanJanFebChlor	0.4219	**0.0491**	14	Intercept: 0.0005 KeoGen: 0.8973 Chlor: **0.0167**	1.003	0.4289	(none)	(none)
Little	1999-2013	logSprDensLit = 2.19611 – 0.26603 logMeanDecFebKeoGen + 1.51214 logMeanJanFebChlor	0.3702	0.0786	14	Intercept: 0.0001 KeoGen: 0.3295 Chlor: **0.0398**	1.000	0.6018	(none)	(none)
Little	1999-2013	logSprDensLit = 1.81607 + 0.02355 logMaxDailyDecFebKeoGen + 1.51447 logMeanJanFebChlor	0.3107	0.1292	14	Intercept: 0.2438 KeoGen: 0.9710 Chlor: **0.0495**	1.023	0.5041	(none)	(none)
Little	1999-2013	logSprDensLit = 2.17352 – 0.20299 logMax30dayDecFebKeoGen + 1.50524 logMeanJanFebChlor	0.3369	0.1044	14	Intercept: 0.0011 KeoGen: 0.5222 Chlor: **0.0450**	1.000	0.5562	(none)	(none)

Appendix Table 46. Multiple regression analysis of total number of forage fish lakewide in spring in Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and lakewide zooplankton densities (organisms/m^3) on Lake Keowee in February. Lakewide densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton were calculated as the average of densities observed at Locations 502 and 508. Analyses utilize data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	logSprFish = 2.00438 – 0.00167 MeanDecFebJocPump + 1.07309 logFebLWCrustZoo	0.5189	**0.0258**	13	Intercept: 0.2644 JocPump: 0.4196 Zoopl: **0.0236**	1.145	0.3263	(none)	(none)
Lakewide	1999-2012	Dep: logSprFish Indep: MeanDecFebJocPump Indep: FebLWRot	0.1786	0.3739	13	Intercept: <0.0001 JocPump: 0.2077 Zoopl: 0.8846	1.328	0.3441	(none)	(none)
Lakewide	1999-2012	Dep: logSprFish Indep: MeanDecFebJocPump Indep: FebLWTotalZoo	0.3879	0.0859	13	Intercept: <0.0001 JocPump: 0.2072 Zoopl: 0.0929	1.032	0.3172	(none)	(none)
Lakewide	1999-2012	logSprFish = 1.56019 – 0.00038 MaxDailyDecFebJocPump + 1.16818 logFebLWCrustZoo	0.4907	**0.0343**	13	Intercept: 0.3715 JocPump: 0.7425 Zoopl: **0.0142**	1.038	0.2035	(none)	(none)
Lakewide	1999-2012	Dep: logSprFish Indep: MaxDailyDecFebJocPump Indep: FebLWRot	0.0475	0.7841	13	Intercept: <0.0001 JocPump: 0.6740 Zoopl: 0.8392	1.490	0.2676	(none)	(none)
Lakewide	1999-2012	Dep: logSprFish Indep: MaxDailyDecFebJocPump Indep: FebLWTotalZoo	0.3175	0.1481	13	Intercept: <0.0001 JocPump: 0.4566 Zoopl: 0.0729	1.000	0.2479	**1999 (SR=2.523)**	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	logSprFish = 1.71603 – 0.00098 Max30dayDecFebJocPump + 1.13327 logFebLWCrustZoo	0.5046	**0.0299**	13	Intercept: 0.3187 JocPump: 0.5425 Zoopl: **0.0164**	1.063	0.3200	(none)	(none)
Lakewide	1999-2012	Dep: logSprFish Indep: Max30dayDecFebJocPump Indep: FebLWRot	0.0939	0.6106	13	Intercept: <0.0001 JocPump: 0.4191 Zoopl: 0.9435	1.335	0.2428	(none)	(none)
Lakewide	1999-2012	Dep: logSprFish Indep: Max30dayDecFebJocPump Indep: FebLWTotalZoo	0.3475	0.1183	13	Intercept: <0.0001 JocPump: 0.3217 Zoopl: 0.0768	1.006	0.2404	(none)	(none)

Appendix Table 47. Repeat of multiple regression analyses in Appendix Table JocPump KeoZoo Spr1 where data for 1999 were identified as outlying, utilizing data collected 1999-2012, excluding 1999. Results are reported only for regression where observation for 1999 was identified as outlying.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012 (excl 1999)	logSprFish = 5.42199 – 0.00044 MaxDailyDecFebJocPump + 0.00004 FebLWTotalZoo	0.6385	**0.0103**	12	Intercept: <0.0001 JocPump: 0.6015 Zoopl: **0.0035**	1.002	0.2580	(none)	(none)

Appendix Table 48. Multiple regression analysis of spring forage fish density (no/ha) in the Keowee River basin of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) at Location 508 in the Keowee River basin of Lake Keowee in February. Zooplankton variables include densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton. Analyses utilized data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	logSprDensKeo = -1.82915 – 0.00147 MeanDecFebJocPump + 1.07038 logFebCrustZoo	0.5244	**0.0243**	13	Intercept: 0.2726 JocPump: 0.4847 Zoopl: **0.0170**	1.106	0.4155	(none)	(none)
Keowee	1999-2012	Dep: logSprDensKeo Indep: MeanDecFebJocPump Indep: FebRot	0.1503	0.4429	13	Intercept: <0.0001 JocPump: 0.4238 Zoopl: 0.6922	1.432	0.3498	(none)	(none)
Keowee	1999-2012	Dep: logSprDensKeo Indep: MeanDecFebJocPump Indep: FebTotalZoo	0.3069	0.1600	13	Intercept: 0.0003 JocPump: 0.2576 Zoopl: 0.1476	1.015	0.1400	**1999 (SR=2.587)**	(none)
Keowee	1999-2012	logSprDensKeo = -2.20113 – 0.00021 MaxDailyDecFebJocPump + 1.14138 logFebCrustZoo	0.5011	**0.0309**	13	Intercept: 0.1939 JocPump: 0.8573 Zoopl: **0.0118**	1.038	0.2295	(none)	(none)
Keowee	1999-2012	Dep: logSprDensKeo Indep: MaxDailyDecFebJocPump Indep: FebRot	0.0912	0.6199	13	Intercept: 0.0001 JocPump: 0.9938 Zoopl: 0.4334	1.523	0.3064	(none)	(none)
Keowee	1999-2012	Dep: logSprDensKeo Indep: MaxDailyDecFebJocPump Indep: FebTotalZoo	0.2371	0.2585	13	Intercept: 0.0020 JocPump: 0.5443 Zoopl: 0.1310	1.000	0.1282	**1999 (SR=2.623)**	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	logSprDensKeo = -2.02872 – 0.00095 Max30dayDecFebJocPump + 1.11274 logFebCrustZoo	0.5170	**0.0263**	13	Intercept: 0.2098 JocPump: 0.5590 Zoopl: **0.0124**	1.037	0.3927	(none)	(none)
Keowee	1999-2012	Dep: logSprDensKeo Indep: Max30dayDecFebJocPump Indep: FebRot	0.1063	0.5700	13	Intercept: <0.0001 JocPump: 0.6894 Zoopl: 0.5358	1.386	0.2869	(none)	(none)
Keowee	1999-2012	Dep: logSprDensKeo Indep: Max30dayDecFebJocPump Indep: FebTotalZoo	0.2711	0.2058	13	Intercept: 0.0004 JocPump: 0.3706 Zoopl: 0.1274	1.001	0.1350	**1999 (SR=2.601)**	(none)

Appendix Table 49. Repeat of multiple regression analyses in Appendix Table JocPump KeoZoo Spr3, excluding data for 1999, identified as outlying in three regressions. Results are reported only for those analyses where the observation for 1999 was identified as an outlier.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012 (excl 1999)	logSprDensKeo = 1.66400 – 0.00099 MeanDecFebJocPump + 0.00004 FebTotalZoo	0.6350	**0.0107**	12	Intercept: 0.0002 JocPump: 0.5236 Zoopl: **0.0049**	1.039	0.6908	(none)	(none)
Keowee	1999-2012 (excl 1999)	logSprDensKeo = 1.61380 – 0.00026 MaxDailyDecFebJocPump + 0.00004 FebTotalZoo	0.6212	**0.0127**	12	Intercept: 0.0005 JocPump: 0.7636 Zoopl: **0.0041**	1.002	0.7186	**2001 (SR=2.534)**	(none)
Keowee	1999-2012 (excl 1999)	logSprDensKeo = 1.60932 – 0.00050 Max30dayDecFebJocPump + 0.00004 FebTotalZoo	0.6247	**0.0122**	12	Intercept: 0.0001 JocPump: 0.6798 Zoopl: **0.0042**	1.008	0.7133	(none)	(none)

Appendix Table 50. Multiple regression analysis of spring forage fish density (no/ha) in the Little River basin of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) at Location 502 in the Little River basin of Lake Keowee in February. Zooplankton variables include densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton. Analyses utilized data collected 1999-2012.

Basin	**Years**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**Maximum VIF**	**SPEC**	**Outliers |SR|≥2.5**	**Significant Cook's D**
Little	1999-2012	Dep: logSprDensLit Indep: MeanDecFebJocPump Indep: logFebCrustZoo	0.4354	0.0574	13	Intercept: 0.4908 JocPump: 0.4034 Zoopl: 0.0552	1.137	0.6790	(none)	(none)
Little	1999-2012	Dep: logSprDensLit Indep: MeanDecFebJocPump Indep: FebRot	0.1912	0.3461	13	Intercept: <0.0001 JocPump: 0.1553 Zoopl: 0.6155	1.149	0.6943	(none)	(none)
Little	1999-2012	Dep: logSprDensLit Indep: MeanDecFebJocPump Indep: FebTotalZoo	0.3837	0.0889	13	Intercept: 0.0012 JocPump: 0.2387 Zoopl: 0.0918	1.041	0.6700	(none)	(none)
Little	1999-2012	Dep: logSprDensLit Indep: MaxDailyDecFebJocPump Indep: logFebCrustZoo	0.4021	0.0764	13	Intercept: 0.3400 JocPump: 0.6947 Zoopl: **0.0330**	1.023	0.1594	(none)	(none)
Little	1999-2012	Dep: logSprDensLit Indep: MaxDailyDecFebJocPump Indep: FebRot	0.0444	0.7968	13	Intercept: 0.0004 JocPump: 0.5114 Zoopl: 0.7853	1.263	0.4332	(none)	(none)
Little	1999-2012	Dep: logSprDensLit Indep: MaxDailyDecFebJocPump Indep: FebTotalZoo	0.3206	0.1447	13	Intercept: 0.0047 JocPump: 0.4978 Zoopl: 0.0682	1.000	0.5293	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	Dep: logSprDensLit Indep: Max30dayDecFebJocPump Indep: logFebCrustZoo	0.4129	0.0698	13	Intercept: 0.3772 JocPump: 0.5680 Zoopl: **0.0404**	1.067	0.3094	(none)	(none)
Little	1999-2012	Dep: logSprDensLit Indep: Max30dayDecFebJocPump Indep: FebRot	0.1001	0.5903	13	Intercept: <0.0001 JocPump: 0.3168 Zoopl: 0.7171	1.174	0.6037	(none)	(none)
Little	1999-2012	Dep: logSprDensLit Indep: Max30dayDecFebJocPump Indep: FebTotalZoo	0.3428	0.1226	13	Intercept: 0.0016 JocPump: 0.3784 Zoopl: 0.0770	1.013	0.5671	(none)	(none)

Appendix Table 51. Multiple regression analyses relating total lakewide numbers of forage fish in spring on Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) in Lake Keowee measured in February, utilizing data collected winter 1999 through spring 2012. Zooplankton variables include densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton. Lakewide densities were calculated as the average of densities observed at Locations 502 and 508.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	logSprFish = 0.53027 + 0.17686 logMeanDecFebKeoGen + 1.34630 logFebLWCrustZoo	0.5081	**0.0288**	13	Intercept: 0.7904 KeoGen: 0.5076 Zoopl: **0.0121**	1.341	0.1728	(none)	(none)
Lakewide	1999-2012	logSprFish logMeanDecFebKeoGen FebLWRot	0.0789	0.6631	13	Intercept: <0.0001 KeoGen: 0.4813 Zoopl: 0.5766	1.000	0.2677	(none)	(none)
Lakewide	1999-2012	logSprFish logMeanDecFebKeoGen FebLWTotalZoo	0.2806	0.1926	13	Intercept: <0.0001 KeoGen: 0.8168 Zoopl: 0.1025	1.373	0.3370	**1999 (SR=2.538)**	(none)
Lakewide	1999-2012	logSprFish = 0.30414 + 0.35712 logMaxDailyDecFebKeoGen + 1.25533 logFebLWCrustZoo	0.5065	**0.0293**	13	Intercept: 0.8929 KeoGen: 0.5225 Zoopl: **0.0095**	1.060	0.2301	(none)	(none)
Lakewide	1999-2012	logSprFish logMaxDailyDecFebKeoGen FebLWRot	0.0336	0.8429	13	Intercept: 0.0040 KeoGen: 0.8425 Zoopl: 0.5712	1.056	0.1843	(none)	(none)
Lakewide	1999-2012	logSprFish logMaxDailyDecFebKeoGen FebLWTotalZoo	0.3092	0.1573	13	Intercept: 0.0229 KeoGen: 0.5077 Zoopl: 0.0606	1.151	0.3717	**1999 (SR=2.519)**	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	logSprFish = 0.75719 + 0.16464 logMax30dayDecFebKeoGen + 1.28276 logFebLWCrustZoo	0.5020	**0.0306**	13	Intercept: 0.6899 KeoGen: 0.5701 Zoopl: **0.0109**	1.157	0.1697	(none)	(none)
Lakewide	1999-2012	logSprFish logMax30dayDecFebKeoGen FebLWRot	0.0557	0.7507	13	Intercept: <0.0001 KeoGen: 0.6102 Zoopl: 0.5424	1.022	0.2319	(none)	(none)
Lakewide	1999-2012	logSprFish logMax30dayDecFebKeoGen FebLWTotalZoo	0.2964	0.1724	13	Intercept: <0.0001 KeoGen: 0.6072 Zoopl: 0.0748	1.316	0.4039	**1999 (SR=2.525)**	(none)

Appendix Table 52. Repeat of multiple regression analyses in Appendix Table KeoGen KeoZoo Spr1, excluding data for 1999, identified as an outlying observation in three regression analyses. Results are reported only for those regressions where the observation for 1999 was identified as an outlier in initial regression analysis.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012 (excl 1999)	LogSprFish = 5.32358 – 0.01591 LogMeanDecFebKeoGen + 0.00004 FebLWTotalZoo	0.6270	**0.0118**	12	Intercept: <0.0001 KeoGen: 0.9381 Zoopl: **0.0088**	1.334	0.1648	(none)	(none)
Lakewide	1999-2012 (excl 1999)	LogSprFish = 4.91821 + 0.15666 LogMaxDailyDecFebKeoGen + 0.00004 FebLWTotalZoo	0.6322	**0.0111**	12	Intercept: 0.0012 KeoGen: 0.7242 Zoopl: **0.0041**	1.122	0.1263	(none)	(none)
Lakewide	1999-2012 (excl 1999)	logSprFish logMax30dayDecFebKeoGen FebLWTotalZoo	0.6283	0.0116	12	Intercept: <0.0001 KeoGen: 0.8500 Zoopl: 0.0082	1.264	0.3042	(none)	(none)

Appendix Table 53. Multiple regression analyses relating spring forage fish density in the Keowee River basin of Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) measured in February at Location 508 on Lake Keowee, utilizing data collected winter 1999 through spring 2012. Zooplankton variables include densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	logSprDensKeo = -5.03194 + 0.56208 logMeanDecFebKeoGen + 1.66481 logFebCrustZoo	0.6895	**0.0029**	13	Intercept: 0.0102 KeoGen: **0.0328** Zoopl: **0.0008**	1.513	0.1741	(none)	(none)
Keowee	1999-2012	logSprDensKeo logMeanDecFebKeoGen FebRot	0.1079	0.5651	13	Intercept: 0.0003 KeoGen: 0.6747 Zoopl: 0.3043	1.054	0.3919	(none)	(none)
Keowee	1999-2012	logSprDensKeo logMeanDecFebKeoGen FebTotalZoo	0.2925	0.1773	13	Intercept: 0.1659 KeoGen: 0.2974 Zoopl: 0.0708	1.646	0.6765	**1999 (SR=2.729)**	(none)
Keowee	1999-2012	logSprDensKeo = -5.96831 + 1.13188 logMaxDailyDecFebKeoGen + 1.43133 logFebCrustZoo	0.6816	**0.0033**	13	Intercept: 0.0112 KeoGen: **0.0378** Zoopl: **0.0010**	1.158	0.8434	(none)	(none)
Keowee	1999-2012	logSprDensKeo logMaxDailyDecFebKeoGen FebRot	0.0913	0.6196	13	Intercept: 0.2362 KeoGen: 0.9731 Zoopl: 0.3917	1.213	0.2983	(none)	(none)
Keowee	1999-2012	logSprDensKeo = -0.85235 + 1.08733 logMaxDailyDecFebKeoGen + 0.00004 FebTotalZoo	0.3599	0.1075	13	Intercept: 0.6369 KeoGen: 0.1532 Zoopl: **0.0435**	1.273	0.3723	**1999 (SR=2.746)**	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	logSprDensKeo = -4.40016 + 0.53666 logMax30dayDecFebKeoGen + 1.47995 logFebCrustZoo	0.6527	**0.0051**	13	Intercept: 0.0189 KeoGen: 0.0619 Zoopl: **0.0015**	1.259	0.1341	(none)	(none)
Keowee	1999-2012	logSprDensKeo logMax30dayDecFebKeoGen FebRot	0.0932	0.6131	13	Intercept: 0.0026 KeoGen: 0.8842 Zoopl: 0.3365	1.061	0.3504	(none)	(none)
Keowee	1999-2012	logSprDensKeo logMax30dayDecFebKeoGen FebTotalZoo	0.3169	0.1487	13	Intercept: 0.3007 KeoGen: 0.2333 Zoopl: 0.0569	1.427	0.1796	**1999 (SR=2.626)**	(none)

Appendix Table 54. Repeat of multiple regression analyses in Appendix Table KeoGen KeoZoo Spr3, excluding data for 1999, identified as an outlying observation in three regression analyses. Results are reported only for those regressions where the observation for 1999 was identified as an outlier in initial regression analysis.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012 (excl 1999)	logSprDensKeo = 0.93542 + 0.32934 logMeanDecFebKeoGen + 0.00005 FebTotalZoo	0.7123	**0.0037**	12	Intercept: 0.0397 KeoGen: 0.1185 Zoopl: **0.0014**	1.586	0.1439	**2001 (SR=2.618)**	(none)
Keowee	1999-2012 (excl 1999)	logSprDensKeo = -0.42971 + 0.80848 logMaxDailyDecFebKeoGen + 0.00005 FebTotalZoo	0.7490	**0.0020**	12	Intercept: 0.6513 KeoGen: 0.0577 Zoopl: 0.0006	1.227	0.1731	(none)	(none)
Keowee	1999-2012 (excl 1999)	logSprDensKeo = 1.06311 + 0.25196 logMax30dayDecFebKeoGen + 0.00004 FebTotalZoo	0.6622	**0.0076**	12	Intercept: 0.0509 KeoGen: 0.3017 Zoopl: **0.0029**	1.353	0.2252	**2001 (SR=2.577)**	(none)

Appendix Table 55. Multiple regression analyses relating spring forage fish density in the Little River basin of Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flows (m^3/sec) observed December-February (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) measured in February at Location 502 on Lake Keowee, utilizing data collected winter 1999 through spring 2012. Zooplankton variables include densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	logSprDensLit = -1.75380 – 0.08247 logMeanDecFebKeoGen + 1.02600 logFebCrustZoo	0.3972	0.0796	13	Intercept: 0.3953 KeoGen: 0.7841 Zoopl: **0.0470**	1.160	0.1726	(none)	(none)
Little	1999-2012	logSprDensLit logMeanDecFebKeoGen FebRot	0.0898	0.6247	13	Intercept: 0.0003 KeoGen: 0.3443 Zoopl: 0.8931	1.031	0.5318	(none)	(none)
Little	1999-2012	logSprDensLit logMeanDecFebKeoGen FebTotalZoo	0.3001	0.1679	13	Intercept: 0.0141 KeoGen: 0.6742 Zoopl: 0.1124	1.143	0.5253	(none)	(none)
Little	1999-2012	logSprDensLit = -1.63151 – 0.15981 logMaxDailyDecFebKeoGen + 1.06051 logFebCrustZoo	0.3961	0.0803	13	Intercept: 0.5066 KeoGen: 0.8095 Zoopl: **0.0315**	1.015	0.1167	(none)	(none)
Little	1999-2012	logSprDensLit logMaxDailyDecFebKeoGen FebRot	0.0190	0.9088	13	Intercept: 0.1327 KeoGen: 0.6706 Zoopl: 0.9658	1.001	0.1744	(none)	(none)
Little	1999-2012	logSprDensLit logMaxDailyDecFebKeoGen FebTotalZoo	0.2874	0.1838	13	Intercept: 0.3436 KeoGen: 0.9446 Zoopl: 0.0809	1.051	0.4454	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	logSprDensLit = -1.76106 – 0.09989 logMax30dayDecFebKeoGen + 1.03952 logFebCrustZoo	0.3980	0.0791	13	Intercept: 0.3812 KeoGen: 0.7669 Zoopl: **0.0379**	1.070	0.2730	(none)	(none)
Little	1999-2012	logSprDensLit logMax30dayDecFebKeoGen FebRot	0.0543	0.7563	13	Intercept: 0.0027 KeoGen: 0.4664 Zoopl: 0.9506	1.001	0.4620	(none)	(none)
Little	1999-2012	logSprDensLit logMax30dayDecFebKeoGen FebTotalZoo	0.2883	0.1826	13	Intercept: 0.0514 KeoGen: 0.8947 Zoopl: 0.0996	1.159	0.5833	(none)	(none)

Appendix Table 56. Multiple regression analyses relating spring forage fish densities (no/ha) measured in both the Keowee River and Little River basins of Lake Keowee to combinations of variables for mean basinwide surface (0-10 m) chlorophyll concentrations measured January-February; and density (no/km) and biomass (kg/km) of total black basses in spring shoreline electrofishing, utilizing data collected in 1999, 2002, 2005, 2008, 2010, and 2011.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logSprDens = 2.62012 + 1.85503 logJanFebBasinChlor – 0.60390 logBLBnumkm	0.5948	**0.0172**	12	Intercept: 0.0023 JanFebChl: **0.0074** BLBnumkm: 0.2118	1.002	0.5530	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logSprDens = 1.89006 + 1.91474 logJanFebBasinChlor – 0.02361 BLBkgkm	0.5234	**0.0356**	12	Intercept: <0.0001 JanFebChl: **0.0133** BLBkgkm: 0.6743	1.134	0.7441	(none)	(none)

Appendix Table 57. Multiple regression analyses relating spring forage fish densities in the Keowee River and Little River basins of Lake Keowee to combinations of variables for zooplankton densities in February (total crustacean zooplankton, rotifers, total zooplankton) and basinwide littoral abundance of total black basses in spring (no/km and kg/km) based on spring shoreline electrofishing. Data were available for the years 1999, 2002, 2005, 2008, 2010, and 2011. Data for both basins are utilized in the same analysis to obtain sufficient observations for regression analysis with two independent variables.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logSprDens logFebCrustZoo logBLBnumkm	0.2775	0.2316	12	Intercept: 0.6529 Zoopl: 0.1370 BLB: 0.9126	1.392	0.3974	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logSprDens logFebCrustZoo BLBkgkm	0.3376	0.1567	12	Intercept: 0.4098 Zoopl: 0.0687 BLB: 0.3859	1.031	0.6499	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logSprDens FebRot logBLBnumkm	0.2899	0.2143	12	Intercept: 0.0030 Zoopl: 0.1246 BLB: 0.4183	1.001	0.1701	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logSprDens FebRot BLBkgkm	0.2805	0.2273	12	Intercept: <0.0001 Zoopl: 0.1064 BLB: 0.4610	1.018	0.0924	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logSprDens FebTotalZoo logBLBnumkm	0.0669	0.7322	12	Intercept: 0.0594 Zoopl: 0.8604 BLB: 0.5715	1.334	0.1728	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logSprDens FebTotalZoo BLBkgkm	0.0608	0.7541	12	Intercept: 0.0044 Zoopl: 0.5632 BLB: 0.6071	1.011	0.5916	(none)	(none)

Appendix Table 58. Multiple regression analyses relating total number of forage fish lakewide in fall on Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Keowee Hydroelectric Station generation flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average), utilizing data from 1999 through 2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPumpcms Indep: MeanMayOctKeoGencms	0.0475	0.7653	14	Intercept: 0.1010 JocPump: 0.4753 KeoGen: 0.9775	1.000	0.6451	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPumpcms Indep:logMaxDailyMayOctKeoGencms	0.0529	0.7414	14	Intercept: 0.3934 JocPump: 0.4518 KeoGen: 0.8044	1.054	0.6843	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPumpcms Indep: Max30dayMayOctKeoGencms	0.0513	0.7484	14	Intercept: 0.1126 JocPump: 0.4687 KeoGen: 0.8349	1.002	0.5192	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPumpcms Indep: MeanMayOctKeoGencms	0.0502	0.7534	14	Intercept: 0.1720 JocPump: 0.4626 KeoGen: 0.9293	1.032	0.5369	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPumpcms Indep:logMaxDailyMayOctKeoGencms	0.0654	0.6893	14	Intercept: 0.3284 JocPump: 0.4009 KeoGen: 0.6732	1.205	0.2588	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPumpcms Indep: Max30dayMayOctKeoGencms	0.0506	0.7518	14	Intercept: 0.1867 JocPump: 0.4723 KeoGen: 0.9129	1.008	0.5019	(none)	(none)
Lakewide	1999-2012	FallFish = 26,474,453 – 77,883 Max30dayMayOctJocPumpcms + 347.25526 MeanMayOctKeoGencms	0.3506	0.0931	14	Intercept: 0.0050 JocPump: **0.0330** KeoGen: 0.9970	1.000	0.6665	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	FallFish = 35,826,178 – 81,139 Max30dayMayOctJocPumpcms – 3,745,491 logMaxDailyMayOctKeoGencms	0.3684	0.0799	14	Intercept: 0.0755 JocPump: **0.0279** KeoGen: 0.5886	1.034	0.2443	(none)	(none)
Lakewide	1999-2012	FallFish = 25,788,312 – 78,472 Max30dayMayOctJocPumpcms + 20,641 Max30dayMayOctKeoGencms	0.3576	0.0877	14	Intercept: 0.0057 JocPump: **0.0314** KeoGen: 0.7349	1.003	0.6949	(none)	(none)

Appendix Table 59. Multiple regression analyses relating fall forage fish density (no/ha) in the Keowee River basin of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Keowee Hydroelectric Station generation flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average), utilizing data from 1999 through 2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctJocPumpcms Indep: MeanMayOctKeoGencms	0.1874	0.3194	14	Intercept: 0.0271 JocPump: 0.1859 KeoGen: 0.4923	1.000	0.5407	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctJocPumpcms Indep:logMaxDailyMayOctKeoGencms	0.1509	0.4067	14	Intercept: 0.3088 JocPump: 0.1946 KeoGen: 0.9218	1.054	0.7661	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctJocPumpcms Indep: Max30dayMayOctKeoGencms	0.2021	0.2888	14	Intercept: 0.0294 JocPump: 0.1678 KeoGen: 0.4152	1.002	0.5610	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MaxDailyMayOctJocPumpcms Indep: MeanMayOctKeoGencms	0.1735	0.3507	14	Intercept: 0.0607 JocPump: 0.2100 KeoGen: 0.6358	1.032	0.4242	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MaxDailyMayOctJocPumpcms Indep:logMaxDailyMayOctKeoGencms	0.1683	0.3630	14	Intercept: 0.2027 JocPump: 0.1681 KeoGen: 0.6906	1.205	0.3121	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MaxDailyMayOctJocPumpcms Indep: Max30dayMayOctKeoGencms	0.1864	0.3215	14	Intercept: 0.0601 JocPump: 0.1926 KeoGen: 0.5321	1.008	0.4344	(none)	(none)
Keowee	1999-2012	FallDensKeo = 2927.63302 – 8.82970 Max30dayMayOctJocPumpcms + 7.20369 MeanMayOctKeoGencms	0.4706	**0.0302**	14	Intercept: 0.0015 JocPump: **0.0123** KeoGen: 0.4109	1.000	0.2151	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	FallDensKeo = 3522.12296 – 9.03257 Max30dayMayOctJocPumpcms – 175.22488 logMaxDailyMayOctKeoGencms	0.4392	**0.0415**	14	Intercept: 0.0706 JocPump: **0.0139** KeoGen: 0.7919	1.034	0.4985	(none)	(none)
Keowee	1999-2012	FallDensKeo = 2877.82971 – 9.05549 Max30dayMayOctJocPumpcms + 6.16329 Max30dayMayOctKeoGencms	0.4955	**0.0232**	14	Intercept: 0.0015 JocPump: **0.0094** KeoGen: 0.2770	1.003	0.3617	(none)	(none)

Appendix Table 60. Multiple regression analyses relating fall forage fish density (no/ha) in the Little River basin of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Keowee Hydroelectric Station generation flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average), utilizing data from 1999 through 2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPumpcms Indep: MeanMayOctKeoGencms	0.0024	0.9871	14	Intercept: <0.0001 JocPump: 0.8749 KeoGen: 0.9921	1.000	0.6860	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPumpcms Indep:logMaxDailyMayOctKeoGencms	0.0343	0.8251	14	Intercept: 0.0179 JocPump: 0.7731 KeoGen: 0.5583	1.054	0.4931	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPumpcms Indep: Max30dayMayOctKeoGencms	0.0055	0.9701	14	Intercept: <0.0001 JocPump: 0.8683 KeoGen: 0.8554	1.002	0.4355	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPumpcms Indep: MeanMayOctKeoGencms	0.0030	0.9837	14	Intercept: 0.0019 JocPump: 0.8595 KeoGen: 0.9698	1.032	0.4734	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPumpcms Indep:logMaxDailyMayOctKeoGencms	0.0442	0.7798	14	Intercept: 0.0337 JocPump: 0.6620 KeoGen: 0.5045	1.205	0.1344	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPumpcms Indep: Max30dayMayOctKeoGencms	0.0053	0.9713	14	Intercept: 0.0020 JocPump: 0.8741 KeoGen: 0.8729	1.008	0.4320	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPumpcms Indep: MeanMayOctKeoGencms	0.1927	0.3081	14	Intercept: <0.0001 JocPump: 0.1334 KeoGen: 0.9686	1.000	0.6000	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPumpcms Indep:logMaxDailyMayOctKeoGencms	0.2538	0.1999	14	Intercept: 0.0022 JocPump: 0.0945 KeoGen: 0.3626	1.034	0.4300	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPumpcms Indep: Max30dayMayOctKeoGencms	0.1985	0.2961	14	Intercept: <0.0001 JocPump: 0.1296 KeoGen: 0.7803	1.003	0.6137	(none)	(none)

Appendix Table 61. Multiple regression analyses relating total number of forage fish lakewide in fall in Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Lake Keowee lake level (meters below full pool, positive number) observed May-October (mean, lowest daily, lowest 30-day average), utilizing data from 1999 through 2012. Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	**Years**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**Maximum VIF**	**SPEC**	**Outliers |SR|≥2.5**	**Significant Cook's D**
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPumpcms Indep: MeanMayOctLL	0.1527	0.4019	14	Intercept: 0.1644 JocPump: 0.3928 LakeLevel: 0.2670	1.009	0.1569	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPumpcms Indep: MaxDailyMayOctLL	0.0583	0.7188	14	Intercept: 0.1317 JocPump: 0.4290 LakeLevel: 0.7284	1.133	0.6142	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPumpcms Indep: Max30dayMayOctLL	0.0914	0.5901	14	Intercept: 0.1761 JocPump: 0.3761 LakeLevel: 0.4806	1.074	0.5295	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPumpcms Indep: MeanMayOctLL	0.1621	0.3781	14	Intercept: 0.1886 JocPump: 0.3573 LakeLevel: 0.2495	1.018	0.3140	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPumpcms Indep: MaxDailyMayOctLL	0.0605	0.7094	14	Intercept: 0.1708 JocPump: 0.4199 LakeLevel: 0.7260	1.130	0.5044	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPumpcms Indep: Max30dayMayOctLL	0.0931	0.5843	14	Intercept: 0.2001 JocPump: 0.3703 LakeLevel: 0.4822	1.069	0.4316	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	FallFish = 22,887,600 -74,770 Max30dayMayOctJocPumpcms + 2,733,048 MeanMayOctLL	0.4119	0.0539	14	Intercept: 0.0129 JocPump: **0.0324** LakeLevel: 0.3070	1.009	0.1882	(none)	(none)
Lakewide	1999-2012	FallFish = 24,575,165 – 82,264 Max30dayMayOctJocPumpcms + 1,655,369 MaxDailyMayOctLL	0.3739	0.0761	14	Intercept: 0.0090 JocPump: **0.0265** LakeLevel: 0.5348	1.047	0.6628	(none)	(none)
Lakewide	1999-2012	FallFish = 23,129,851 – 83,388 Max30dayMayOctJocPumpcms + 3,104,218 Max30dayMayOctLL	0.4119	0.0540	14	Intercept: 0.0114 JocPump: **0.0205** LakeLevel: 0.3073	1.029	0.7400	(none)	(none)

Appendix Table 62. Multiple regression analyses relating fall forage fish density (no/ha) in the Keowee River basin of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Lake Keowee lake level (meters below full pool, positive number) observed May-October (mean, lowest daily, lowest 30-day average), utilizing data from 1999 through 2012. Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctJocPumpcms Indep: MeanMayOctLL	0.1636	0.3744	14	Intercept: 0.0274 JocPump: 0.1783 LakeLevel: 0.6821	1.009	0.6583	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctJocPumpcms Indep: MaxDailyMayOctLL	0.1875	0.3192	14	Intercept: 0.0339 JocPump: 0.1417 LakeLevel: 0.4916	1.133	0.6804	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctJocPumpcms Indep: Max30dayMayOctLL	0.2397	0.2215	14	Intercept: 0.0470 JocPump: 0.1133 LakeLevel: 0.2791	1.074	0.7741	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MaxDailyMayOctJocPumpcms Indep: MeanMayOctLL	0.1734	0.3508	14	Intercept: 0.0419 JocPump: 0.1640 LakeLevel: 0.6361	1.018	0.5814	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MaxDailyMayOctJocPumpcms Indep: MaxDailyMayOctLL	0.1934	0.3066	14	Intercept: 0.0410 JocPump: 0.1348 LakeLevel: 0.4878	1.130	0.6166	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MaxDailyMayOctJocPumpcms Indep: Max30dayMayOctLL	0.2441	0.2146	14	Intercept: 0.0489 JocPump: 0.1090 LakeLevel: 0.2808	1.069	0.6922	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	FallDensKeo = 3059.93680 – 8.85866 Max30dayMayOctJocPumpcms + 19.03949 MeanMayOctLL	0.4358	**0.0430**	14	Intercept: 0.0023 JocPump: **0.0146** LakeLevel: 0.9420	1.009	0.1330	(none)	(none)
Keowee	1999-2012	FallDensKeo = 2837.54713 – 9.44851 Max30dayMayOctJocPumpcms + 214.79561 MaxDailyMayOctLL	0.4731	**0.0295**	14	Intercept: 0.0025 JocPump: **0.0095** LakeLevel: 0.3946	1.047	0.3524	(none)	(none)
Keowee	1999-2012	FallDensKeo = 2667.37626 – 9.56580 Max30dayMayOctJocPumpcms + 386.70999 Max30dayMayOctLL	0.5264	**0.0164**	14	Intercept: 0.0029 JocPump: **0.0062** LakeLevel: 0.1742	1.029	0.4289	(none)	(none)

Appendix Table 63. Multiple regression analyses relating fall forage fish density (no/ha) in the Little River basin of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Lake Keowee lake level (meters below full pool, positive number) observed May-October (mean, lowest daily, lowest 30-day average), utilizing data from 1999 through 2012. Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPumpcms Indep: MeanMayOctLL	0.1016	0.5546	14	Intercept: 0.0001 JocPump: 0.7914 LakeLevel: 0.2938	1.009	0.2333	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPumpcms Indep: MaxDailyMayOctLL	0.0029	0.9842	14	Intercept: 0.0001 JocPump: 0.8622 LakeLevel: 0.9398	1.133	0.4724	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPumpcms Indep: Max30dayMayOctLL	0.0149	0.9206	14	Intercept: 0.0002 JocPump: 0.8038 LakeLevel: 0.7149	1.074	0.5300	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPumpcms Indep: MeanMayOctLL	0.1047	0.5442	14	Intercept: 0.0012 JocPump: 0.7443 LakeLevel: 0.2870	1.018	0.3704	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPumpcms Indep: MaxDailyMayOctLL	0.0035	0.9811	14	Intercept: 0.0014 JocPump: 0.8492 LakeLevel: 0.9357	1.130	0.3328	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPumpcms Indep: Max30dayMayOctLL	0.0156	0.9173	14	Intercept: 0.0016 JocPump: 0.7934 LakeLevel: 0.7133	1.069	0.2735	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPumpcms Indep: MeanMayOctLL	0.2648	0.1842	14	Intercept: <0.0001 JocPump: 0.1400 LakeLevel: 0.3210	1.009	0.1653	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPumpcms Indep: MaxDailyMayOctLL	0.2028	0.2876	14	Intercept: <0.0001 JocPump: 0.1226 LakeLevel: 0.7148	1.047	0.6307	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPumpcms Indep: Max30dayMayOctLL	0.2218	0.2517	14	Intercept: <0.0001 JocPump: 0.1108 LakeLevel: 0.5333	1.029	0.8071	(none)	(none)

Appendix Table 64. Multiple regression analyses relating total number of forage fish in fall on Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Lake Keowee lake level (meters below full pool, positive number) observed May-October (mean, lowest daily, lowest 30-day average). Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	FallFish = -8,938,360 + 311,291 MeanMayOctKeoGencms + 10,850,058 MeanMayOctLL	0.3099	0.1300	14	Intercept: 0.3014 KeoGen: 0.0891 Lake level: **0.0482**	3.151	0.4579	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0009	0.9953	14	Intercept: 0.2446 KeoGen: 0.9544 Lake level: 0.9318	1.038	0.5147	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctKeoGencms Indep: Max30dayMayOctLL	0.0224	0.8827	14	Intercept: 0.3864 KeoGen: 0.9070 Lake level: 0.6265	1.024	0.4840	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep:logMaxDailyMayOctKeoGencms Indep: MeanMayOctLL	0.1432	0.4274	14	Intercept: 0.5589 KeoGen: 0.4337 Lake level: 0.2031	1.723	0.4517	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep:logMaxDailyMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0008	0.9954	14	Intercept: 0.6788 KeoGen: 0.9561 Lake level: 0.9560	1.106	0.3505	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep:logMaxDailyMayOctKeoGencms Indep: Max30dayMayOctLL	0.0213	0.8884	14	Intercept: 0.8054 KeoGen: 0.9721 Lake level: 0.6388	1.057	0.3686	(none)	(none)
Lakewide	1999-2012	FallFish = -11,105,800 + 209,927 Max30dayMayOctKeoGencms + 10,909,820 MeanMayOctLL	0.3457	0.0970	14	Intercept: 0.2178 KeoGen: 0.0632 Lake level: **0.0352**	2.877	0.6195	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	Dep: FallFish Indep: Max30dayMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0038	0.9790	14	Intercept: 0.2973 KeoGen: 0.8521 Lake level: 0.9142	1.032	0.6249	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: Max30dayMayOctKeoGencms Indep: Max30dayMayOctLL	0.0273	0.8586	14	Intercept: 0.4676 KeoGen: 0.7965 Lake level: 0.6085	1.030	0.6037	(none)	(none)

Appendix Table 65. Multiple regression analyses relating fall forage fish density (no/ha) in the Keowee River basin of Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Lake Keowee lake level (meters below full pool, positive number) observed May-October (mean, lowest daily, lowest 30-day average). Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctKeoGencms Indep: MeanMayOctLL	0.2301	0.2374	14	Intercept: 0.5867 KeoGen: 0.1013 Lake level: 0.1279	3.151	0.2619	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0483	0.7619	14	Intercept: 0.2960 KeoGen: 0.4819 Lake level: 0.7672	1.038	0.5461	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctKeoGencms Indep: Max30dayMayOctLL	0.0891	0.5986	14	Intercept: 0.4733 KeoGen: 0.4366 Lake level: 0.4589	1.024	0.4564	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep:logMaxDailyMayOctKeoGencms Indep: MeanMayOctLL	0.0278	0.8562	14	Intercept: 0.8862 KeoGen: 0.6315 Lake level: 0.6110	1.723	0.5854	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep:logMaxDailyMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0087	0.9531	14	Intercept: 0.8691 KeoGen: 0.7965 Lake level: 0.8167	1.106	0.5865	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep:logMaxDailyMayOctKeoGencms Indep: Max30dayMayOctLL	0.0465	0.7698	14	Intercept: 0.9866 KeoGen: 0.7241 Lake level: 0.4967	1.057	0.6321	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	Dep: FallDensKeo Indep: Max30dayMayOctKeoGencms Indep: MeanMayOctLL	0.2222	0.2511	14	Intercept: 0.5592 KeoGen: 0.1084 Lake level: 0.1407	2.877	0.2485	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: Max30dayMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0516	0.7473	14	Intercept: 0.3515 KeoGen: 0.4660 Lake level: 0.7715	1.032	0.5200	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: Max30dayMayOctKeoGencms Indep: Max30dayMayOctLL	0.0953	0.5764	14	Intercept: 0.5733 KeoGen: 0.4103 Lake level: 0.4459	1.030	0.4264	(none)	(none)

Appendix Table 66. Multiple regression analyses relating fall forage fish density (no/ha) in the Little River basin of Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and Lake Keowee lake level (meters below full pool, positive number) observed May-October (mean, lowest daily, lowest 30-day average). Variable name for lowest daily lake level: MaxDailyDecFebLL. Variable name for lowest 30-day average lake level: Max30dayDecFebLL.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctKeoGencms Indep: MeanMayOctLL	0.2980	0.1429	14	Intercept: 0.0033 KeoGen: 0.1026 Lake level: 0.0536	3.151	0.5208	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0000	0.9998	14	Intercept: <0.0001 KeoGen: 0.9971 Lake level: 0.9872	1.038	0.6990	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctKeoGencms Indep: Max30dayMayOctLL	0.0093	0.9499	14	Intercept: <0.0001 KeoGen: 0.9668 Lake level: 0.7541	1.024	0.5718	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep:logMaxDailyMayOctKeoGencms Indep: MeanMayOctLL	0.0980	0.5671	14	Intercept: 0.1624 KeoGen: 0.8686 Lake level: 0.3711	1.723	0.4377	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep:logMaxDailyMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0290	0.8508	14	Intercept: 0.0201 KeoGen: 0.5785 Lake level: 0.8753	1.106	0.5000	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep:logMaxDailyMayOctKeoGencms Indep: Max30dayMayOctLL	0.0302	0.8449	14	Intercept: 0.0226 KeoGen: 0.6347 Lake level: 0.8456	1.057	0.3749	(none)	(none)
Little	1999-2012	logFallDensLit = 1.77882 + 0.01363 Max30dayMayOctKeoGencms + 0.70826 MeanMayOctLL	0.3607	0.0854	14	Intercept: 0.0067 KeoGen: 0.0560 Lake level: **0.0305**	2.877	0.6596	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctKeoGencms Indep: MaxDailyMayOctLL	0.0031	0.9830	14	Intercept: <0.0001 KeoGen: 0.8569 Lake level: 0.9612	1.032	0.7148	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctKeoGencms Indep: Max30dayMayOctLL	0.0142	0.9243	14	Intercept: <0.0001 KeoGen: 0.8163 Lake level: 0.7291	1.030	0.6809	(none)	(none)

Appendix Table 67. Multiple regressions of fall forage fish lakewide numbers (FallFish) and fall forage fish densities (no/ha) (FallDens) in the Keowee River and Little River basins of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) May-October (mean, maximum daily, maximum 30-day average); and maximum summer surface (0-5 m) temperatures in the middle region of the Keowee River basin (mean of temperatures at Locations 505 and 506) and in the Little River basin (mean of temperatures at Locations 500, 501, 502).

Basin (fish)	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPumpcms Indep: KeoMiddleMaxTemp	0.1928	0.3080	14	Intercept: 0.1259 JocPump: 0.8690 MaxTemp: 0.1869	1.194	0.6421	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPumpcms Indep: KeoMiddleMaxTemp	0.1986	0.2959	14	Intercept: 0.1116 JocPump: 0.7472 MaxTemp: 0.1803	1.111	0.4934	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: Max30dayMayOctJocPumpcms Indep: KeoMiddleMaxTemp	0.3927	0.0644	14	Intercept: 0.1848 JocPump: 0.0821 MaxTemp: 0.4010	1.218	0.6523	(none)	(none)
Keowee	1999-2012	FallDensKeo = 12988 – 2.52541 MeanMayOctJocPumpcms – 366.61551 KeoMiddleMaxTemp	0.4256	**0.0474**	14	Intercept: 0.0201 JocPump: 0.5435 MaxTemp: **0.0422**	1.194	0.6213	(none)	(none)
Keowee	1999-2012	FallDensKeo = 13329 – 2.45034 MaxDailyMayOctJocPumpcms – 363.52090 KeoMiddleMaxTemp	0.4468	**0.0385**	14	Intercept: 0.0135 JocPump: 0.3822 MaxTemp: **0.0349**	1.111	0.6457	(none)	(none)
Keowee	1999-2012	FallDensKeo = 11251 – 6.40157 Max30dayMayOctJocPumpcms – 278.14919 KeoMiddleMaxTemp	0.5909	**0.0073**	14	Intercept: 0.0177 JocPump: **0.0471** MaxTemp: 0.0657	1.218	0.6118	(none)	(none)

Basin (fish)	**Years**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**Maximum VIF**	**SPEC**	**Outliers |SR|≥2.5**	**Significant Cook's D**
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPumpcms Indep: LitMaxTemp	0.3750	0.0754	14	Intercept: 0.0228 JocPump: 0.3357 MaxTemp: **0.0352**	1.002	0.1703	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPumpcms Indep: LitMaxTemp	0.3710	0.0781	14	Intercept: 0.0227 JocPump: 0.3538 MaxTemp: **0.0371**	1.000	0.4763	(none)	(none)
Lakewide	1999-2012	FallFish = 125,039,005 – 62,901 Max30dayMayOctJocPumpcms – 3,360,287 LitMaxTemp	0.5307	**0.0156**	14	Intercept: 0.0254 JocPump: **0.0470** MaxTemp: 0.0645	1.072	0.3970	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPumpcms Indep: LitMaxTemp	0.3294	0.1111	14	Intercept: 0.0091 JocPump: 0.7796 MaxTemp: **0.0409**	1.002	0.2648	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPumpcms Indep: LitMaxTemp	0.3283	0.1121	14	Intercept: 0.0094 JocPump: 0.8050 MaxTemp: **0.0414**	1.000	0.5697	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPumpcms Indep: LitMaxTemp	0.4153	0.0523	14	Intercept: 0.0090 JocPump: 0.2177 MaxTemp: 0.0653	1.072	0.3474	(none)	(none)

Appendix Table 68. Multiple regression analyses of total forage fish lakewide numbers in fall in Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean lakewide surface (0-10 m) chlorophyll concentrations measured in May (MayChlor) and averaged May through October (MeanMayOctChlor), utilizing data from 1999 through 2012.

Basin	**Years**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**Maximum VIF**	**SPEC**	**Outliers |SR|≥2.5**	**Significant Cook's D**
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPump Indep: MayLWChlor	0.0484	0.7614	14	Intercept: 0.2038 JocPump: 0.4749 Chlor: 0.9183	1.086	0.1668	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MeanMayOctJocPump Indep: MeanMayOctLWChlor	0.0474	0.7654	14	Intercept: 0.3232 JocPump: 0.4944 Chlor: 0.9826	1.119	0.3988	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPump Indep: MayLWChlor	0.0511	0.7492	14	Intercept: 0.2098 JocPump: 0.4618 Chlor: 0.8918	1.111	0.3545	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: MaxDailyMayOctJocPump Indep: MeanMayOctLWChlor	0.0495	0.7562	14	Intercept: 0.3312 JocPump: 0.4838 Chlor: 0.9768	1.120	0.4283	**2001 (SR=2.552)**	(none)
Lakewide	1999-2012	FallFish = 23,638,178 – 82,576 Max30dayMayOctJocPump + 1,926,328 MayLWChlor	0.3674	0.0806	14	Intercept: 0.0227 JocPump: **0.0283** Chlor: 0.5991	1.075	0.7430	(none)	(none)
Lakewide	1999-2012	Dep: FallFish Indep: Max30dayMayOctJocPump Indep: MeanMayOctLWChlor	0.3649	0.0823	14	Intercept: 0.0261 JocPump: **0.0295** Chlor: 0.6279	1.100	0.7454	**2001 (SR=2.610)**	(none)

Appendix Table 69. Repeat of multiple regression analyses in Appendix Table JocPump Chl Fall1, excluding data for 2001, identified as outlying in two regressions. Results are listed only for analyses where the observation for 2001 was identified as outlying in initial regression analysis.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012 (excl 2001)	FallFish = 48,005,095 – 75,602 MaxDailyMayOctJocPump – 5,993,794 MeanMayOctLWChlor	0.4560	**0.0476**	13	Intercept: 0.0069 JocPump: **0.0179** Chlor: 0.0816	1.323	0.7042	(none)	(none)
Lakewide	1999-2012 (excl 2001)	FallFish = 27,239,083 – 76,879 Max30dayMayOctJocPump – 800,978 MeanMayOctLWChlor	0.5069	**0.0292**	13	Intercept: 0.0033 JocPump: **0.0134** Chlor: 0.7912	1.082	0.3980	(none)	(none)

Appendix Table 70. Multiple regression analyses of fall forage fish density (no/ha) in the Keowee River basin of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean basinwide surface (0-10 m) chlorophyll concentrations measured in May (MayChlor) and averaged over May through October (MeanMayOctChlor), utilizing data from 1999 through 2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctJocPump Indep: MayChlor	0.1501	0.4087	14	Intercept: 0.0712 JocPump: 0.1909 Chlor: 0.9874	1.000	0.3541	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MeanMayOctJocPump Indep: MeanMayOctChlor	0.1532	0.4006	14	Intercept: 0.1005 JocPump: 0.1969 Chlor: 0.8440	1.154	0.9064	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MaxDailyMayOctJocPump Indep: MayChlor	0.1560	0.3935	14	Intercept: 0.0723 JocPump: 0.1817 Chlor: 0.9484	1.001	0.5211	(none)	(none)
Keowee	1999-2012	Dep: FallDensKeo Indep: MaxDailyMayOctJocPump Indep: MeanMayOctChlor	0.1578	0.3888	14	Intercept: 0.1030 JocPump: 0.1894 Chlor: 0.8688	1.129	0.8678	**2001 (SR=2.615)**	(none)
Keowee	1999-2012	FallDensKeo = 3418.82799 – 9.11667 Max30dayMayOctJocPump - 168.39803 MayChlor	0.4465	**0.0386**	14	Intercept: 0.0055 JocPump: **0.0125** Chlor: 0.6487	1.028	0.4748	(none)	(none)
Keowee	1999-2012	FallDensKeo = 3798.49812 – 9.86530 Max30dayMayOctJocPump – 220.84285 MeanMayOctChlor	0.4667	**0.0315**	14	Intercept: 0.0060 JocPump: **0.0105** Chlor: 0.4395	1.172	0.3669	(none)	(none)

Appendix Table 71. Repeat of multiple regression analyses in Appendix Table JocPump Chl Fall3, excluding data for 2001, identified as outlying in one regression. Results are listed only for analyses where the observation for 2001 was identified as outlying in initial regression analysis.

Basin	**Years**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**Maximum VIF**	**SPEC**	**Outliers |SR|≥2.5**	**Significant Cook's D**
Keowee	1999-2012 (excl 2001)	FallDensKeo = 6803.97838 – 11.31534 MaxDailyMayOctJocPump – 868.76296 MeanMayOctChlor	0.6388	**0.0061**	13	Intercept: 0.0007 JocPump: **0.0019** Chlor: **0.0151**	1.581	0.3904	(none)	(none)

Appendix Table 72. Multiple regression analyses of fall forage fish density (no/ha) in the Little River basin of Lake Keowee on combinations of variables for Jocassee Pumped Storage Station pumping flows (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean basinwide surface (0-10 m) chlorophyll concentrations measured in May (MayChlor) and averaged over May through October (MeanMayOctChlor), utilizing data from 1999 through 2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPump Indep: MayChlor	0.0599	0.7122	14	Intercept: <0.0001 JocPump: 0.8524 Chlor: 0.4295	1.209	0.6958	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MeanMayOctJocPump Indep: MeanMayOctChlor	0.0521	0.7452	14	Intercept: 0.0015 JocPump: 0.7373 Chlor: 0.4634	1.062	0.2366	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPump Indep: MayChlor	0.0602	0.7108	14	Intercept: 0.0009 JocPump: 0.8450 Chlor: 0.4301	1.246	0.6813	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: MaxDailyMayOctJocPump Indep: MeanMayOctChlor	0.0551	0.7323	14	Intercept: 0.0051 JocPump: 0.7026 Chlor: 0.4520	1.084	0.1680	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPump Indep: MayChlor	0.1930	0.3075	14	Intercept: <0.0001 JocPump: 0.2002 Chlor: 0.9416	1.338	0.3306	(none)	(none)
Little	1999-2012	Dep: logFallDensLit Indep: Max30dayMayOctJocPump Indep: MeanMayOctChlor	0.2737	0.1722	14	Intercept: 0.0001 JocPump: 0.0877 Chlor: 0.2913	1.031	0.6216	(none)	(none)

Appendix Table 73. Multiple regression analyses relating total lakewide number of forage fish in fall on Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean lakewide surface (0-10 m) chlorophyll concentrations in May (MayChlor) and averaged May through October (MeanMayOctChlor), utilizing data from 1999 through 2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	FallFish MeanMayOctKeoGen MayLWChlor	0.0010	0.9944	14	Intercept: 0.3582 KeoGen: 0.9890 Chlor: 0.9244	1.082	0.7873	(none)	(none)
Lakewide	1999-2012	FallFish MeanMayOctKeoGen MayOctLWChlor	0.0047	0.9744	14	Intercept: 0.5173 KeoGen: 0.9402 Chlor: 0.8267	1.024	0.6304	(none)	(none)
Lakewide	1999-2012	FallFish logMaxDailyMayOctKeoGen MayLWChlor	0.0019	0.9894	14	Intercept: 0.6160 KeoGen: 0.9213 Chlor: 0.9040	1.043	0.8456	(none)	(none)
Lakewide	1999-2012	FallFish logMaxDailyMayOctKeoGen MayOctLWChlor	0.0057	0.9693	14	Intercept: 0.6531 KeoGen: 0.9006 Chlor: 0.8165	1.050	0.7229	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctKeoGen MayLWChlor	0.0033	0.9819	14	Intercept: 0.3765 KeoGen: 0.8758 Chlor: 0.9378	1.023	0.7566	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctKeoGen MayOctLWChlor	0.0086	0.9534	14	Intercept: 0.5856 KeoGen: 0.8281 Chlor: 0.8029	1.042	0.6018	(none)	(none)

Appendix Table 74. Multiple regression analyses relating fall forage fish density (no/ha) in the Keowee River basin of Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean basinwide surface (0-10 m) chlorophyll concentrations in May (MayChlor) and averaged May through October (MeanMayOctChlor), utilizing data from 1999 through 2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	FallDensKeo MeanMayOctKeoGen MayChlor	0.0444	0.7789	14	Intercept: 0.4439 KeoGen: 0.4896 Chlor: 0.8313	1.086	0.2076	(none)	(none)
Keowee	1999-2012	FallDensKeo MeanMayOctKeoGen MayOctChlor	0.0658	0.6877	14	Intercept: 0.6302 KeoGen: 0.4269 Chlor: 0.5946	1.107	0.6834	(none)	(none)
Keowee	1999-2012	FallDensKeo logMaxDailyMayOctKeoGen MayChlor	0.0037	0.9796	14	Intercept: 0.7723 KeoGen: 0.8433 Chlor: 0.9724	1.008	0.2199	(none)	(none)
Keowee	1999-2012	FallDensKeo logMaxDailyMayOctKeoGen MayOctChlor	0.0107	0.9426	14	Intercept: 0.8035 KeoGen: 0.8661 Chlor: 0.7845	1.009	0.8273	(none)	(none)
Keowee	1999-2012	FallDensKeo Max30dayMayOctKeoGen MayChlor	0.0471	0.7669	14	Intercept: 0.4687 KeoGen: 0.4764 Chlor: 0.8518	1.059	0.1849	(none)	(none)
Keowee	1999-2012	FallDensKeo Max30dayMayOctKeoGen MayOctChlor	0.0713	0.6657	14	Intercept: 0.7114 KeoGen: 0.4050 Chlor: 0.5805	1.115	0.7316	(none)	(none)

Appendix Table 75. Multiple regression analyses relating fall forage fish density (no/ha) in the Little River basin of Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean basinwide surface (0-10 m) chlorophyll concentrations in May (MayChlor) and averaged May through October (MeanMayOctChlor), utilizing data from 1999 through 2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	logFallDensLit MeanMayOctKeoGen MayChlor	0.0738	0.6558	14	Intercept: 0.0008 KeoGen: 0.8022 Chlor: 0.3691	1.086	0.6763	**2010 (SR=-2.648)**	(none)
Little	1999-2012	logFallDensLit MeanMayOctKeoGen MayOctChlor	0.0058	0.9685	14	Intercept: 0.0003 KeoGen: 0.9438 Chlor: 0.8046	1.107	0.4852	(none)	(none)
Little	1999-2012	logFallDensLit logMaxDailyMayOctKeoGen MayChlor	0.0880	0.6025	14	Intercept: 0.0299 KeoGen: 0.6354 Chlor: 0.4081	1.008	0.8088	**2010 (SR=-2.717)**	(none)
Little	1999-2012	logFallDensLit logMaxDailyMayOctKeoGen MayOctChlor	0.0346	0.8237	14	Intercept: 0.0144 KeoGen: 0.5750 Chlor: 0.7688	1.009	0.5768	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctKeoGen MayChlor	0.0824	0.6230	14	Intercept: 0.0010 KeoGen: 0.6886 Chlor: 0.3498	1.059	0.5712	**2010 (SR=-2.629)**	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctKeoGen MayOctChlor	0.0120	0.9358	14	Intercept: 0.0006 KeoGen: 0.7907 Chlor: 0.7563	1.115	0.4918	(none)	(none)

Appendix Table 76. Repeat of regressions in Appendix Table KeoGen Chlor Fall3, excluding data for 2010, identified as an outlier in three regressions. Results are listed only for those regressions in which the observation for 2010 was identified as outlying in initial regression analysis.

Basin	**Years**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**Maximum VIF**	**SPEC**	**Outliers |SR|≥2.5**	**Significant Cook's D**
Little	1999-2012 (excl 2010)	logFallDensLit = 2.16710 + 0.00509 MeanMayOctKeoGen + 0.51762 MayChlor	0.4134	0.0695	13	Intercept: 0.0001 KeoGen: 0.2971 Chlor: **0.0248**	1.109	0.2603	(none)	(none)
Little	1999-2012 (excl 2010)	logFallDensLit = 0.97396 + 0.56598 logMaxDailyMayOctKeoGen + 0.52076 MayChlor	0.4762	**0.0394**	13	Intercept: 0.3183 KeoGen: 0.1410 Chlor: **0.0167**	1.064	0.1892	(none)	(none)
Little	1999-2012 (excl 2010)	logFallDensLit = 2.17718 + 0.00304 Max30dayMayOctKeoGen + 0.49956 MayChlor	0.4044	0.0750	13	Intercept: 0.0002 KeoGen: 0.3318 Chlor: **0.0276**	1.067	0.3936	(none)	(none)

Appendix Table 77. Multiple regression analyses relating total number of forage fish lakewide in fall on Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean lakewide zooplankton densities (organisms/m^3) measured on Lake Keowee in May. Lakewide densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton were calculated as the average of densities observed at Locations 502 and 508. Analyses utilize data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	FallFish MeanMayOctJocPump logMayLWCrustZoo	0.0609	0.7304	13	Intercept: 0.8991 JocPump: 0.7563 Zoo: 0.6977	1.564	0.4759	(none)	(none)
Lakewide	1999-2012	FallFish = -53,991,757 + 34,335 MeanMayOctJocPump + 13,382,663 logMayLWRot	0.4754	**0.0397**	13	Intercept: 0.0515 JocPump: 0.4029 Zoo: **0.0169**	1.489	0.1676	(none)	(none)
Lakewide	1999-2012	FallFish MeanMayOctJocPump logMayLWTotalZoo	0.4355	0.0573	13	Intercept: 0.0449 JocPump: 0.2774 Zoo: **0.0253**	1.893	0.5311	(none)	(none)
Lakewide	1999-2012	FallFish MaxDailyMayOctJocPump logMayLWCrustZoo	0.0818	0.6527	13	Intercept: 0.9784 JocPump: 0.5775 Zoo: 0.7425	1.374	0.3217	(none)	(none)
Lakewide	1999-2012	FallFish = -50,017,418 + 15,430 MaxDailyMayOctJocPump + 12,513,241 logMayLWRot	0.4519	**0.0495**	13	Intercept: 0.0963 JocPump: 0.5955 Zoo: **0.0249**	1.469	0.5495	(none)	(none)
Lakewide	1999-2012	FallFish MaxDailyMayOctJocPump logMayLWTotalZoo	0.3855	0.0876	13	Intercept: 0.0970 JocPump: 0.5417 Zoo: 0.0473	1.708	0.6609	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctJocPump logMayLWCrustZoo	0.3578	0.1092	13	Intercept: 0.2582 JocPump: 0.0538 Zoo: 0.5153	1.649	0.5913	(none)	(none)
Lakewide	1999-2012	FallFish = -21,011,946 – 26,977 Max30dayMayOctJocPump + 8,439,651 logMayLWRot	0.4621	**0.0450**	13	Intercept: 0.4958 JocPump: 0.4970 Zoo: 0.1462	1.905	0.7038	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctJocPump logMayLWTotalZoo	0.3859	0.0873	13	Intercept: 0.6030 JocPump: 0.5380 Zoo: 0.3567	2.710	0.7499	(none)	(none)

Appendix Table 78. Multiple regression analyses relating fall forage fish density (no/ha) in the Keowee River basin of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) measured at Location 508 on Lake Keowee in May. Analyses utilize data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	FallDensKeo MeanMayOctJocPump MayCrustZoo	0.1788	0.3735	13	Intercept: 0.0454 JocPump: 0.1764 Zoo: 0.7827	1.143	0.5359	(none)	(none)
Keowee	1999-2012	FallDensKeo = -3897.49525 – 2.80794 MeanMayOctJocPump + 1312.22338 logMayRot	0.6191	**0.0080**	13	Intercept: 0.0555 JocPump: 0.3484 Zoo: **0.0065**	1.102	0.7866	(none)	(none)
Keowee	1999-2012	FallDensKeo MeanMayOctJocPump logMayTotalZoo	0.4376	0.0563	13	Intercept: 0.1285 JocPump: 0.5139 Zoo: 0.0549	1.214	0.6736	(none)	(none)
Keowee	1999-2012	FallDensKeo MaxDailyMayOctJocPump MayCrustZoo	0.2371	0.2585	13	Intercept: 0.0357 JocPump: 0.1117 Zoo: 0.7382	1.127	0.7295	(none)	(none)
Keowee	1999-2012	FallDensKeo = -3240.41619 – 2.76542 MaxDailyMayOctJocPump + 1275.54342 logMayRot	0.6550	**0.0049**	13	Intercept: 0.1055 JocPump: 0.1772 Zoo: **0.0056**	1.090	0.4731	(none)	(none)
Keowee	1999-2012	FallDensKeo = -5937.76234 – 2.69716 MaxDailyMayOctJocPump + 1758.20466 logMayTotalZoo	0.4765	**0.0393**	13	Intercept: 0.1752 JocPump: 0.2924 Zoo: 0.0544	1.166	0.6079	(none)	(none)
Keowee	1999-2012	FallDensKeo = 3431.11985 – 8.72036 Max30dayMayOctJocPump – 0.01686 MayCrustZoo	0.4716	**0.0412**	13	Intercept: 0.0035 JocPump: **0.0140** Zoo: 0.4291	1.162	0.7333	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	FallDensKeo = -2452.05628 - 3.98278 Max30dayMayOctJocPump + 1071.56345 logMayRot	0.6592	**0.0046**	13	Intercept: 0.2793 JocPump: 0.1637 Zoo: **0.0283**	1.469	0.5132	(none)	(none)
Keowee	1999-2012	FallDensKeo = -3268.56571 – 5.00149 Max30dayMayOctJocPump + 1213.37987 logMayTotalZoo	0.5171	**0.0263**	13	Intercept: 0.5096 JocPump: 0.1707 Zoo: 0.2233	1.694	0.5718	(none)	(none)

Appendix Table 79. Multiple regression analyses relating fall forage fish density (no/ha) in the Little River basin of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) measured at Location 502 on Lake Keowee in May. Analyses utilize data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	logFallDensLit MeanMayOctJocPump logMayCrustZoo	0.0234	0.8883	13	Intercept: 0.4044 JocPump: 0.7937 Zoo: 0.6360	1.602	0.3984	(none)	(none)
Little	1999-2012	logFallDensLit MeanMayOctJocPump logMayRot	0.1285	0.5027	13	Intercept: 0.3026 JocPump: 0.5341 Zoo: 0.2528	1.454	0.1906	(none)	(none)
Little	1999-2012	logFallDensLit MeanMayOctJocPump logMayTotalZoo	0.0983	0.5960	13	Intercept: 0.7076 JocPump: 0.5337 Zoo: 0.3213	1.721	0.2141	(none)	(none)
Little	1999-2012	logFallDensLit MaxDailyMayOctJocPump logMayCrustZoo	0.0178	0.9142	13	Intercept: 0.2694 JocPump: 0.9071 Zoo: 0.7820	1.383	0.3206	(none)	(none)
Little	1999-2012	logFallDensLit MaxDailyMayOctJocPump logMayRot	0.1016	0.5853	13	Intercept: 0.3077 JocPump: 0.7555 Zoo: 0.3361	1.515	0.3531	(none)	(none)
Little	1999-2012	logFallDensLit MaxDailyMayOctJocPump logMayTotalZoo	0.0661	0.7104	13	Intercept: 0.5458 JocPump: 0.8180 Zoo: 0.4557	1.657	0.2749	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctJocPump logMayCrustZoo	0.2062	0.3152	13	Intercept: 0.0442 JocPump: 0.1531 Zoo: 0.5194	1.748	0.6695	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctJocPump logMayRot	0.1733	0.3861	13	Intercept: 0.0511 JocPump: 0.3458 Zoo: 0.8649	1.702	0.7681	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctJocPump logMayTotalZoo	0.1766	0.3785	13	Intercept: 0.1053 JocPump: 0.2632 Zoo: 0.7954	2.105	0.6587	(none)	(none)

Appendix Table 80. Multiple regression analyses relating total number of forage fish lakewide in fall on Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean lakewide zooplankton densities (organisms/m^3) measured on Lake Keowee in May and August (variable analyzed is mean of May and August data). Lakewide densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton were calculated as the average of densities observed at Locations 502 and 508. Analyses utilize data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	FallFish MeanMayOctJocPump MayAugLWCrustZoo	0.0459	0.7905	13	Intercept: 0.2467 JocPump: 0.5500 Zoo: 0.9873	1.289	0.4322	(none)	(none)
Lakewide	1999-2012	FallFish MeanMayOctJocPump logMayAugLWRot	0.0945	0.6087	13	Intercept: 0.7757 JocPump: 0.9837 Zoo: 0.4806	1.870	0.4211	(none)	(none)
Lakewide	1999-2012	FallFish MeanMayOctJocPump logMayAugLWTotalZoo	0.0512	0.7691	13	Intercept: 0.9927 JocPump: 0.7815 Zoo: 0.8186	2.274	0.3678	(none)	(none)
Lakewide	1999-2012	FallFish MaxDailyMayOctJocPump MayAugLWCrustZoo	0.0713	0.6907	13	Intercept: 0.2158 JocPump: 0.4332 Zoo: 0.9906	1.165	0.3426	(none)	(none)
Lakewide	1999-2012	FallFish MaxDailyMayOctJocPump logMayAugLWRot	0.1129	0.5495	13	Intercept: 0.9927 JocPump: 0.6585 Zoo: 0.5093	1.303	0.3896	(none)	(none)
Lakewide	1999-2012	FallFish MaxDailyMayOctJocPump logMayAugLWTotalZoo	0.0779	0.6666	13	Intercept: 0.8898 JocPump: 0.5546 Zoo: 0.7943	1.372	0.3131	(none)	(none)
Lakewide	1999-2012	FallFish = 29,711,386 – 77,904 Max30dayMayOctJocPump – 96.61140 MayAugLWCrustZoo	0.3558	0.1110	13	Intercept: 0.0161 JocPump: **0.0429** Zoo: 0.5307	1.226	0.4160	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctJocPump logMayAugLWRot	0.3313	0.1337	13	Intercept: 0.4042 JocPump: 0.0892 Zoo: 0.8451	1.262	0.6428	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctJocPump logMayAugLWTotalZoo	0.3359	0.1292	13	Intercept: 0.3404 JocPump: 0.0622 Zoo: 0.7475	1.321	0.4057	(none)	(none)

Appendix Table 81. Multiple regression analyses relating fall forage fish density (no/ha) in the Keowee River basin of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) measured at Location 508 on Lake Keowee in May and August (variable analyzed is mean of May and August data). Analyses utilize data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	FallDensKeo = 3575.60611 – 9.87698 MeanMayOctJocPump – 0.03408 MayAugCrustZoo	0.4045	0.0970	12	Intercept: 0.0065 JocPump: **0.0404** Zoo: 0.1104	1.365	0.2080	(none)	(none)
Keowee	1999-2012	FallDensKeo MeanMayOctJocPump logMayAugRot	0.2244	0.3187	12	Intercept: 0.9074 JocPump: 0.4239 Zoo: 0.5867	1.623	0.8810	(none)	(none)
Keowee	1999-2012	FallDensKeo MeanMayOctJocPump logMayAugTotalZoo	0.2096	0.3469	12	Intercept: 0.4609 JocPump: 0.2088 Zoo: 0.7135	1.870	0.8866	(none)	(none)
Keowee	1999-2012	FallDensKeo = 4518.38235 – 7.53202 MaxDailyMayOctJocPump – 0.03187 MayAugCrustZoo	0.4935	**0.0468**	12	Intercept: 0.0037 JocPump: **0.0181** Zoo: 0.0926	1.243	0.7226	(none)	(none)
Keowee	1999-2012	FallDensKeo MaxDailyMayOctJocPump logMayAugRot	0.3327	0.1620	12	Intercept: 0.6634 JocPump: 0.1657 Zoo: 0.4903	1.212	0.9207	(none)	(none)
Keowee	1999-2012	FallDensKeo MaxDailyMayOctJocPump logMayAugTotalZoo	0.2957	0.2065	12	Intercept: 0.4300 JocPump: 0.1093 Zoo: 0.8959	1.280	0.6910	(none)	(none)
Keowee	1999-2012	FallDensKeo = 4011.74467 – 9.81913 Max30dayMayOctJocPump – 0.02762 MayAugCrustZoo	0.6565	**0.0082**	12	Intercept: 0.0004 JocPump: **0.0028** Zoo: 0.0662	1.116	0.4387	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	FallDensKeo = 1807.84620 – 7.50277 Max30dayMayOctJocPump + 226.43717 logMayAugRot	0.5073	**0.0414**	12	Intercept: 0.4127 JocPump: **0.0336** Zoo: 0.5862	1.197	0.7588	(none)	(none)
Keowee	1999-2012	FallDensKeo = 4028.26646 – 8.60952 Max30dayMayOctJocPump – 211.63820 logMayAugTotalZoo	0.4960	**0.0458**	12	Intercept: 0.2583 JocPump: **0.0198** Zoo: 0.7484	1.210	0.5225	(none)	(none)

Appendix Table 82. Multiple regression analyses relating fall forage fish density (no/ha) in the Little River basin of Lake Keowee to combinations of variables for Jocassee Pumped Storage Station pumping flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) measured at Location 502 on Lake Keowee in May and August (variable analyzed is mean of May and August data). Analyses utilize data collected 1999-2012.

Basin	Years	Regression Equation or Variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Little	1999-2012	logFallDensLit MeanMayOctJocPump MayAugCrustZoo	0.0359	0.8330	13	Intercept: 0.0005 JocPump: 0.8306 Zoo: 0.5563	1.213	0.2627	(none)	(none)
Little	1999-2012	logFallDensLit MeanMayOctJocPump logMayAugRot	0.0327	0.8469	13	Intercept: 0.2691 JocPump: 0.7157 Zoo: 0.5748	1.933	0.5294	(none)	(none)
Little	1999-2012	logFallDensLit MeanMayOctJocPump logMayAugTotalZoo	0.0043	0.9787	13	Intercept: 0.4248 JocPump: 0.8998 Zoo: 0.8425	2.342	0.4025	(none)	(none)
Little	1999-2012	logFallDensLit MaxDailyMayOctJocPump MayAugCrustZoo	0.0328	0.8462	13	Intercept: 0.0018 JocPump: 0.8997 Zoo: 0.6364	1.138	0.2937	(none)	(none)
Little	1999-2012	logFallDensLit MaxDailyMayOctJocPump logMayAugRot	0.0203	0.9027	13	Intercept: 0.1125 JocPump: 0.9151 Zoo: 0.7512	1.341	0.3639	(none)	(none)
Little	1999-2012	logFallDensLit MaxDailyMayOctJocPump logMayAugTotalZoo	0.0099	0.9517	13	Intercept: 0.2005 JocPump: 0.7925 Zoo: 0.9929	1.413	0.2260	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctJocPump MayAugCrustZoo	0.1712	0.3910	13	Intercept: 0.0001 JocPump: 0.2229 Zoo: 0.9427	1.288	0.5052	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctJocPump logMayAugRot	0.1748	0.3826	13	Intercept: 0.0136 JocPump: 0.1995 Zoo: 0.8295	1.283	0.6887	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctJocPump logMayAugTotalZoo	0.2077	0.3122	13	Intercept: 0.0317 JocPump: 0.1388 Zoo: 0.5104	1.372	0.5944	(none)	(none)

Appendix Table 83. Multiple regression analyses relating total lakewide number of forage fish in fall on Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and mean lakewide zooplankton densities (organisms/m^3) measured on Lake Keowee in May and August (variable analyzed is mean of May and August data). Lakewide densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton were calculated as the average of densities observed at Locations 502 and 508. Analyses utilize data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Lakewide	1999-2012	FallFish MeanMayOctKeoGen MayAugLWCrustZoo	0.0148	0.9281	13	Intercept: 0.2468 KeoGen: 0.8197 Zoo: 0.7392	1.026	0.6097	(none)	(none)
Lakewide	1999-2012	FallFish MeanMayOctKeoGen logMayAugLWRot	0.0963	0.6027	13	Intercept: 0.5977 KeoGen: 0.8892 Zoo: 0.3342	1.002	0.3719	(none)	(none)
Lakewide	1999-2012	FallFish MeanMayOctKeoGen logMayAugLWTotalZoo	0.0497	0.7748	13	Intercept: 0.6747 KeoGen: 0.8022 Zoo: 0.5003	1.011	0.2964	(none)	(none)
Lakewide	1999-2012	FallFish logMaxDailyMayOctKeoGen MayAugLWCrustZoo	0.0656	0.7121	13	Intercept: 0.7295 KeoGen: 0.4558 Zoo: 0.7781	1.001	0.6954	(none)	(none)
Lakewide	1999-2012	FallFish logMaxDailyMayOctKeoGen logMayAugLWRot	0.1189	0.5311	13	Intercept: 0.4709 KeoGen: 0.6100 Zoo: 0.4245	1.097	0.3509	(none)	(none)
Lakewide	1999-2012	FallFish logMaxDailyMayOctKeoGen logMayAugLWTotalZoo	0.0873	0.6332	13	Intercept: 0.5341 KeoGen: 0.5039 Zoo: 0.5821	1.027	0.2622	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctKeoGen MayAugLWCrustZoo	0.0186	0.9102	13	Intercept: 0.3211 KeoGen: 0.7653 Zoo: 0.7194	1.051	0.7307	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctKeoGen logMayAugLWRot	0.0971	0.6001	13	Intercept: 0.5958 KeoGen: 0.8683 Zoo: 0.3370	1.005	0.3798	(none)	(none)
Lakewide	1999-2012	FallFish Max30dayMayOctKeoGen logMayAugLWTotalZoo	0.0522	0.7648	13	Intercept: 0.6668 KeoGen: 0.7675 Zoo: 0.4976	1.010	0.3220	(none)	(none)

Appendix Table 84. Multiple regression analyses relating fall forage fish density (no/ha) in the Keowee River basin of Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) measured at Location 508 on Lake Keowee in May and August (variable analyzed is mean of May and August data). Analyses utilize data collected 1999-2012.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Keowee	1999-2012	FallDensKeo MeanMayOctKeoGen MayAugCrustZoo	0.0751	0.7037	12	Intercept: 0.1246 KeoGen: 0.5057 Zoo: 0.7902	1.095	0.2853	(none)	(none)
Keowee	1999-2012	FallDensKeo MeanMayOctKeoGen logMayAugRot	0.2457	0.2812	12	Intercept: 0.3542 KeoGen: 0.3491 Zoo: 0.1787	1.004	0.6694	(none)	(none)
Keowee	1999-2012	FallDensKeo MeanMayOctKeoGen logMayAugTotalZoo	0.1542	0.4707	12	Intercept: 0.4992 KeoGen: 0.3169 Zoo: 0.3616	1.066	0.5765	(none)	(none)
Keowee	1999-2012	FallDensKeo logMaxDailyMayOctKeoGen MayAugCrustZoo	0.1956	0.3755	12	Intercept: 0.5496 KeoGen: 0.2013 Zoo: 0.6355	1.001	0.2303	(none)	(none)
Keowee	1999-2012	FallDensKeo logMaxDailyMayOctKeoGen logMayAugRot	0.2812	0.2263	12	Intercept: 0.1948 KeoGen: 0.2565 Zoo: 0.2767	1.043	0.6802	(none)	(none)
Keowee	1999-2012	FallDensKeo logMaxDailyMayOctKeoGen logMayAugTotalZoo	0.2132	0.3399	12	Intercept: 0.3554 KeoGen: 0.2033 Zoo: 0.5204	1.003	0.6766	(none)	(none)
Keowee	1999-2012	FallDensKeo Max30dayMayOctKeoGen MayAugCrustZoo	0.0568	0.7687	12	Intercept: 0.1506 KeoGen: 0.5995 Zoo: 0.7695	1.107	0.2006	(none)	(none)
Keowee	1999-2012	FallDensKeo Max30dayMayOctKeoGen logMayAugRot	0.2121	0.3421	12	Intercept: 0.3897 KeoGen: 0.4773 Zoo: 0.2032	1.000	0.5853	(none)	(none)
Keowee	1999-2012	FallDensKeo Max30dayMayOctKeoGen logMayAugTotalZoo	0.1216	0.5579	12	Intercept: 0.5485 KeoGen: 0.4098 Zoo: 0.4053	1.047	0.5607	(none)	(none)

Appendix Table 85. Multiple regression analyses relating fall forage fish density (no/ha) in the Little River basin of Lake Keowee to combinations of variables for Keowee Hydroelectric Station generation flow (m^3/sec) observed May-October (mean, maximum daily, maximum 30-day average) and zooplankton densities (organisms/m^3) measured at Location 502 on Lake Keowee in May and August (variable analyzed is mean of May and August data). Analyses utilize data collected 1999-2012.

Basin	**Years**	**Regression equation or variables**	**R^2**	**Pr>F**	**N**	**Prob>|t|**	**Maximum VIF**	**SPEC**	**Outliers |SR|≥2.5**	**Significant Cook's D**
Little	1999-2012	logFallDensLit MeanMayOctKeoGen MayAugCrustZoo	0.0387	0.8207	13	Intercept: <0.0001 KeoGen: 0.7854 Zoo: 0.5655	1.009	0.3256	(none)	(none)
Little	1999-2012	logFallDensLit MeanMayOctKeoGen logMayAugRot	0.0222	0.8936	13	Intercept: 0.0244 KeoGen: 0.8609 Zoo: 0.6815	1.009	0.4749	(none)	(none)
Little	1999-2012	logFallDensLit MeanMayOctKeoGen logMayAugTotalZoo	0.0077	0.9622	13	Intercept: 0.1248 KeoGen: 0.8259 Zoo: 0.8677	1.001	0.4056	(none)	(none)
Little	1999-2012	logFallDensLit logMaxDailyMayOctKeoGen MayAugCrustZoo	0.0697	0.6967	13	Intercept: 0.0505 KeoGen: 0.5345 Zoo: 0.6162	1.009	0.2844	(none)	(none)
Little	1999-2012	logFallDensLit logMaxDailyMayOctKeoGen logMayAugRot	0.0499	0.7742	13	Intercept: 0.1043 KeoGen: 0.5817 Zoo: 0.8224	1.128	0.4585	(none)	(none)
Little	1999-2012	logFallDensLit logMaxDailyMayOctKeoGen logMayAugTotalZoo	0.0449	0.7949	13	Intercept: 0.2145 KeoGen: 0.5210 Zoo: 0.9855	1.049	0.4130	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctKeoGen MayAugCrustZoo	0.0491	0.7774	13	Intercept: <0.0001 KeoGen: 0.6738 Zoo: 0.5298	1.046	0.2139	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctKeoGen logMayAugRot	0.0256	0.8784	13	Intercept: 0.0247 KeoGen: 0.8014 Zoo: 0.6869	1.010	0.4720	(none)	(none)
Little	1999-2012	logFallDensLit Max30dayMayOctKeoGen logMayAugTotalZoo	0.0121	0.9410	13	Intercept: 0.1307 KeoGen: 0.7633 Zoo: 0.8592	1.004	0.4046	(none)	(none)

Appendix Table 86. Multiple regression analyses of fall forage fish densities in the Keowee River and Little River basins of Lake Keowee on combinations of variables for mean basinwide chlorophyll concentrations (mg/m^3) measured in May, May-June, and May-October, and littoral basinwide density (no/km) and biomass (kg/km) of total black basses (BLB) measured in spring electrofishing, utilizing data collected 1999, 2002, 2005, 2008, 2010, and 2011.

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logFallDens = 4.10585 + 0.19804 MayBasinChl – 1.17903 logBLBnumkm	0.4308	0.0792	12	Intercept: <0.0001 Chlor: 0.2669 BLB: **0.0299**	1.540	0.5650	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logFallDens MayJunBasinChl logBLBnumkm	0.3435	0.1505	12	Intercept: <0.0001 Chlor: 0.8990 BLB: 0.1429	2.053	0.5236	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logFallDens MayOctBasinChl logBLBnumkm	0.3447	0.1493	12	Intercept: <0.0001 Chlor: 0.8578 BLB: 0.2365	2.370	0.5854	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logFallDens MayBasinChl BLBkgkm	0.0655	0.7373	12	Intercept: <0.0001 Chlor: 0.4936 BLB: 0.4887	1.674	0.5492	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logFallDens MayJunBasinChl BLBkgkm	0.3088	0.1898	12	Intercept: <0.0001 Chlor: 0.0812 BLB: 0.1915	1.426	0.6999	(none)	(none)

Basin	Years	Regression equation or variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Both basins	1999, 2002, 2005, 2008, 2010, 2011	logFallDens = 4.07431 – 0.60996 MayOctBasinChl + 0.06631 BLBkgkm	0.3725	0.1229	12	Intercept: <0.0001 Chlor: **0.0492** BLB: 0.1833	1.282	0.4464	(none)	(none)

Appendix Table 87. Multiple regression analyses relating fall forage fish densities in the Keowee River and Little River basins of Lake Keowee to combinations of variables for basin zooplankton densities (organisms/m^3) measured in May and basinwide mean littoral density (no/km) and biomass (kg/km) of total black basses as measured in spring shoreline electrofishing . Zooplankton density for the Keowee River basin was measured at Location 508; zooplankton density for the Little River basin was measured at Location 502. Zooplankton variables analyzed are densities of total crustacean zooplankton (sum of copepod and cladoceran densities), rotifers, and total zooplankton. Analyses utilize data collected 1999, 2002, 2005, 2008, and 2011.

Basin	Years	Regression Equation or Variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Both basins	1999, 2002, 2005, 2008, 2011	logFallDens logMayCrustZoo logBLBnumkm	0.2215	0.4163	10	Intercept: 0.0419 Zoo: 0.4580 BLB: 0.3133	1.010	0.6919	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2011	logFallDens logMayRot logBLBnumkm	0.1618	0.5391	10	Intercept: 0.0089 Zoo: 0.7929 BLB: 0.2955	1.260	0.6234	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2011	logFallDens logMayTotalZoo logBLBnumkm	0.1530	0.5592	10	Intercept: 0.0541 Zoo: 0.9746 BLB: 0.3276	1.169	0.4046	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2011	logFallDens logMayCrustZoo BLBkgkm	0.0925	0.7121	10	Intercept: 0.0632 Zoo: 0.4266 BLB: 0.8992	1.015	0.7091	(none)	(none)
Both basins	1999, 2002, 2005, 2008, 2011	logFallDens logMayRot BLBkgkm	0.0125	0.9570	10	Intercept: 0.0164 Zoo: 0.7759 BLB: 0.8758	1.271	0.4480	(none)	(none)

Basin	Years	Regression Equation or Variables	R^2	Pr>F	N	Prob>|t|	Maximum VIF	SPEC	Outliers |SR|≥2.5	Significant Cook's D
Both basins	1999, 2002, 2005, 2008, 2011	logFallDens logMayTotalZoo BLBkgkm	0.0250	0.9153	10	Intercept: 0.0661 Zoo: 0.6854 BLB: 0.8425	1.222	0.4911	(none)	(none)

CHAPTER 4

SUMMARY AND CONCLUSIONS

Duke Energy conducted a 12-month study to estimate species, numbers, and sizes of fish entrained during the generation and pumping modes of operation at the JPSS. This study was conducted primarily during a regional drought when water levels in Lake Jocassee were well below full pond (> 20 ft) and water levels in Lake Keowee were about 5 ft below full pond. A previously conducted fish entrainment study at the Bad Creek Pumped Storage Station indicated entrainment of the thermally sensitive threadfin shad was known to increase significantly when Lake Jocassee water levels were > 14 ft below full pond during the coldest months of the year (Barwick et al. 1994). While it remains unknown if a similar pattern of fish entrainment occurred at the JPSS during the 2012-2013 entrainment study, we suspect this may have been the case.

From July 2012 through June 2013, under potentially worst-case conditions, total estimated entrainment at the JPSS was 552,894 fish during generation and 1,519,102 fish during pumping (Chapter 1). Based on purse seine collections in both lakes, these entrained fish were predominantly threadfin shad and blueback herring measuring < 6 in long (Appendix C). Predicted survival of these entrained fish was > 97% (Appendix A) and resulted in a total estimated entrainment mortality of only 13,253 fish during generation and 24,328 fish during pumping.

During the 2012-2013 fish entrainment study, hydroacoustic surveys in November 2012 and March 2013 were conducted to estimate the number of forage fish in Lakes Jocassee and Keowee. In November 2012, 13.1 million forage fish were the estimated in Lake Jocassee and 7.3 million fish in Lake Keowee. Entrainment mortality accounted for only 0.10% and 0.33% of the November 2012 forage fish population estimates in Lakes Jocassee and Keowee, respectively. Due to significant over-winter mortality, forage fish population estimates in Lake Jocassee (7.1 million) and Lake Keowee (2.1 million) were lower in March 2013 than noted during the previous fall. Thus, fish entrainment mortality percentages based on spring population estimates were somewhat higher (0.19% in Lake Jocassee and 1.15% in Lake

Keowee) than noted in the fall, but still appeared insignificant overall. However, regression analyses indicated fall forage fish populations in Lake Jocassee tended to be lower (in Zone 1 and lakewide) during periods of higher generation flows and fall forage fish populations in Lake Keowee tended to be lower (in the Keowee River basin and lakewide) when higher periods of sustained pumping flows were observed at the JPSS.

Even though fish entrainment mortality associated with operation of the JPSS appeared to be minimal in the 2012-2013 study, the statistical analyses of the long-term data collected from these lakes seemed to indicate otherwise. However, these significant negative statistical relations noted for Lakes Jocassee and Keowee forage fish populations and JPSS operations were dependent on data collected in only one year out of a 17-year study period for Lake Jocassee and on only one year out of a 15-year study period for Lake Keowee. Significance in the Lake Jocassee relations was dependent on excluding the 2012 fall data (when the forage fish population estimate was highest noted in recent history) from the analyses. For Lake Keowee, significance in the noted negative relations required including 2000 fall data (forage fish population estimate was one of the highest noted for Lake Keowee during a year when the JPSS operations were curtailed considerably) in the analyses. If the 2000 data were not included in the Lake Keowee analysis, the negative relations between fall forage fish populations and JPSS operations were no longer significant.

Drawing conclusions using relations where significance is dependent on only a single year of data demonstrates a lack of robustness in the data and the results from such analyses should be viewed with caution. Furthermore, Chapters 2 and 3 of this report indicate several other factors (e.g., severe winters, nutrients, chlorophyll, zooplankton, and predation) which also significantly impacted forage fish abundance during this study. Clearly, forage fish populations in Lakes Jocassee and Keowee are dynamic and these dynamics appear to result from intereactions with several parameters that possibly change from year to year. It is this interaction that may confound the statistical analyses associated with determing the impact of JPSS operations on forage fish populations.

Overall, fish mortality associated with entrainment appears to minimally impact forage fish populations in Lakes Jocassee and Keowee. Observed fish kills associated with JPPS operations are rare and the abundance of forage fish in both Lake Jocassee and Lake Keowee is similar to estimates noted in other nearby conventional hydroelectric reservoirs with similar levels of fertility. Furthermore, largemouth bass (a resident sport fish predator) in both Lakes Jocassee and Keowee demonstrate good to excellent relative weights (which are indicative of adequate prey) (Rankin and Hayes 2006, 2007, 2008). It should also be noted five state record fish (spotted bass, smallmouth bass, redeye bass, brown trout, and rainbow trout) have been caught from Lake Jocassee and one (yellow perch) from Lake Keowee (SCDNR 2013). These lakes continue to support viable sport fisheries and fishing continues to be one of many reasons for visiting Lakes Jocassee and Keowee.

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APPENDICES

APPENDIX A

DESKTOP STUDY OF ENTRAINMENT SURVIVAL

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

FERC NO. 2503

NORMANDEAU PROJECT NUMBER 22677.004

October 2013

DESKTOP STUDY OF ENTRAINMENT SURVIVAL

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

FERC NO. 2503

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October 2013

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APPENDIX A

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ABBREVIATIONS AND DEFINITIONS

ADCP	acoustic Doppler current profiler
cfs	cubic feet per second
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
ft	feet
ft/s	feet per second
GPS	global positioning system
ILP	Integrated Licensing Process
JPSS	Jocassee Pumped Storage Station
kPa	kilopascals
in.	inches
L/s	body lengths per second
m	meter
min	minute
MSL	mean sea level
NRC	Nuclear Regulatory Commission
PAD	Keowee-Toxaway Project Preliminary Application Document
Project	Keowee-Toxaway Project
psi	pounds per square inch
rpm	revolutions per minute
s	second
tailwater	JPSS tailwater in upper Lake Keowee
USACE	U.S. Army Corps of Engineers

EXECUTIVE SUMMARY

As part of the FERC Integrated Licensing Process (ILP) Study Plan for the Keowee-Toxaway Project (FERC No. 2503) Relicensing, Duke Energy has conducted an entrainment evaluation using fixed-aspect hydroacoustics to estimate fish entrainment rates, abundance, and fish size at the Jocassee Pumped Storage Station (JPSS).

The purpose of this report is to supplement the empirical estimation of turbine entrainment with predicted survival for fishes entrained by JPSS so that a more complete assessment of impact may be considered.

The potential for survival of entrained fish was qualitatively assessed based on EPRI data in consideration of station characteristics and the target species. Overall, passage survival was characterized as moderate-high for JPSS based on the qualitative review, but model calculations yielded high probabilities of survival. Given there are many empirical studies documenting the importance of fish size relative to the size of the turbine unit of interest, it is apparent a high proportion of the size fish being entrained at the JPSS survive passage.

1.0 INTRODUCTION

As part of the FERC Integrated Licensing Process (ILP) Study Plan for the Keowee-Toxaway Project (FERC No. 2503) Relicensing, Duke Energy has conducted an entrainment evaluation using fixed-aspect hydroacoustics to estimate fish entrainment rates, abundance, and fish size at the Jocassee Pumped Storage Station (JPSS).

The purpose of this report is to supplement the empirical estimation of fish entrainment with estimates of survival for the various sizes of fishes entrained by JPSS so that a more complete assessment of impact may be considered.

2.0 SITE DESCRIPTION

The JPSS, part of the Jocassee Development, is located on the Keowee River approximately 20 miles north of Seneca, South Carolina. The JPSS is adjacent to the Jocassee Dam, which separates Lake Jocassee (upper impoundment) from Lake Keowee (lower impoundment) (Figure 1). The Jocassee main dam is 385 ft high and 1,800 ft long. The powerhouse includes four reversible turbines that facilitate the re-use of water for generation of electricity. During generation, water from Lake Jocassee flows downstream through the turbines. During pumping, the units are reversed to pump water from Lake Keowee to Lake Jocassee for later hydroelectric generation when power demands are relatively high (Duke Energy 2011, Keowee-Toxaway Project No. 2503, Preliminary Application Document, PAD). In the upper impoundment, JPSS has two radial intake towers with eight intake bays each for water withdrawal (Figure 1). The JPSS discharge structure in the tailwater has three discharge bays per unit at a nominal depth of 43 – 66 ft (13 – 20 m, ceiling to floor) below full-pond elevation. Table 1 contains relevant pump back turbine specifications and operations information. Pump back operations are primarily on weeknights and weekends, but are not regulated to time of day.

3.0 TARGET SPECIES BIOLOGY

3.1 Species Composition and Target Species Relative Abundance

Pelagic schooling species expected to comprise the majority of entrained fish at JPSS include Threadfin Shad (*Dorosoma petenense*) and Blueback Herring (*Alosa aestivalis*). Threadfin Shad were intentionally stocked into Lakes Keowee and Jocassee from the Cooper River, South Carolina in the early 1970's by the South Carolina Wildlife and Marine Resources Department to provide forage for sport fish, and it is believed that juvenile anadromous Blueback Herring were inadvertently stocked into the reservoirs along with the Threadfin Shad. Subsequently, it was determined that both species established reproducing populations in the reservoirs, and that the Blueback Herring populations were then lake-locked (Prince and Barwick 1981).

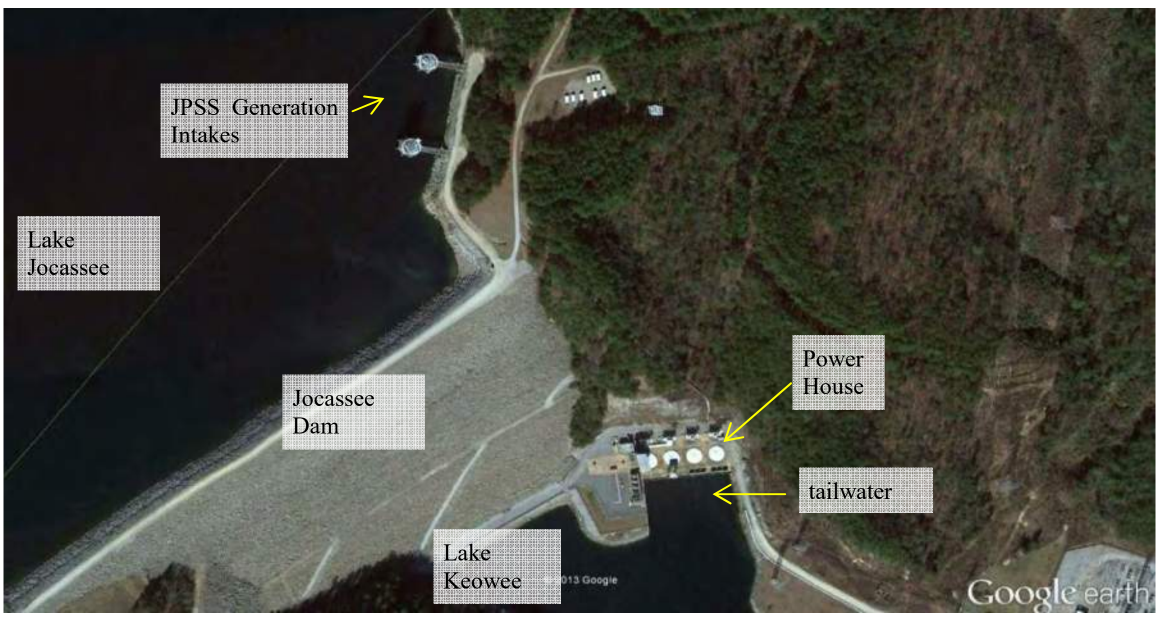

Figure 1. Aerial view of the Jocassee Pumped Storage Station.

Table 1. Turbine specifications of Jocassee Pump Storage Station Turbines 1-4.

Turbine Characteristics		Generation	Pumping
Turbine Type (No's 1 – 4):		Francis reversible pump	
No. of Buckets:		9	
Runner Diameter (ft):	inlet	24.33	17.5
	outlet	17.5	24.33
RPM:		120	
Head (ft):		316	301
Hydraulic Capacity (cfs):		9,050 (7,500 cfs best efficiency)	7,050

Mobile hydroacoustic techniques were used to estimate pelagic fish abundance in spring (March) and fall (November or early December) in both Lake Keowee and Lake Jocassee. Abundance estimates were made in Lake Keowee from 1999 through 2013 and in Lake Jocassee from 1989 through 2013. Additionally, species composition of pelagic fish was determined in conjunction with fall surveys using a purse seine (122-m x 9-m, 4.8-mm mesh) (Barwick et al. 2007 as cited in PAD, Duke Energy unpublished data). Purse seine data collected during September and November 2012 and March 2013 in upper Lake Keowee and in the JPSS forebay in Lake Jocassee indicated that Threadfin Shad dominate the species composition in September, but the November and March samples were clearly dominated by Blueback Herring (Duke Energy unpublished data). In Lake Keowee that shift resulted from a migration of the Threadfin Shad downstream with winter abundance centered in the areas influenced by thermal discharge from the Oconee Nuclear Station (H. Barwick, Duke Energy, personal communication). Length ranges of Blueback Herring and Threadfin Shad overlapped and modal lengths increased over the period sampled from around 2.56 – 2.76 in. in September, 2.76 – 3.15 in. in November, and 3.07 - 3.78 in. in March (Table 2).

Table 2. Summary of Blueback Herring and Threadfin Shad collections by purse seine in upper Lake Keowee and the Jocassee Pumped Storage Station forebay (Lake Jocassee), September and November 2012 and March 2013.

Month	Lake	N. Blueback Herring	N. Threadfin Shad	Length (mode and range, in.), Blueback Herring	Length (mode and range, in.), Threadfin Shad
September 2012	Keowee	28	245	2.76 (2.16-3.15)	2.76 (2.16-3.74)
	Jocassee	258	9	2.56 (1.97 – 4.53)	2.76 (1.77-4.33)
November 2012	Keowee	100	294	3.15 (2.36-4.33)	2.95 (2.56-4.72)
	Jocassee	421	1	2.95 (2.16–6.10)	2.76
March 2013	Keowee	270	8	3.74 (2.44-5.43)	3.07* (2.68-3.74)
	Jocassee	247	0	3.78 (2.99-5.47)	NA

* all lengths were unique; median was substituted for mode.

Studies pursuant to Duke Energy's ILP study plan were conducted to characterize entrainment of fish by JPSS using split-beam hydroacoustic techniques (Aquacoustics, Inc. 2013). The estimated length of tracked fish ranged from 2 – 30 in. and entrained fish composition was generally dominated by small fish (Figure 2). In pumping operations, 86% of entrained fish overall were < 6 in. In generation operations, lengths were more variable with 71% overall < 6 in. and 81% < 8 in.

3.2 Swimming Speed

For individuals susceptible to entrainment and impingement at water intakes, avoidance of the intakes is related to fish size and swimming performance (Castro-Santos and Haro 2005). Three swim speed modes are generally recognized for fishes, though terminology differs slightly among authors. Sustained swim speed is that which can be maintained for an indefinite period (longer than 200 minutes) and does not involve fatigue; prolonged swim speed can last between 15 seconds and 200 minutes and if maintained will end in fatigue; burst swim speed is characterized by rapid movements of short duration and high speed, maintained for less than 15 seconds (Beamish 1978). Laboratory testing of prolonged swim speeds for specific time intervals results in estimates of critical swim speed (U) accompanied by a time stamp (e.g., $U_{crit\ 2}$ = maximum prolonged speed for 2 minutes). Burst or sprint swim speeds (also startle, fast-start, or dart) are the fastest attainable and are generally associated with fish well-being or survival (Beamish 1978; Wardle 1980), as they are also related to a fish's ability to capture prey, avoid predators, or in the present case, avoid water intake velocities or structural elements.

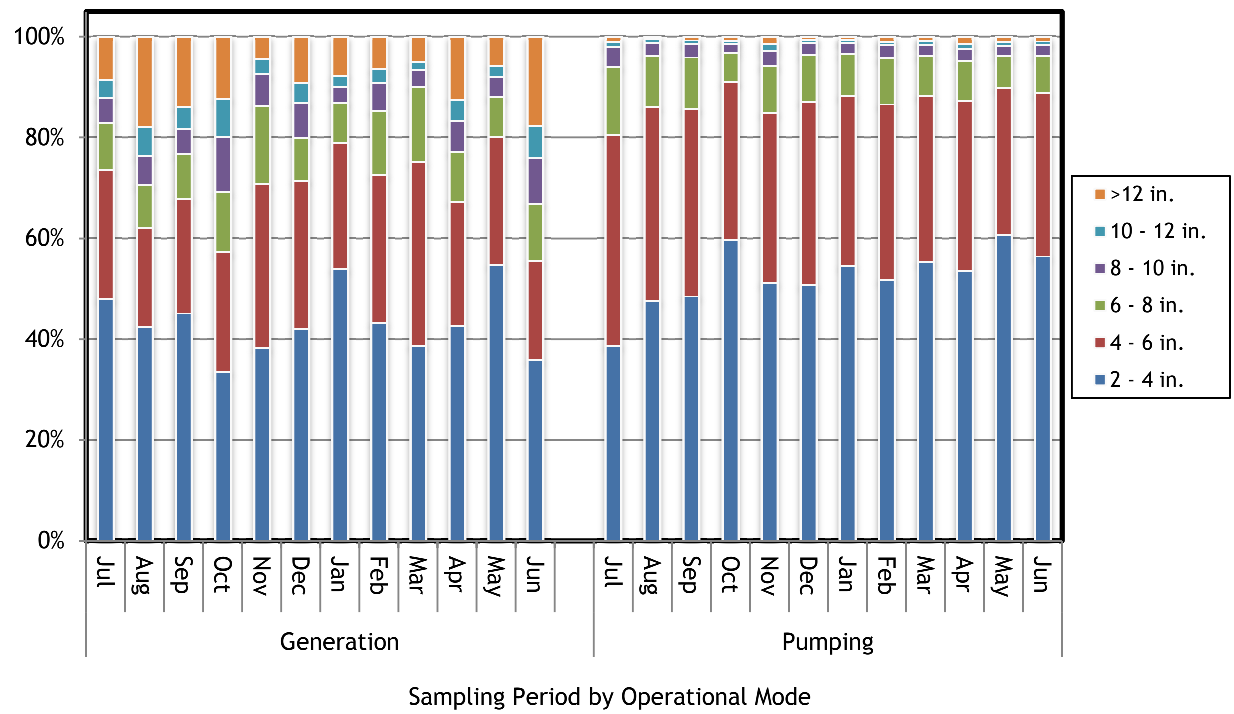

Figure 2. Length frequency distribution of fish entrained by the Jocassee Pumped Storage Station (preliminary data) by sampling period (month) and operational mode for July 2012 – June 2013 (Unpublished data, Aquacoustics, Inc., Sterling, Alaska).

Utilization of burst swim speed to avoid water intakes also implies the ability to use additional sensory mechanisms to properly detect and orient to the intake. Available stimuli near an intake, in addition to the physical structure, include factors such as turbulence, flow acceleration, pressure changes, and sound (Bell 1991; Castro-Santos and Haro 2005). The ability to utilize available cues to avoid intake structures or flow fields may be compromised by darkness, turbidity, or reduced swimming ability at water temperatures approaching or exceeding cold water tolerances. Swim speeds determined in the laboratory are typically measured by a distance rate (ft/s) for a given fish length range or measure of length central tendency (mean or median lengths). However, in recognition of the role of fish size in swim performance, information on burst swim speed may also be expressed as fish body lengths per second (L/s), termed "relative burst speed." Smaller fish typically have a higher relative swim speed (greater L/s) than larger fish, even though the absolute swim speed (ft/s) of larger fish is greater (Beamish 1970).

Relatively little information regarding burst swimming speeds has been published for the target species, Threadfin Shad and Blueback Herring. However, consideration of reported information as well as cautious use of information for closely related species (Alewife, *A. pseudoharengus* as a surrogate for Blueback Herring; Gizzard Shad, *D. cepedianum* as a surrogate for Threadfin Shad) provides insight (Table 3). Based on available data and other published studies (e.g., Nestler et al. 2002) an expected maximum burst speed of Blueback Herring is approximately 12 body-lengths/s. For the modal lengths documented from the purse seine data, 2.6 – 3.1 in. (65 – 80 mm), burst swimming speed = 2.5 – 3.1 ft/s (0.78 – 0.96 m/s). Alternatively, Richardson (2004) estimated burst swimming speeds to be 2 – 2.6 x the prolonged swimming speed. U_{crit} values presented in Table 3 for juvenile Blueback Herring and Alewife at sizes similar to the observed length modes from purse seine data ranged from approximately 0.75 – 1.6 ft/s (0.23 – 0.5 m/s). Converting that range based upon Richardson's calculation, yields estimated burst speeds of 1.5 - 4.3 ft/s (0.46 – 1.3 m/s). Note that the use of these swim speeds are liberal since they represent modal lengths. Smaller fish within the size frequency distribution would have proportionally reduced burst swimming capabilities.

4.0 ESTIMATES OF SURVIVAL

Factors that can influence fish survival during turbine passage included:

- Turbine type - Among factors related to passage survival, the size of water passage spaces available relative to fish size influences susceptibility to contact with structural elements.
- Turbine speed - The likelihood of fish contact with structural elements increases as the turbine speed (rpm) increases.

Table 3. Compilation of swimming speeds for Blueback Herring, Threadfin Shad, and surrogate species.

Species	Life Stage	Length (in.)	Burst or Startle Speed (ft/s)	U_{crit} or sustained (S) (ft/s)	Source
Blueback Herring	juv.	3.35 (FL)		0.75	Richardson (2004) citing Terpin et al. 1997 in EPRI (2000)
		3.50 (FL)		1.14	Richardson (2004) citing Terpin et al. 1997 in EPRI (2000)
	adult	8.07 (FL)	8.20		Richardson (2004) citing Castro-Santos (2002)
Alewife	juv. – adult	2.0, 3.9, 5.9		1.41, 1.61, 1.74	Peake (2008) citing Griffiths (1979)
	juv	5.35 (FL)		2.09	Richardson (2004) citing Wyllie et al. (1976) in EPRI (2000)
	juv.	5.39 (FL)		1.17	Richardson (2004) citing King (1971b) in EPRI (2000)
	juv.	1.81-5.91 (FL)		1.40-1.76	Richardson (2004) citing Griffiths (1979) in Katopodis and Gervais (1991)
	adult	11.02 (SL)	15.52		FishBase (www.fishbase.org), citing Sambilay (1990)
	adult	10.67-12.28 (TL)	13.62-15.91		Beamish (1978) citing Dow (1962)
	adult	9.25 (FL)	11.15		Haro et al. (2004)
	adult	8.86 (FL)	9.19		Richardson (2004) citing Castro-Santos (2002)
Herring spp.	adult	5.98–11.02 (FL)	6.56		Estimated from Bell (1991)
Gizzard Shad	juv.	0.98-1.97		0.75 (S)	Normandeau (2009)
	juv.			2.8 (S)	Normandeau (2009) estimated from Williamson and Nelson (1985)
	adult	9.84-13.78 TL	8		Normandeau (2009)

- Pressurized intake tunnel - High hydrostatic pressure in penstocks at high-head sites may be suddenly released as fish acclimated to higher pressure pass from pressurized areas or deep water to tailwaters at normal hydrostatic pressure. The sudden relief from high pressure increases the risk to fish of decompression trauma.

- Fish size - More than 90% of fishes entrained at hydro projects are small (EPRI 1997). High survival of small fish (< 8 in) reduces the overall impact of entrainment to fish populations.

4.1 EPRI Source Data

Numerous investigations of fish turbine passage survival have been conducted, providing a considerable dataset from which a qualitative approach to assessing turbine passage survival at JPSS was developed. Winchell et al. (2000) summarized turbine passage survival data reported in the EPRI (1997) database by turbine type and characteristics and fish size. The survival rates reported represented field tests at up to 19 turbines per size class of test fish that met specific acceptability criteria for control fish mortality (could not exceed 10%). Those data were reproduced herein for the Francis type turbine used at JPSS (Table 4). JPSS contains four reversible turbines with 9 buckets and 120 rpm rotation. Winchell et al. (2000) treated Francis units rotating slower than 250 rpm as low-speed turbines. Immediate and 48-hour survival rates were reviewed. Immediate survival data were available for up to 19 turbine tests; 48-hour survival data were available for up to 17 turbine tests. The mean rates were reported irrespective of local site conditions such as shallow or deep intakes or tailrace configuration that could affect ultimate fish survival after turbine passage. Additionally, the survival rates were reported for all species combined. The data suggest that fish size relative to the volume of the turbine passage way is more important than species *per se* when assessing fish survival potential (Franke et al. 1997, Winchell et al. 2000).

The principal survival trend among the reviewed studies of Francis type turbines was higher survival for small fish (generally those less than 8 in.) and for passage through turbines with rotational speeds less than 250 rpm. For fish less than 8 in., mean immediate survival rates ranged between 91.6 and 93.9% for low-speed turbines. Mean survival for passage of large fish through low-speed turbines ranged from 73.2% for fish greater than 12 in. to 86.9% for fish between 8 and 12 in.

The number of turbine studies with 48-hour survival rates is lower than studies with immediate survival rates because the latent mortality holding period in some studies did not extend to 48 hours and more tests were excluded based on low control group survival (<90%). For small fish (less than 8 in.), survival after 48-hours was about 4% lower (mean of 90.4 to 87.8%) than the immediate survival estimate for turbines with rotational speeds less than 250 rpm. For larger fish (between 8 and 12 in.) 48-hour survival was 8 to 9.5% lower (mean of 80.4 to 66.8%).

Table 4. Emperical immediate and 48-hour fish survival rates for representative fish sizes passing Francis turbines (Winchell et al. 2000).

Turbine Type	Runner Speed (rpm)	Hydraulic Capacity (cfs)	Fish Size (in)	Number of Studies	Average Immediate Survival All Species (%)			Survival Potential
					Minimum	Maximum	Mean	
Francis (radial-flow)	<250	440-1,600	<3.9	13	85.9	100	93.9	Moderate-High
		370-1,600	3.9-7.8	19	74.8	100	91.6	Moderate-High
		370-2,450	7.9-11.8	18	59	100	86.9	Moderate
		440-1,600	>11.8	14	36.1	100	73.2	Low

Turbine Type	Runner Speed (rpm)	Hydraulic Capacity (cfs)	Fish Size (in)	Number of Studies	Average 48 Hour Survival All Species (%)			Survival Potential
					Minimum	Maximum[1]	Mean	
Francis (radial-flow)	<250	440-1,600	<3.9	11	80.9	101.1	90.4	Moderate-High
		370-2,450	3.9-7.8	17	73.7	101.8	87.8	Moderate
		440-2,450	7.9-11.8	15	47.4	96.4	80.4	Low-Moderate
		440-1,600	>11.8	13	33.8	94.1	66.8	Low

[1]When the survival of treatment groups is higher than controls, the adjusted survival estimates exceed 100%.

4.2 Predicted Survival

Passage survival for fish passing through the JPSS turbines was analyzed using the formula developed by Franke et al. (1997). The formula was developed as part of a larger project by the Department of Energy (DOE) to design more "fish-friendly" turbines. The formula developed by Franke et al. (1997) to estimate survival through a Francis turbine and used to predict survival at JPSS was:

$$P = \lambda\left(\frac{N * L}{D}\right)\left[\frac{\sin\alpha_t\left(\frac{B}{D_1}\right)}{2Q_{\omega d}} + \frac{\cos\alpha_t}{\pi}\right]$$

S = 1 – P where,

λ = Blade strike correlation factor

N = Number of buckets

L = Fish length

D = Diameter of runner

α_t = Angle to tangential of absolute flow upstream of runner

B = Runner height at inlet

D1 = Diameter of runner at inlet

$Q_{\omega d}$ = Discharge coefficient = $(Q/\omega D^3)$

In developing the formula, Franke et al. (1997) considered previous works that calculated turbine strike probability and new information developed by the authors. Existing empirical data were used to validate the model for conventional hydro projects. A thorough discussion of the derivation and application of the formulas is provided in Franke et al. (1997).

The formula calculates the probability (P) of blade strike by relating such turbine parameters as the number of buckets, runner diameter and height, and operating condition to fish length (see Table 1 for turbine specifications). Although the formula calculates a probability, in the present context it is more conventionally used with results expressed as a survival percentage where survival (S) = 1 – P.

Fish length and available passage space are the principal drivers of the output. For estimates of survival at JPSS, eight representative fish lengths (from 2 to 24 in) were evaluated. For pumping operations, one operating condition was used: maximum unit hydraulic capacity = 7,050 cfs. For generation operations, two operating conditions were used: maximum per unit hydraulic capacity = 9,050 cfs, and per unit hydraulic capacity at best turbine efficiency = 7,500 cfs. Two correlation factors (lambda), used to account for variability in strike potential and to relate the output to empirical data available to the Franke study, were selected for both generating and pumping operating modes: 0.10 and 0.15. Values of lambda in the range of 0.1 to 0.2 were determined by Franke et al. (1997) from Kaplan turbine survival tests.

Estimated survival for generation and pumping operations were essentially the same. Survival estimates for all simulated scenarios were high (≥88.6%, Table 5).

Table 5. Predicted survival of entrained fishes based on Franke et al. (1997) for Jocassee Pumped Storage Station reversible turbines during generation and pumping.

Operation	Discharge (cfs)	Correlation Factor (λ)	Predicted Survival (%) by Fish Length (in)							
			2	4	6	8	10	12	18	24
Generation	9,050 (max)	0.10	99.3	98.7	98.0	97.4	96.7	96.0	94.0	92.1
		0.15	99.0	98.0	97.0	96.0	95.0	94.0	91.1	88.1
	7,500 (best efficiency)	0.10	99.4	98.7	98.1	97.5	96.8	96.2	94.3	92.4
		0.15	99.0	98.1	97.1	96.2	95.2	94.3	91.4	88.6
Pumping	7,050 (max)	0.10	99.4	98.8	98.1	97.5	96.9	96.3	94.4	92.6
		0.15	99.1	98.1	97.2	96.3	95.4	94.4	91.6	88.8

4.3 Potential for Pressure Effects on Survival

Fish passing through a turbine experience pressure changes over a short period. In a conventional hydroelectric facility pressure increases as a fish descends to the upstream side of the runner, drops rapidly upon passing the runner, increases in the draft tube, and then returns to near atmospheric pressure at the surface of the tailrace, or greater pressures if the fish swims to deeper water (Figure 3). This sequence of pressure change is similar at a pump-storage project during the generation phase. During the pumping phase of a pump-storage project, a fish would experience a slight increase in pressure approaching the runner, a rapid pressure decrease through the runner, and then an increase while traveling to the upper reservoir before returning to near atmospheric pressure when the fish surfaces in the storage reservoir. The amount and rate of change in pressure and the capability of fish to adapt to the change are important factors in determining whether such a pressure change may have any physical effects on fish.

Among fish with swim bladders, the response to rapid pressure changes encountered within a turbine is a function of whether the fish is physostomous or physoclistous. Physostomous fish (including Blueback Herring and Threadfin Shad) have a pneumatic duct that connects the swim bladder with the esophagus. Gas can be quickly taken into or vented from the swim bladder through the mouth and pneumatic duct, so that adjustment to changing water pressures can take place rapidly, often on the order of seconds. Physoclistous fish lack a direct connection between the swim bladder and the esophagus. In these fish the contents and pressures within the swim bladder must be adjusted by diffusion into the blood, a process measured on the order of hours.

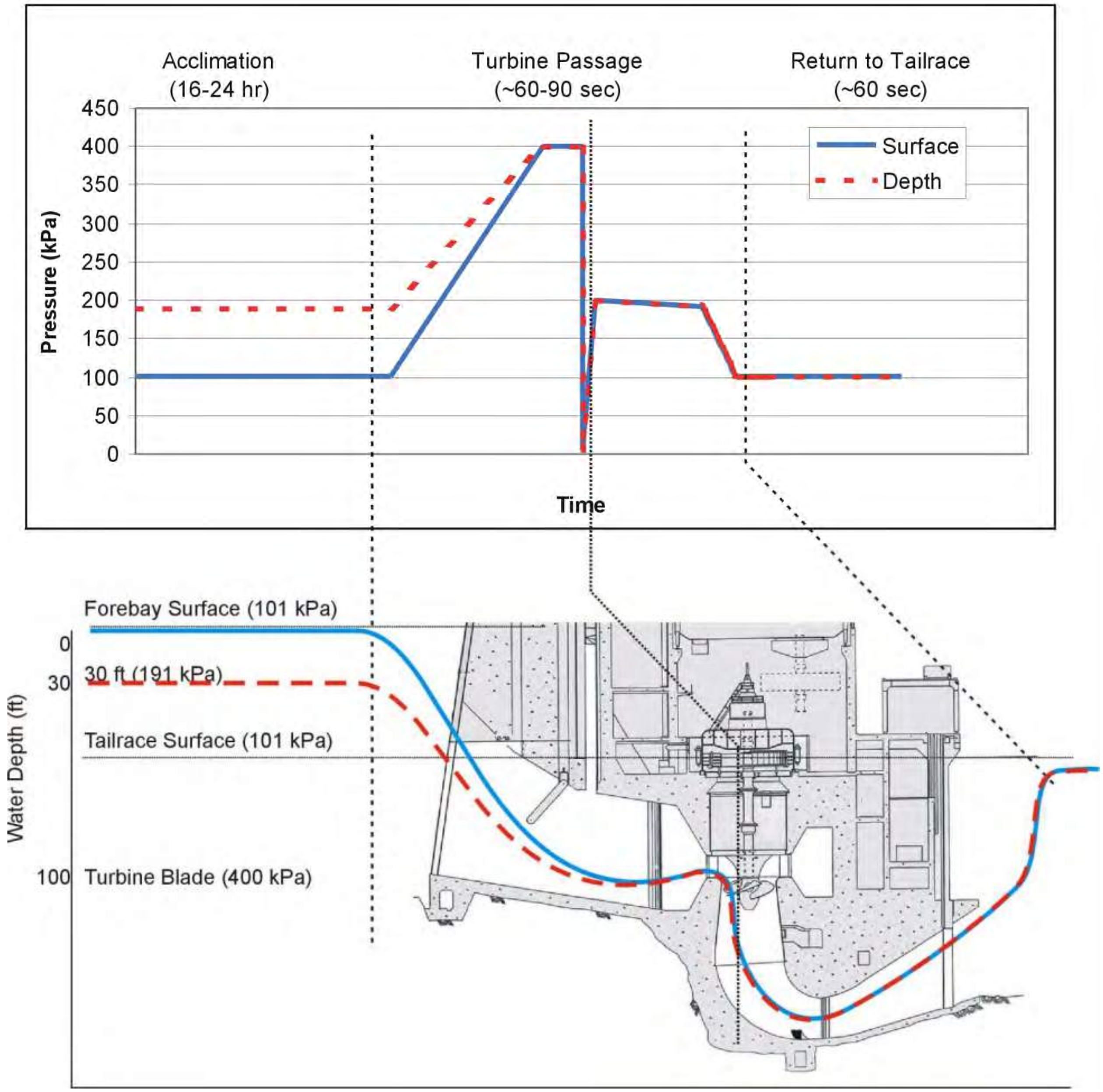

Figure 3. Laboratory simulated surface (101 kPa) and 30 ft depth (191 kPa) acclimation and pressure profile for a fish passing a conventional Kaplan turbine. Pressure increases as the fish's depth increases. Pressure spike occurs as fish pass the turbine blades. Pressures then return to surface pressure as fish pass through the draft tube and enter the tailrace. (Source: Abernethy *et al*. 2001).

Laboratory studies have tested the effect of pressure on fish in pressure chambers. In a review of laboratory controlled pressure studies, Cada et al. (1997) concluded that pressure increases of the magnitude found in hydroelectric turbines are unlikely to injure or kill entrained fish, although some (e.g., Brown et al. 2012) have used laboratory tests to suggest that pressure changes may be a problem for migrating fish that must pass multiple turbines. Reliable field studies using fish acclimated to depth have not been conducted.

Rapid, brief pressure increases caused little or no direct mortality in several studies using a variety of fish that included physostomous and physoclistous species. For example, Foye and Scott (1965) exposed five physostomous fishes: Chain Pickerel, Fallfish, Common Shiner, Lake Trout, and Atlantic Salmon, and one physoclistous species: Yellow Perch, to instantaneous pressure increases up to 2,064 kPa (300 psi), followed by decompression back to atmospheric pressure (1 atmosphere = 101.325 kPa = 14.696 psi) over a 10-min period. No mortality was observed among salmon, Lake Trout, or Fallfish over the subsequent 7-day holding period. Long-term mortalities among the other three species showed considerable variation, but inadequate controls precluded a quantification of mortality or a determination that mortality among test fishes was caused by the pressure increases.

Fish appear to be more sensitive to decreasing pressure. The pressure decreases that fish experience within the runner occur rapidly. The nadir, or lowest pressure a fish may be exposed to depends on where the fish passes the runner. The lowest pressure occurs on the suction side (vs. pressure side) of the blade. Barotrauma may occur in fish when they are exposed to rapidly decreasing pressures. Gas bubbles can develop in the fins and blood vessels may rupture. Gas in the swim bladder expands during decompression and can lead to swim bladder rupture or compression-related injuries caused by an expanded swim bladder compressing against internal organs. For both physoclistous and physostomous fish, the depth of acclimation (depth before turbine passage) prior to decompression relative to the pressure of exposure influences the magnitude of barotraumas.

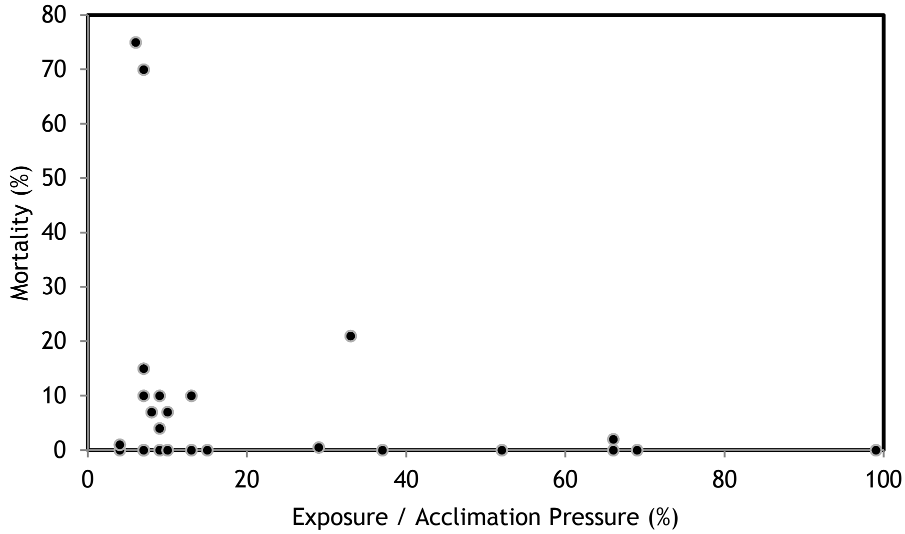

Figure 4. Mortality rate (%) by the ratio of exposure pressure to acclimation pressure induced in laboratory chambers for several physostomous fish species. Data synthesized from Muir 1959, Harvey 1963, Turnpenny et al. 1992, Abernethy et al. 2001, Brown et al. 2009, Stephenson et al. 2010.

Data synthesized from laboratory studies exposing physostomous species to rapid and brief pressure reductions in test chambers indicated mortality was generally low, and especially low when minimum exposure pressure was more than 35% of acclimation pressure (Muir 1959, Harvey 1963, Turnpenny et al. 1992, Abernethy et al. 2001, Brown et al. 2009, Stephenson et al. 2010; Figure 4). Assuming the nadir pressure through the JPSS turbines is similar to or less than the calculated nadir pressure for the Shasta Project (95 kPa), based on the lower head, slower speed, and fewer buckets at JPSS, and given the JPSS intake depth (43 – 66 ft.), the ratio of exposure to acclimation pressure would range from about 41 to 32% (Table 6). Decompression related mortality is expected to be low for target species acclimated from the surface to the full depth of the intakes, and even for fish acclimated to higher pressure the potential of mortality would likely remain low for physostomous fish such as Blueback Herring and Threadfin Shad. The effect of pressure related mortality is expected to be similar or less during pump-back compared to generation. If significant decompression induced mortality of Threadfin Shad or Blueback Herring was occurring at JPSS, given the abundance of these species, the mortality would be evident in the tailwaters. RMC (1992) conducted a year-long entrainment study at the Youghiogheny Dam in Pennsylvania. Significant decompression induced mortality occurred to Alewife passing through the U.S. Army Corps of Engineers flood control outlet pipe through the dam due to severe decompression trauma as fish entrained through the outlet pipe passed the control gate within the pipe (above the control gate the pipe was pressurized and on the downstream side of the control gate the pipe was not pressurized). The mortality to the Alewife of various sizes was readily observable in the tailrace.

Table 6: Exposure pressure relative to acclimation pressure for fish acclimated to four depths and exposed to the nadir pressure (95 kPa) calculated for the Shasta Project turbine (Bell 1991).

Depth	Acclimation Pressure (kPa)	Exposure Pressure (kPa)	Exposure/ Acclimation pressure (%)
10	131	95	72
20	161	95	59
43	229	95	41
66	297	95	32

5.0 CONCLUSIONS

For entrained fish, passage survival was considered to be moderate-high for small (< 4 in.) and medium (4-8 in.) sized fish based on EPRI data. Survival estimates derived for JPSS using the Franke (Franke et al. 1997) model yielded high probabilities of survival. Given that there are many empirical studies documenting the importance of fish size relative to the size of the turbine unit of interest, it is apparent a very high proportion of fish entrained at the JPSS survive passage.

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APPENDIX B

JOCASSEE PUMPED STORAGE STATION FOREBAY AND TAILWATER VELOCITY REPORT

KEOWEE-TOXAWAY PROJECT (FERC NO. 2503)

Prepared for:

DUKE ENERGY CAROLINAS, LLC

CHARLOTTE, NC

Prepared by:

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CHATTANOOGA, TN

JULY 2013

APPENDIX B

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INTRODUCTION

This report fulfills the Federal Energy Regulatory Commission's request (January 27, 2012 Study Plan Determination for the Keowee-Toxaway Hydroelectric Project) for Duke Energy to use an Acoustic Doppler Current Profiler (ADCP) to describe water velocities around the intakes across operational scenarios in order to relate velocity data to historical generation and pumping rates.

SITE DESCRIPTION

The Jocassee Dam and adjacent JPSS are located in Upstate South Carolina (Figure 1). The Jocassee Dam impounds Lake Jocassee (upper pool) and the JPSS releases water downstream into Lake Keowee (lower pool) to generate electricity during periods of peak demand. Unlike a conventional hydroelectric station, the JPSS turbines are reversible (by consuming electricity) and can pump water from Lake Keowee during periods of low demand (e.g., nights and weekends) back into Lake Jocassee for future generation.

Engineered Structures

The identical forebay intakes (A and B) provide water to the hydroelectric turbines via a vertical penstock for each intake. Each penstock bifurcates to provide water to each unit. Intake A provides water to Units 1 and 2, while Intake B serves Units 3 and 4 (Figure 2). The same penstocks provide conveyance of water from Lake Keowee to Lake Jocassee during pumping.

The intakes sit on an excavated berm (Figures 3 and 4) within the epilimnion of Lake Jocassee. The bottom of each intake is at 1043 ft (amsl). Each intake has eight bays, each 17-ft wide and 24-ft high (Figure 4). Lake Jocassee was about 25 ft below full pool when the generation velocity measurements were collected.

The tailwater bays[2] sit on the bottom of an excavated canal at an elevation of 734 ft (AMSL) (Figure 5). The excavated canal is approximately 250-ft wide with a concrete wing wall on the Unit 1 side and a riprap wall on the Unit 4 side (Figure 2). Each unit has 3 discharge bays, each 13.3-ft wide and 23.1-ft high. Lake Keowee was approximately four below full pool at the time pumping velocity data were collected.

[2] Even though the bays serve as intakes during the pumping cycle, they are referred to as the discharge bays

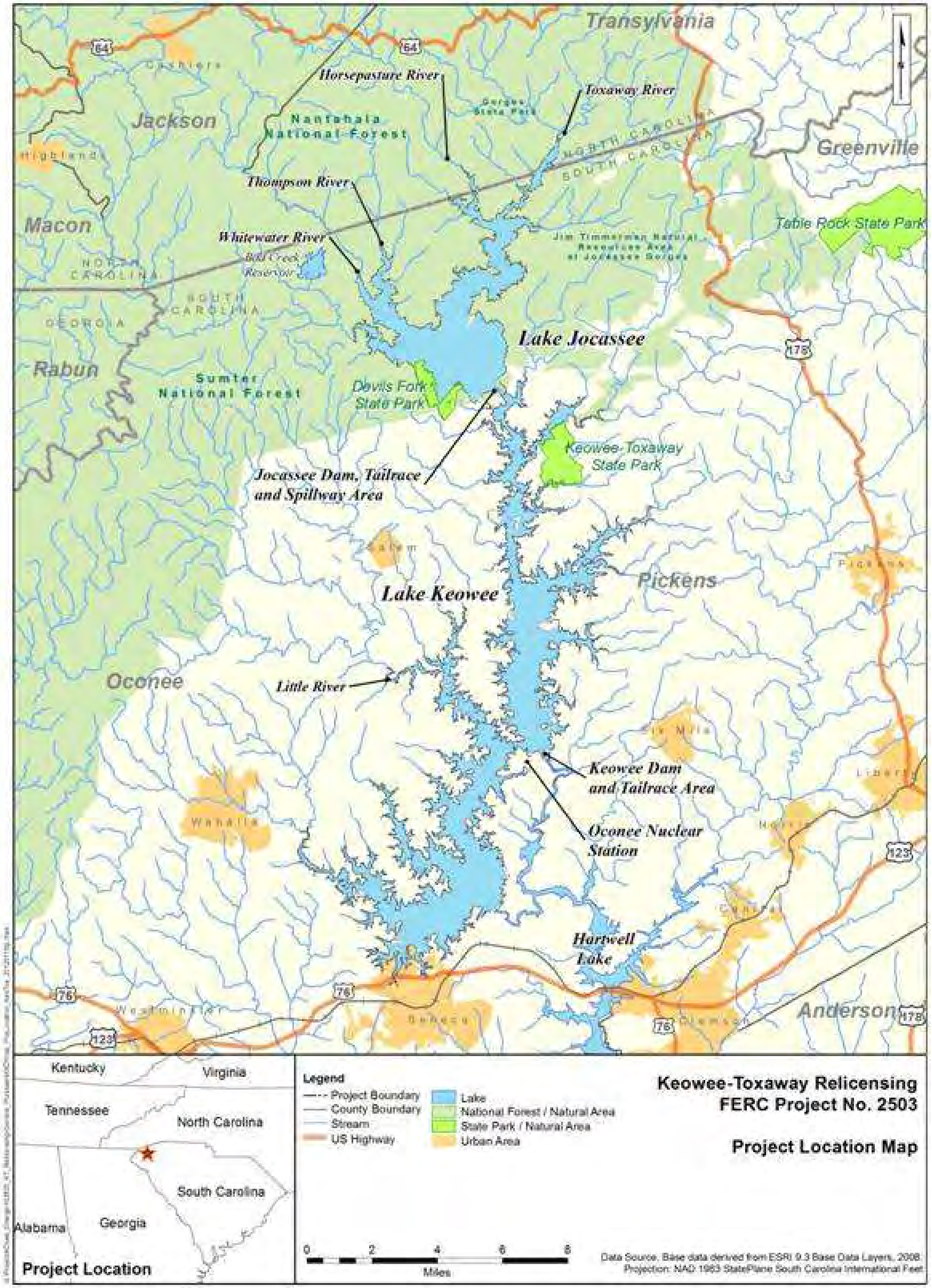

Figure 1. Map of the Keowee-Toxaway Project.

Figure 2. Jocassee Pumped Storage Station complex.

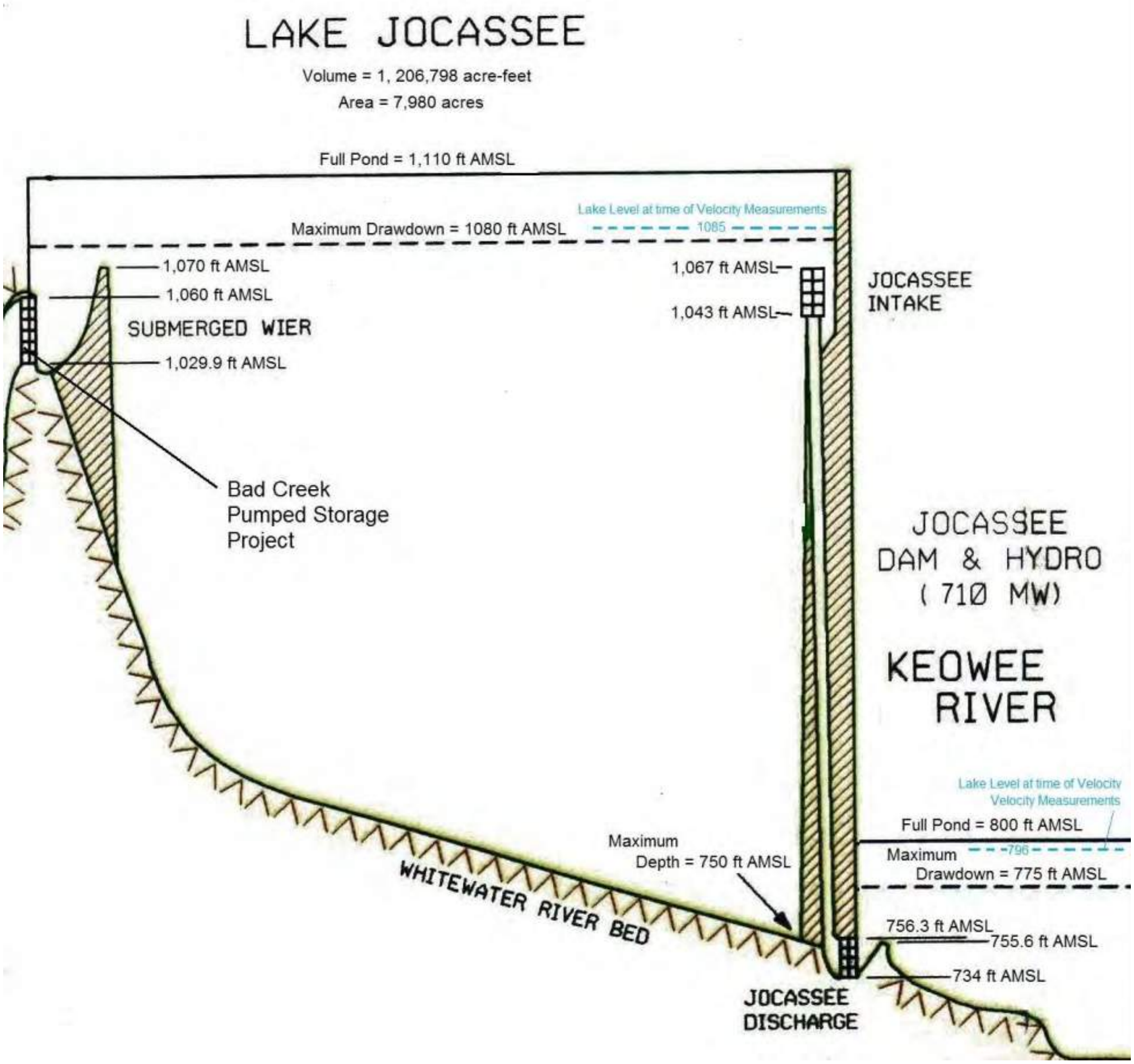

Figure 3. Schematic of Lake Jocassee and elevation (ft amsl) of engineering structures associated with JPSS.

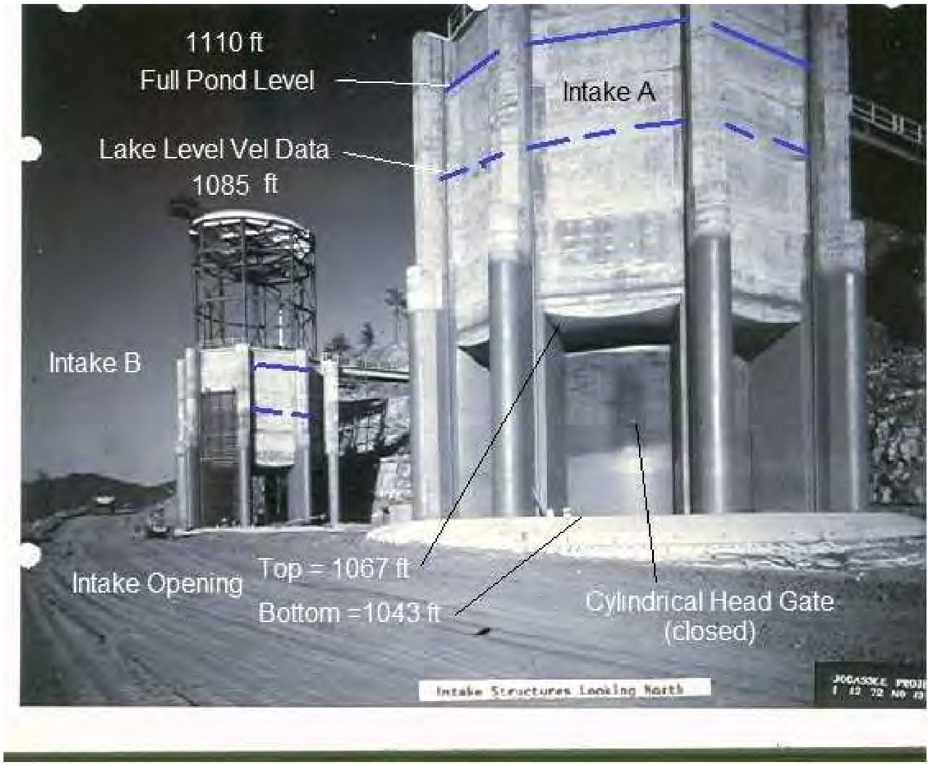

Figure 4. Construction photograph of JPSS forebay intake structures, with elevations.

Figure 5. Construction photograph of JPSS discharge structure, with elevations.

JPSS Operations

Since all of the units were of identical design, the performance, both during generation and pumping, were identical. The amount of electrical generation is primarily a function of gross head (Lake Jocassee level minus Lake Keowee lake level) (Figure 6)[3]. Additional, gross electrical production decreased slightly at the same gross head when two units were sharing a common penstock.

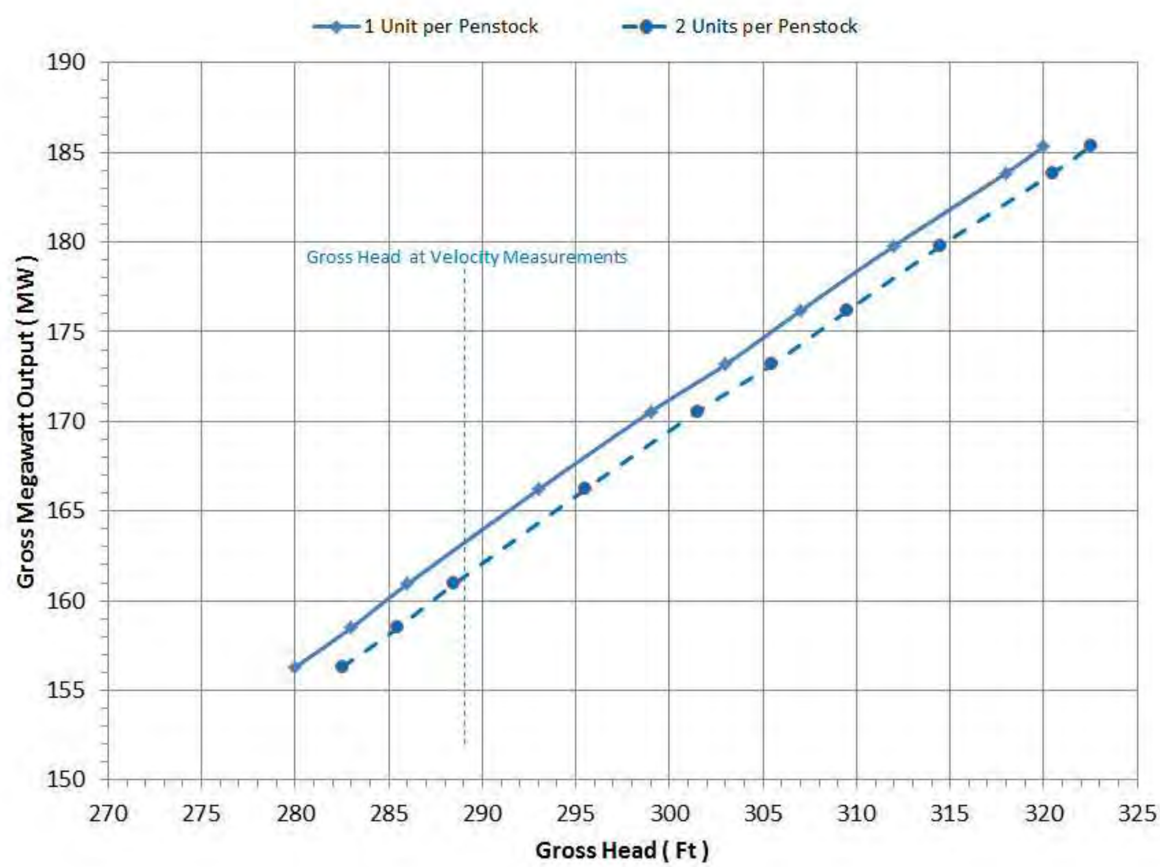

Figure 6. Gross electrical production from JPSS at peak efficiency.

[3] Jocassee Performance data from John Sigmon, HDR, Inc.

Since Duke Energy records gross electrical output and lake levels, the amount of water used for that generation is a function of the design specifications of the units. Efficiency, defined as the amount of water (cfs) needed to generate 1 MW, was a function of Gross Head, 1 or 2 units use of each penstock, and the wicket gate setting (Figure 7). Wicket gate settings range from a minimum setting (design specs) and a maximum setting (design specs). At a point between the two extremes, a wicket setting yeilded optimum efficiency (least water used to generate 1 MW). The result was a 'family' of curves used to calculate water use. The minimum, maximum, and efficiency loads provide the range of operations at a given gross head (Figure 7).

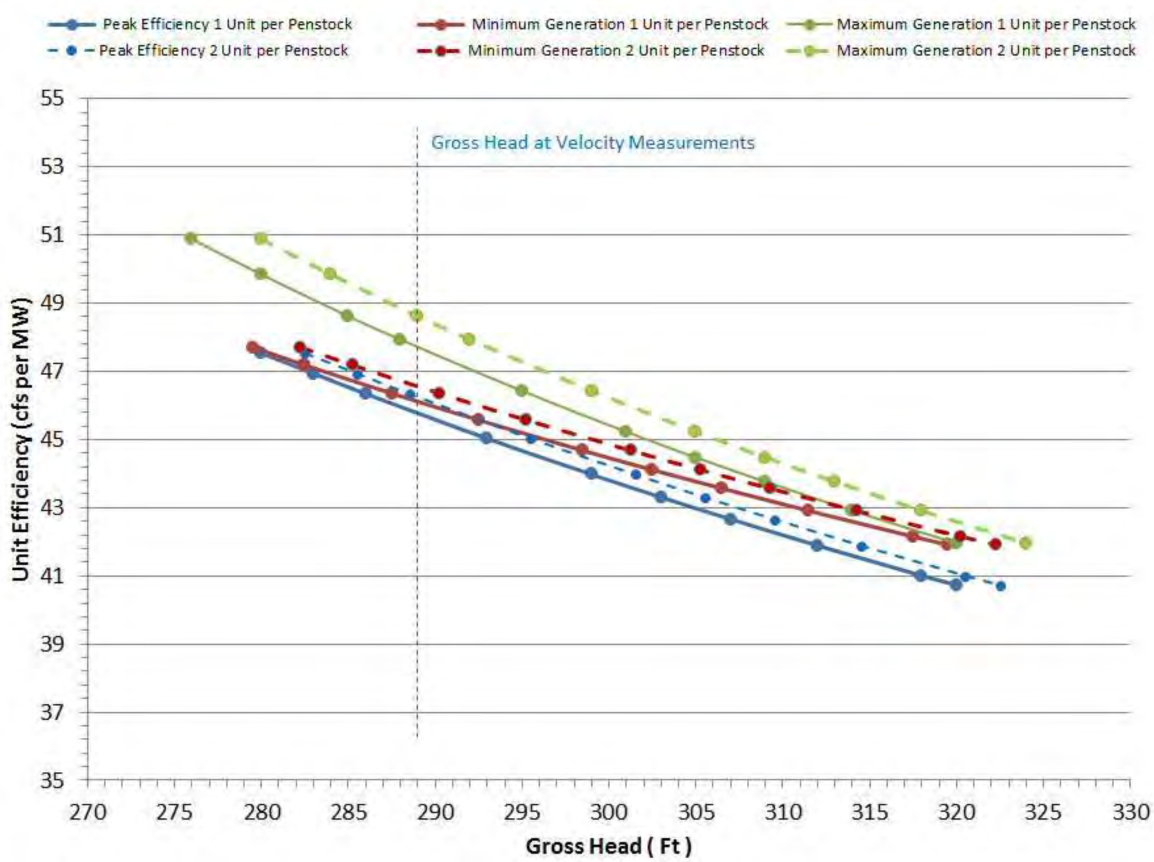

Figure 7. JPSS electrical generation efficiency.

Unlike generation, the wicket gates were in a fixed, open position during pumping. Just like any electrical motor, the amount of water moved to the upper reservoir was a function of the gross head and the amount of energy supplied to the motor. The amount of water moved per MW (Figure 8) decreased as the gross head increased.

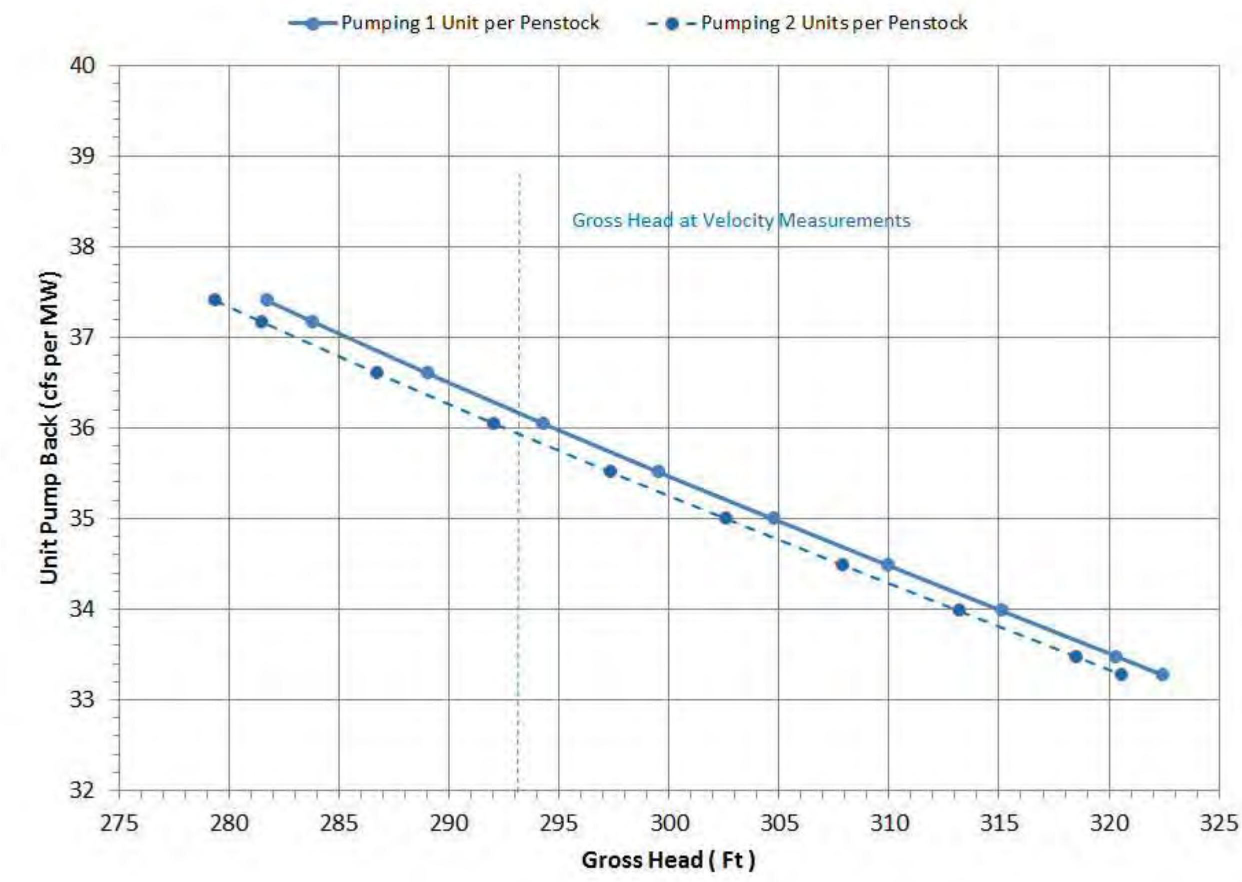

Figure 8. JPSS pumping efficiency.

METHODS

The ADCP used to measure water velocities near the intake towers and in the tailwater near the discharge bays was manufactured by RD Instruments. As described by the manufacturer, 'An ADCP transmits sound bursts into the water column. Suspended particles carried by water currents produce echoes (from these sound bursts) which are "heard" by the ADCP. Echoes arriving later, from deeper in the water column, are assigned greater depths in the echo record. This allows the ADCP to form vertical profiles of current velocity. The ADCP senses in four orthogonal directions simultaneously. Echoes from the particles within the current flow moving towards the instrument exhibit different frequencies from those moving away. This is the Doppler shift, which enables precise measurement of current speed and direction' (www.rdinstruments.com). The ADCP movement, relative to the water, was 'corrected' for movement relative to the earth by an additional 'bottom ping', enabling the water velocities to be earth referenced.

Limitations of an ADCP include:

- Close proximity to structures (sound waves reflect from the structure, preventing velocity calculations)
- Underwater obstructions (sound waves reflect from the obstruction preventing 'bottom ping' corrections)
- Water containing very low concentrations of suspended particles (in Lake Jocassee, the lack of suspended particulate material prevented velocity measures at depths greater than 25 meters)
- High turbulence conditions (and/or excessive water shear) prevent the ADCP from obtaining correlated data to enable velocity calculations
- Sound wave contamination (side-lobe) near the bottom limits the validity of velocity measurements near the bottom

Advantages of an ADCP include:

- Very rapid velocity measurements throughout the water column (a complete water column velocity measurement takes 1.5 – 2 seconds)
- A large amount of water column velocity data enables statistical analysis
- Bottom tracking ('bottom ping') enables water flow (cfs) calculations across a channel transect as well as providing bathymetric data

Data Collection

The intake velocities during various operational scenarios were measured with the 600 kHz Rio Grande® ADCP. This ADCP and a Trimble® AgGPS 132 receiver equipped with an Omnistar real-time differential GPS correction were mounted on a 'boogie board' (Figure 9) and towed by a boat. The GPS / Omnistar system allowed for, at most, a 1 meter error in latitude/longitude measurements. Data were collected by slowly driving the boat while maneuvering the 'boogie board' alongside the boat to collect depth and velocity data. Every attempt was made to get as close as possible to all of the intake openings on each intake structure (see Figure 10). However, there were times when data were not collected due to interference of the structure with the ADCP transducers (e.g. missing data from various quadrats, see Appendix A).

The system for collecting water velocity data in the tailwater was the same as for the intake area except a RD Insturments 600 kHz Broadband® ADCP was used and mounted on a hydraulic lift in the pontoon boat (Figure 11). The Trimble GPS with Omnistar was mounted directly over the ADCP.

For each operational test, velocity data in the JPSS tailwater were collected from four transects each parallel to the discharge structure and at progressively greater distances downstream (Figure 12).

Figure 9. RD Instruments Rio Grande 600 kHz ADCP and GPS mounted on a boogie board.

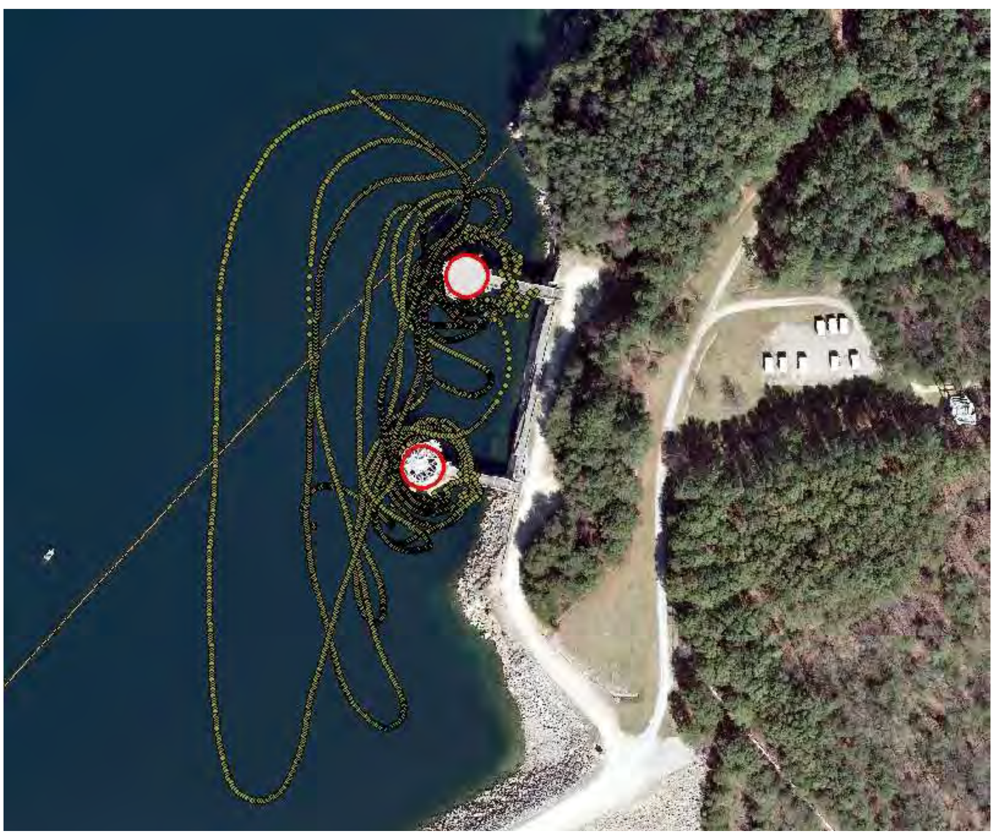

Figure 10. Example of boat track (GPS points during 4 Unit Operations) during data collection at JPSS Intakes.

Figure 11. Boat mounted RD Instruments Broadband 600 kHz ADCP and GPS.

Figure 12. Boat tracks (GPS points during all of the unit operations) and transect number at JPSS in the tailwater.

ADCP Operations

Water column velocity measurements in the JPSS forebay and tailwater were conducted at various combinations of unit flows (Table 1 and 2, respectively). The unit flows were calculated from the information provided in Figures 6, 7, and 8.

Data Reduction and Analysis

The ADCP and GPS data from the intakes and tailwaters were processed to yield bathymetric data (latitude, longitude, and depth) and water velocity vectors (earth-referenced easting and northing vectors) from each GPS point and each depth measured. The following steps were taken to review the data quality, to filter noise in the data and to visualize the data:

- All ADCP datasets were first visualized using Teledyne RD Instruments WinRiver II v2.08 software. The data quality for each dataset was reviewed;
- The ADCP ASCII data were imported to a MS Excel spreadsheet format, plotted and reviewed, and data statistics performed;
- The MS Excel data were then imported into the ESRI ArcGIS database. During the data import the geo-referenced information and water level corresponding to the ADCP data were applied to correct coordinates and elevation;
- Use of the 2012 Duke Energy high resolution digital orthophotos;
- ESRI ArcGIS 10.1 software was used to visualize the data;
- Files containing the still images (screenshots) were recorded and saved.

Table 1. Unit operations during JPSS generation velocity tests.

Generation Unit Operation	Date / Time	Jocassee Lake Level (elev ft-amsl)	Keowee Lake Level (elev ft-amsl)	Gross Head (ft)	Unit 1		Unit 2		Unit 3		Unit 4		Intake A Total Generation Flow (cfs)	Intake B Total Generation Flow (cfs)	Station Total Generation Flow (cfs)
					Generation MW	Generation Flow (cfs)	Generation MW	Generation Flow (cfs)	Generation MW	Generation Flow (cfs)	Generation MW	Generation Flow (cfs)			
No Generation	7/10/2012 8:31	1,085.1	795.8	289.3	0	0	0	0	0	0	0	0	0	0	0
Intake A - 0ne Unit	7/10/12 11:39	1,085.1	795.7	289.4	157	7028	0	0	0	0	0	0	7028	0	7028
Intake A - Two Units	7/13/12 11:21	1,086.7	795.7	291.0	166	7500	164	7404	166	7407	0	0	14903	7407	22311
Intake B - 0ne Unit	7/10/12 13:00	1,085.0	795.9	289.1	164	7320	0	0	162	7238	0	0	7320	7238	14557
Intake B - Two Units	7/13/12 17:27	1,085.7	796.3	289.4	0	0	155	6948	157	7141	159	7209	6948	14349	21298
Units 1, 2, 3, and 4	7/13/12 13:18	1,086.2	796.2	290.0	155	7065	156	7105	156	7106	158	7185	14170	14291	28461

Table 2. Unit operations during JPSS pumping velocity tests.

Pumping Unit Operation	Date / Time	Jocassee Lake Level (elev ft-amsl)	Keowee Lake Level (elev ft-amsl)	Gross Head (ft)	Unit 1		Unit 2		Unit 3		Unit 4		Calculated Station Total Pumping Flow (cfs)
					Pumping MW	Calculated Pumping Flow (cfs)	Pumping MW	Calculated Pumping Flow (cfs)	Pumping MW	Calculated Pumping Flow (cfs)	Pumping MW	Calculated Pumping Flow (cfs)	
No Pumping	9/24/11 21:12	1089.1	796.5	292.6	0	0	0	0	0	0	0	0	0
Unit 1	9/25/11 8:25	1090.7	795.7	295.0	211	7589	0	0	0	0	0	0	7589
Unit 2	9/25/11 7:17	1090.7	795.6	295.1	0	0	209	7500	0	0	0	0	7500
Units 1 and 2	9/25/11 6:25	1090.6	795.6	295.0	209	7469	208	7433	0	0	0	0	14902
Unit 3	9/24/11 22:10	1089.2	796.6	292.6	0	0	0	0	208	7485	0	0	7485
Unit 4	9/24/11 23:08	1089.2	796.6	292.6	0	0	0	0	0	0	207	7449	7449
Units 3 and 4	9/24/11 0:04	1089.1	796.4	292.8	0	0	0	0	208	7482	206	7410	14892
Units 1, 3 and 4	9/25/11 1:00	1089.3	796.2	293.1	210	7595	0	0	207	7486	207	7486	22568
Units 1, 2 and 3	9/25/11 5:20	1089.8	796.5	293.3	209	7496	208	7470	208	7470	0	0	22436
Units 1, 2, 3, and 4	9/25/11 4:25	1090.0	795.7	294.3	208	7448	208	7448	208	7448	207	7425	29769

RESULTS

JPSS Intake Velocities

Since each ADCP ‘ping’ captures the velocity at depth, the individual velocity profiles for each operating scenario were plotted to produce a representation of the overall velocity field around the forebay intakes (Figure 13, an example of velocity profiles during four-unit operation). Another representation of the ‘raw’ ADCP data was to plot the velocities at a given depth to visualize the velocity field (Figure 14, an example of velocities at the center line of the intakes for a 4 unit operation). The most notable observation from this data is water approached the intakes from all directions, but, as the flow neared the intakes, the water ‘swirled’ in a counter clockwise direction before entering the intakes. The closer the water got to the intakes, the velocity increased.

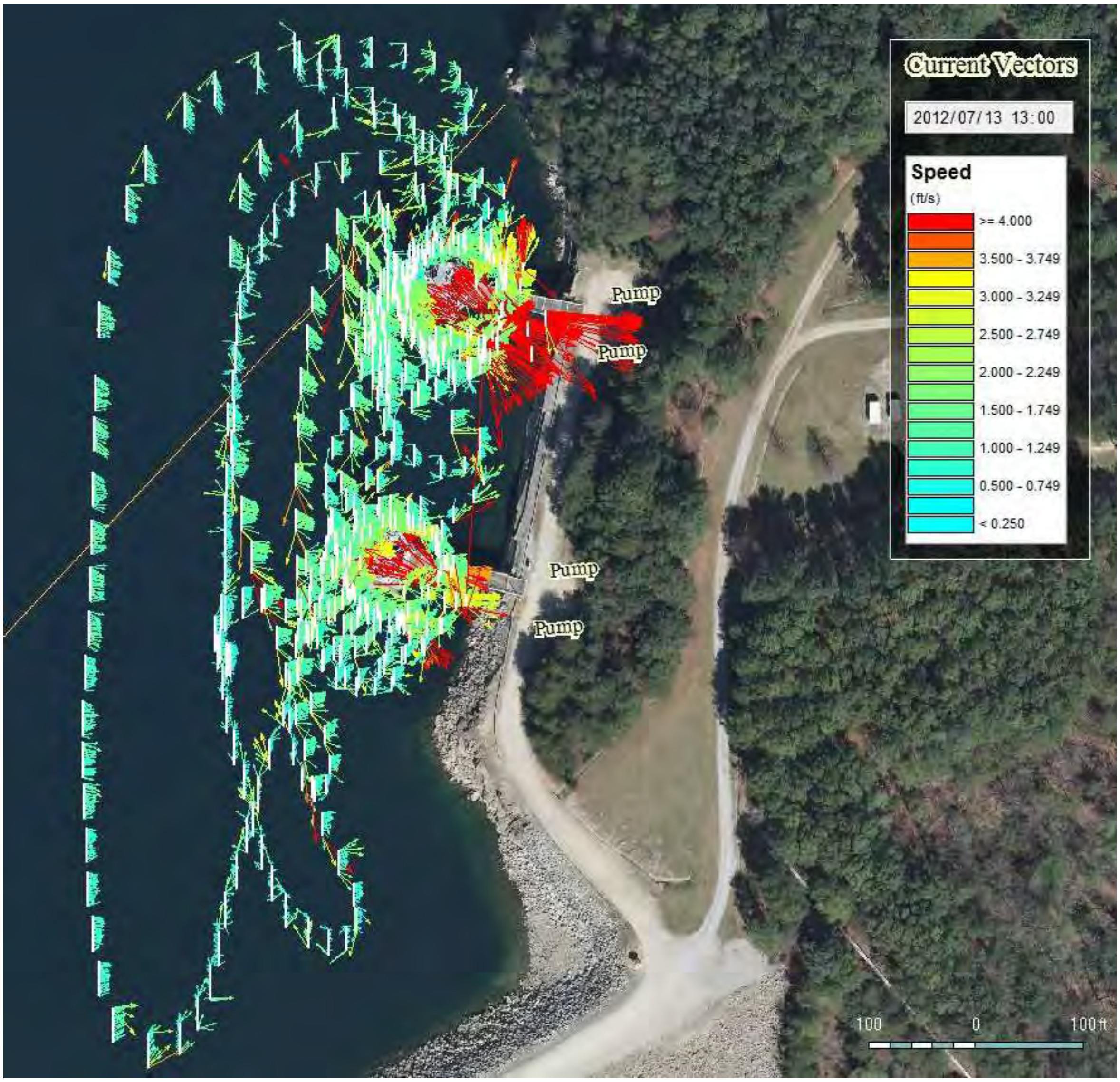

Figure 13. Individual velocity profiles around the JPSS intakes with four- unit generation.

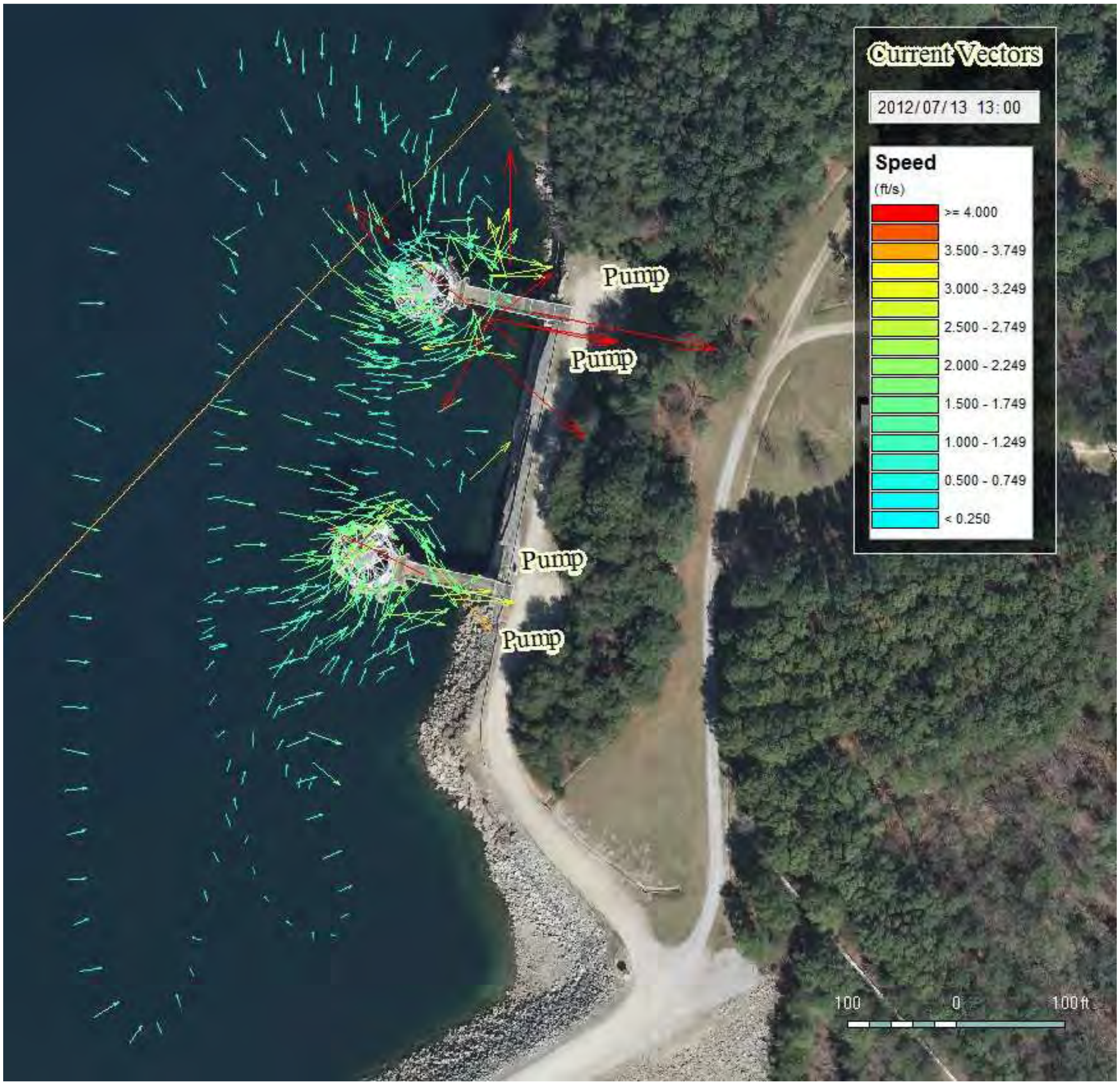

Figure 14. Velocity vectors at the intake center line depth with four-unit generation.

Since the primary purpose of these measurements was to provide information relative to fish entrainment into the intake towers and look for flow abnormalities, the velocity data were analyzed to correspond to the transducers located on the intake structures. Since a set of transducers were placed on every other intake bay, the intake velocities were categorized into which 'quadrat' of the intake the data were collected. The quadrats were established by dividing the area around the intakes into 4 equal areas of 90° each and originating from a perpendicular line to the bank (Figure 15). The velocity profile data in each quadrat for each intake for each operational scenario was further categorized by the distance the profile was taken from the intake. From this classification, the mean velocity was calculated for the 'easting' and 'northing' vector components at each depth. The velocity magnitude (maximum resultant vector) was also calculated for each depth and the maximum velocity measured at each depth, for each quadrat, for each intake, and at each operational scenario was determined. The results of these individual calculations are presented in Appendix A.

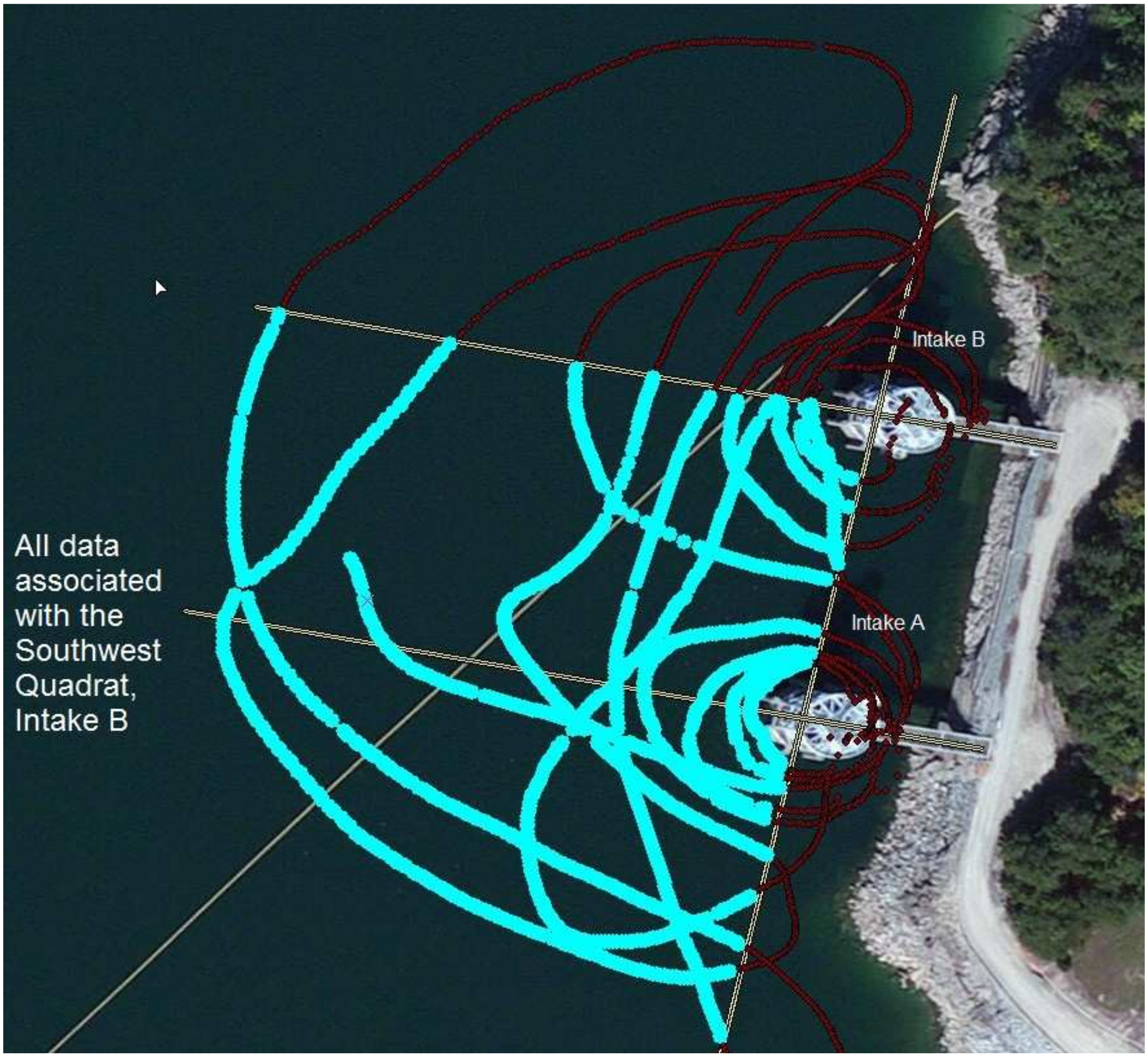

Figure 15. Example of classifying JPSS Intake velocity data (e.g. southwest quadrant, Intake B).

Example graphic representations of the 'quadrant' mean velocities (mean resultant vector, magnitude and direction) of Intake A with all 4 Jocassee Units generating (Figure 16) indicate highly variable flows between the 4 quadrants and with respect to depth and distance from the intake. The quadrants closest to the shore (Northeast and Southeast) exhibited less 'swirling' than the outer most intake bays; however, the magnitude of the velocities immediately in front of the intake openings was much less in the Southeast quadrant compared to the Northeast facing intakes.

Comparison of the velocities associated with increasing generation (Figure 17) (using the Northeast quadrant as an example) showed very low velocities around the intake at no generation; however, velocities associated with turbine leakage were noticed at the bottom of the intake opening. At 1 Unit generation, the velocities were uniformly distributed throughout the opening of the intake, whereas, at 2 Unit generation, velocities increased significantly throughout the water column, with higher mean velocities towards the lower portion of the intake opening.

The mean velocity magnitudes at each depth[4] at increased generation capacity for each intake (Figure 18) showed little difference between the two intakes at all generation levels. Both Intakes exhibited slightly higher velocities at the lower levels of the intake opening reflecting leakage flow. At 1 unit generation, all mean velocities were well below 1 ft/sec, increasing to slightly greater than 1 ft/sec at 2-unit generation. Operation of the second intake had little influence on the velocities associated with the first.

The mean velocities at each depth were calculated from the total number of 'count' values, (Appendix A), however, the maximum observed velocities represent the highest single velocity recorded from all of the sampled points around the intake at 0-10 ft distance. These maximum recorded velocities (Appendix A and Figure 18) illustrate the highly variable velocities around the intakes. The 'swirling' action and the mass of water entering the intakes created a turbulent flow pattern with highly variable instantaneous velocities.

[4] Calculated from northing and easting vectors 0-10 feet distance, from all Intake A quadrats at each unit generation

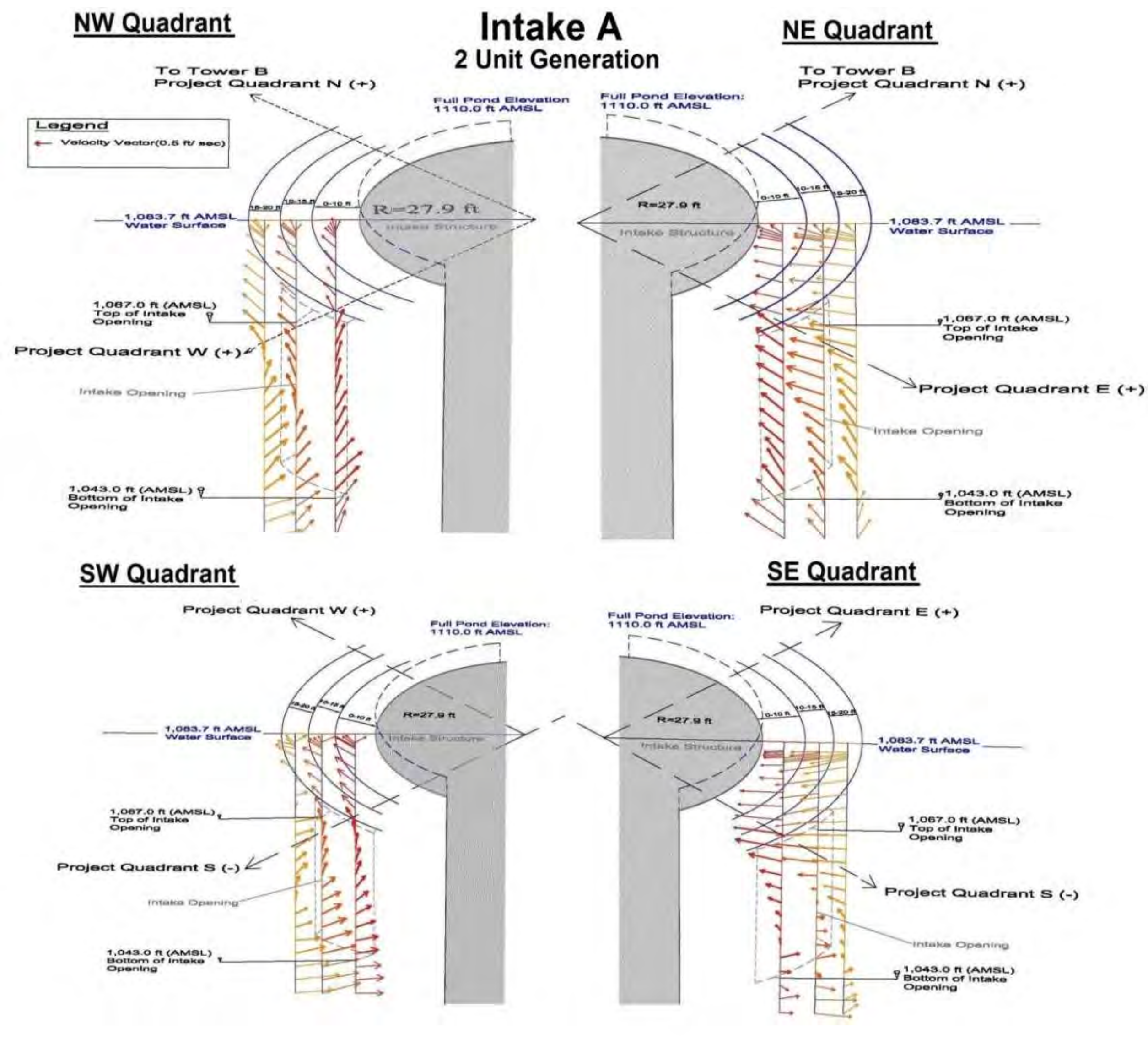

Figure 16. Graphic representation of mean quadrant current vectors at JPSS Intake A with two units generating from Intake A and four units generating at the JPSS.

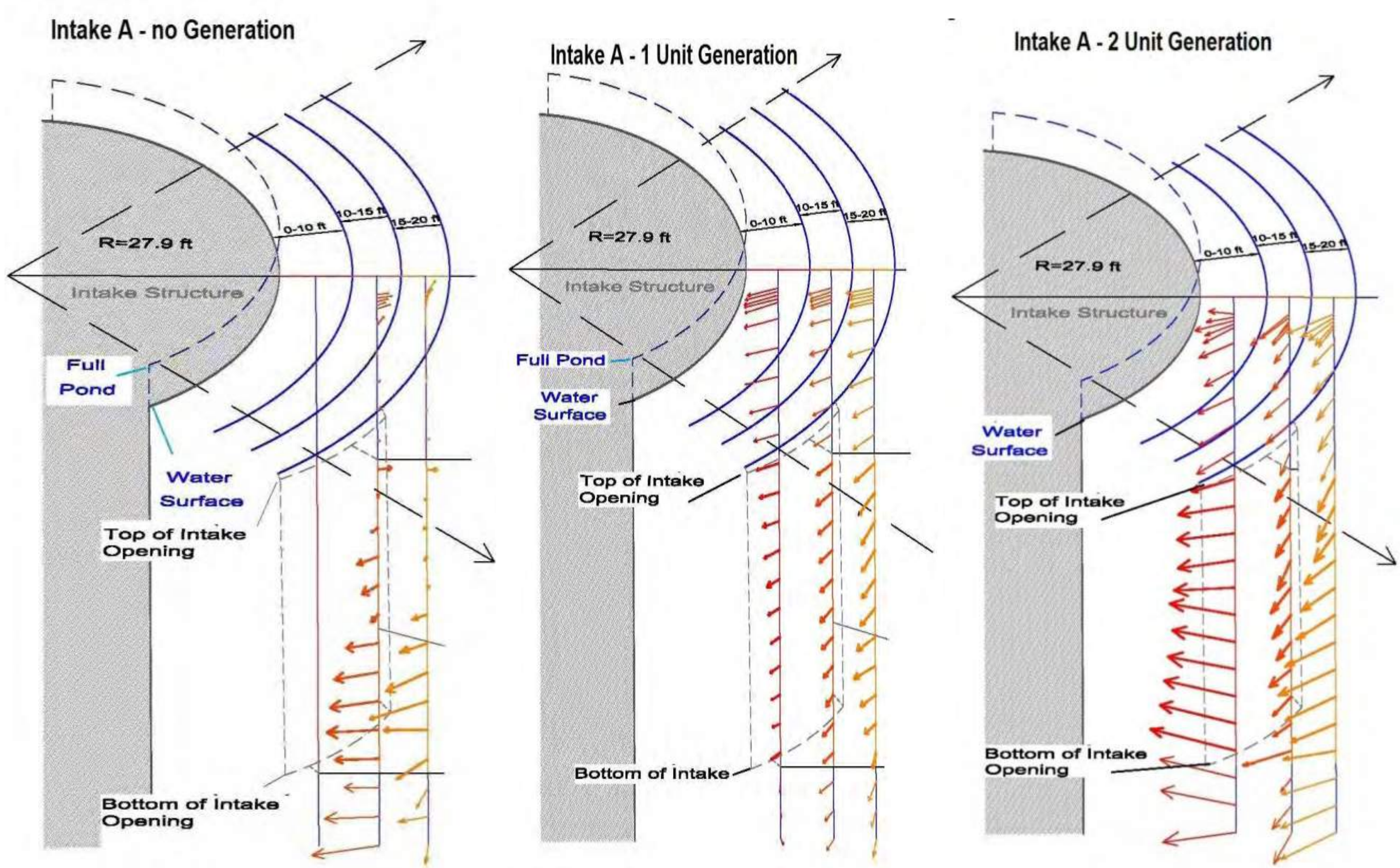

Figure 17. Graphic representation of JPSS Intake A, two-unit generation, Northeast Quadrant mean current vectors at various generation scenarios and various distances (ft) from the Intake.

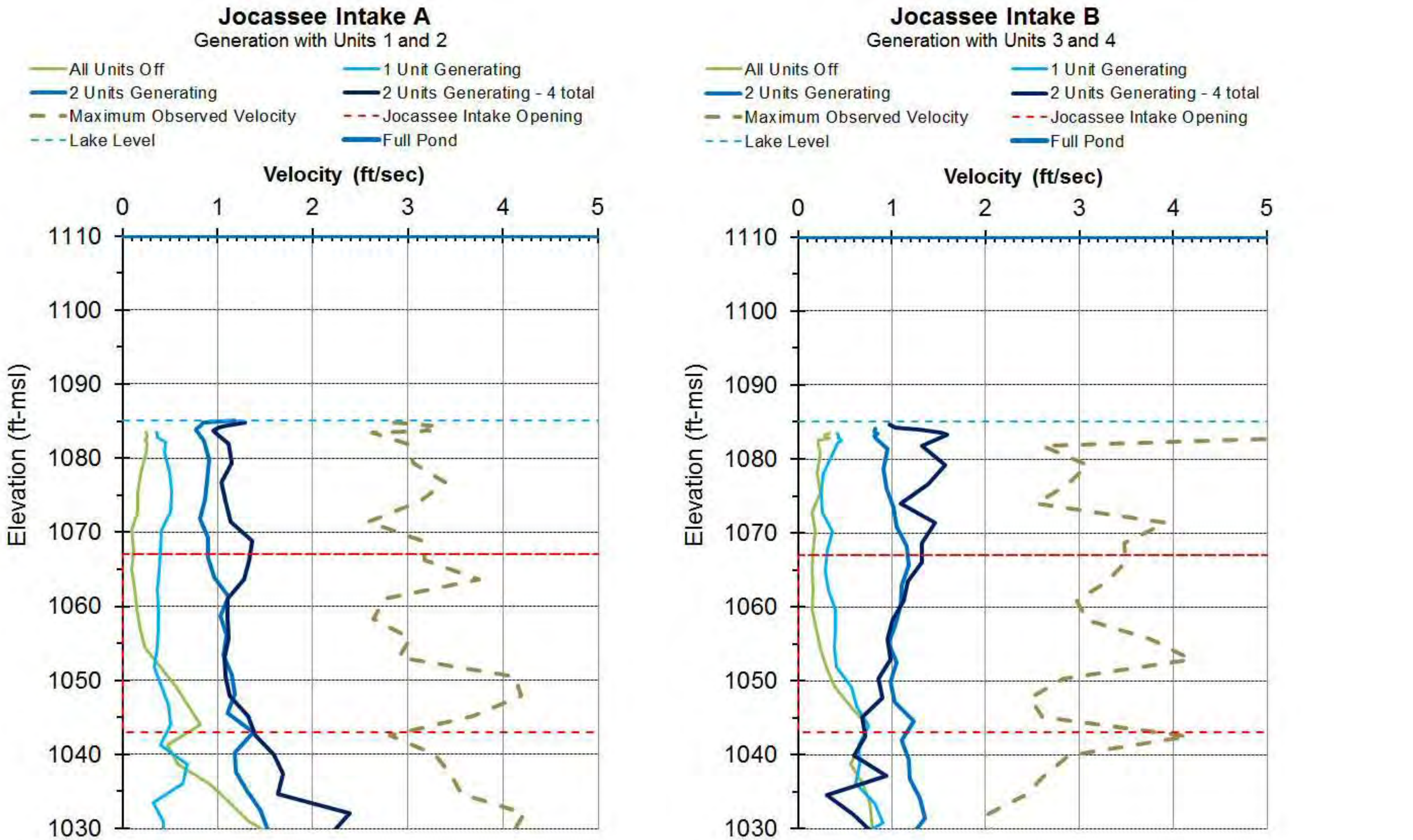

Figure 18. Graphic representation of mean quadrant current vectors at 0-10 ft distance from each intake at various generation scenarios.

Jocassee Tailwater

Unlike the intakes, the Jocassee immediate tailwater was a relatively confined area, with a concrete wing wall on the west and a steep riprapped shoreline on the east. The narrow discharge canal, especially at higher flow, made maneuvering the boat and navigating the projected transects difficult. Generally, the further from the discharge structure, the more complete the ADCP data.

As with the intake data, the individual velocity profiles for each operating scenario were plotted to produce a representation of the overall velocity field of the tailwater (Figure 19). With one unit (unit 1), the relatively small velocities were confined to the side of the canal associated with the operating unit. As more units were brought on line, the velocities increased throughout the water column. Notably, the strongest currents throughout the canal were observed on the wing wall side of the tailwater. Even with 4 units pumping, water velocities along the eastern riprap bank were significantly less than the western and middle sections of the tailwater.

The frequency of occurrence of velocities of various magnitudes (Figure 20) illustrates the increased water turbulence in the tailwater at increased flow. At single unit operations (examples of Units 3 and 4, Figure 20), flows were of a relatively uniform magnitude, with few high velocities noted. However, as successive units were brought on line, the mean velocities ranged over a greater magnitude, a few maximum velocities reached 5 to 6 ft/sec. The frequency distribution of the mean and maximum velocities at greater flow rates (more units pumping) became less pronounced with a progressive increase from lower to higher velocities and an increased variability (greater standard deviation). This pattern of frequency distribution was indicative of progressively increased turbulence at increased flows.

Also noteworthy, only the velocities from 3 transects were presented in Figure 19a and 19b. Whereas Figure 12 (Methods section) indicated that 4 transects were measured for each operational scenario. Transects 1 and 2 became interchangeable, especially at higher flows. In addition, much of the data collected from transect 1 were un-useable since the ADCP was pinging off the discharge structure.

Water velocity profiles were calculated from the useable data (as close to the discharge structure as possible) during the operation of a specific unit. The raw data (as displayed in the RDI WinRiver® program) was delineated for the velocity profile calculations. Average velocities (and maximum observed velocities at 4 unit pumping) at each depth recorded by the ADCP (Figure 21) revealed relatively similar velocities throughout the water column at each operational flow. As expected, the mean water column velocities increased with increased pumping. Maximum recorded velocities with 4 units pumping averaged between 5 and 6 ft/sec compared to an average of 2.5 to 3.5 ft/sec at the same flow. Again, these data indicate a high level of turbulence at progressively higher flows.

Figure 19a. Individual velocity profiles in the JPSS Tailwater with one unit pumping.

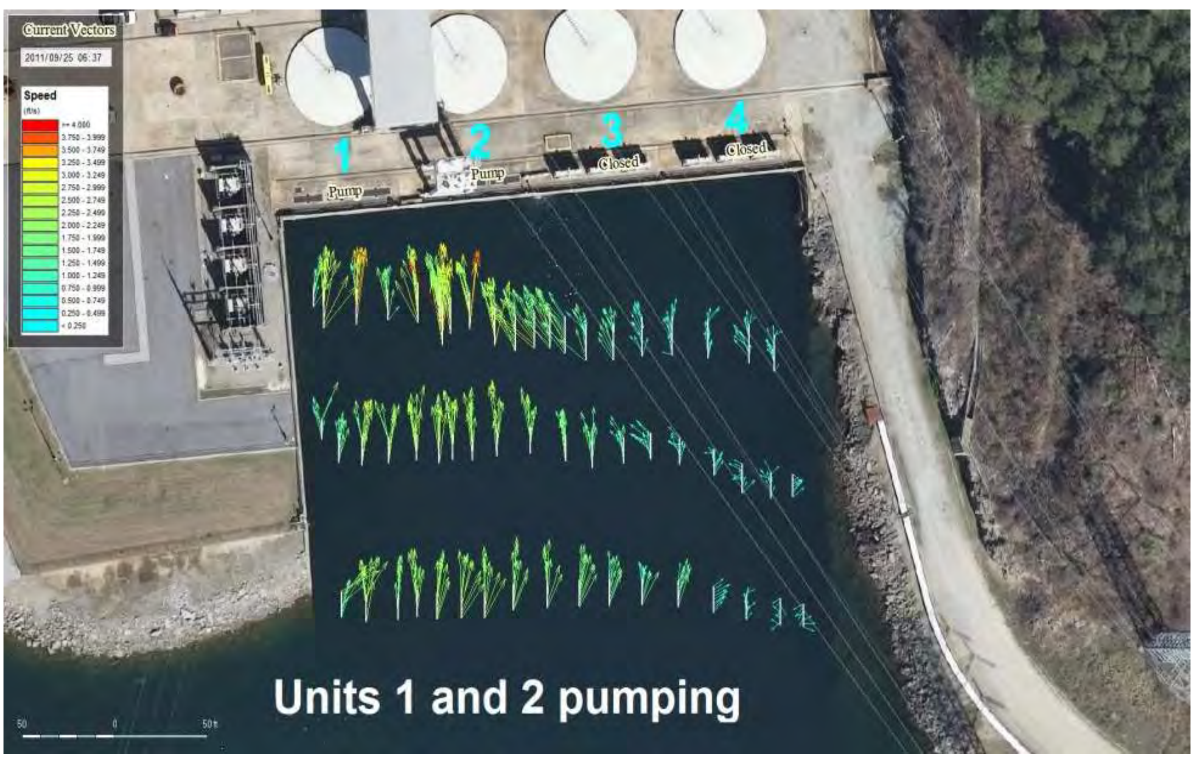

Figure 19b. Individual velocity profiles in the JPSS Tailwater with two units pumping.

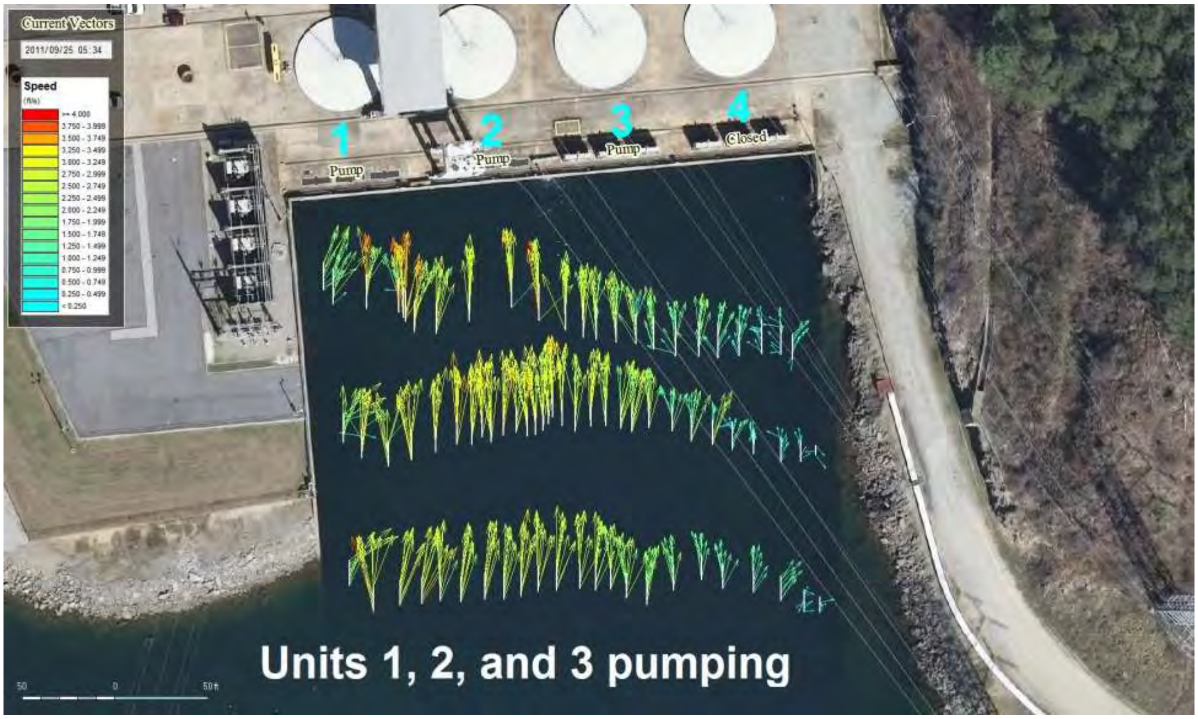

Figure 19c. Individual velocity profiles in the JPSS Tailwater with three units pumping.

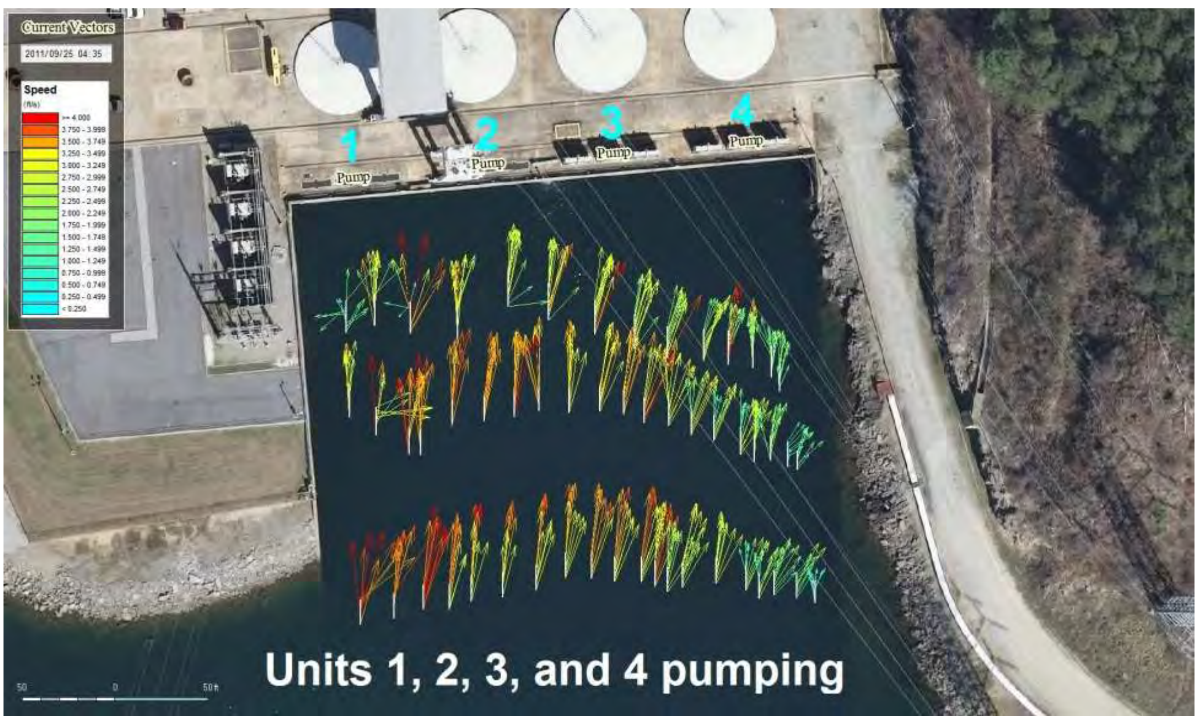

Figure 19d. Individual velocity profiles in the JPSS Tailwater with four units pumping.

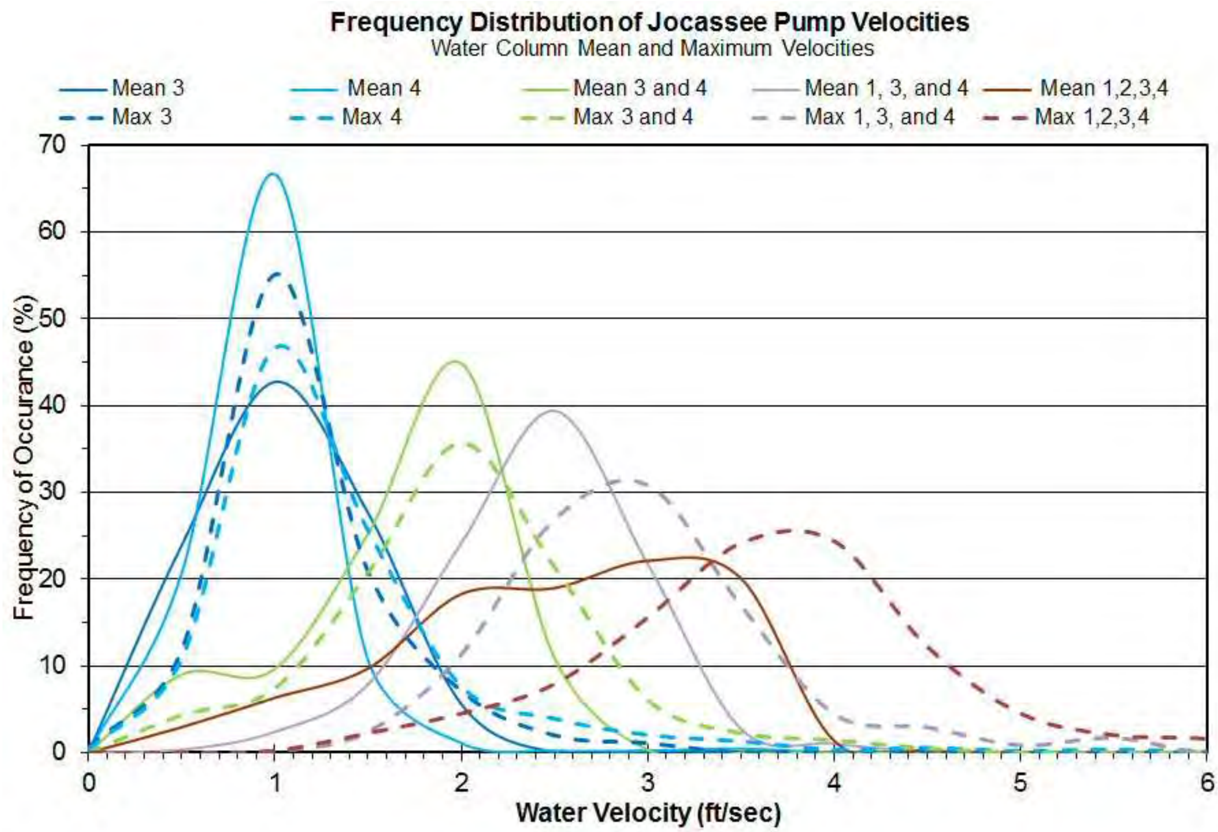

Figure 20. Frequency distribution of all JPSS Tailwater mean and maximum water column velocities at various pumping scenarios.

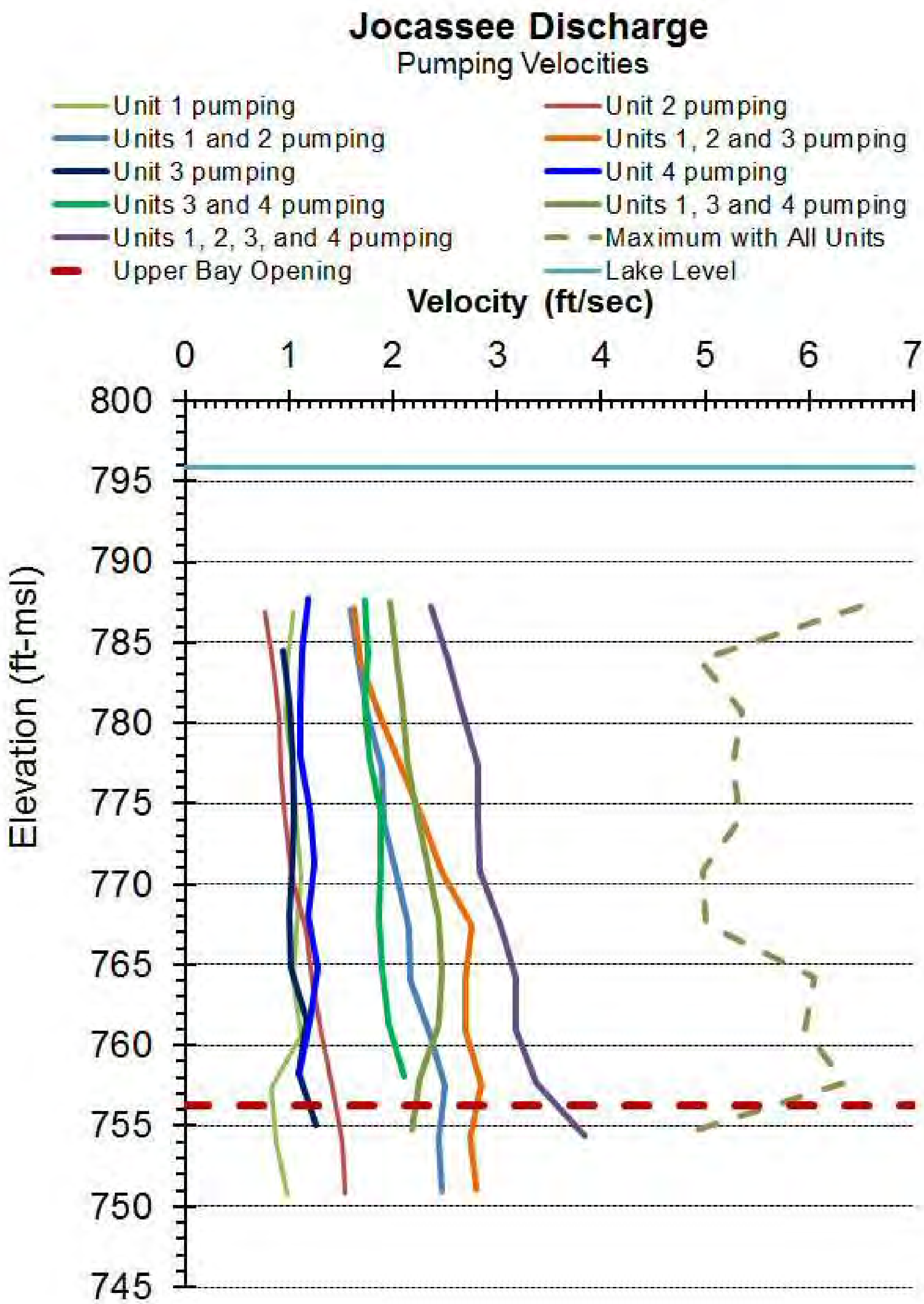

Figure 21. Mean (and maximum at four-unit pumping) water velocity profiles close to the JPSS Discharge Structure during various pumping scenarios.

Most notable from the profile data (Figure 21) was the lack of velocity data below the upper opening of the discharge bays. This lack of data was attributed to high turbulence and/or shear, proximity to the vertical concrete walls and metal trash racks, the confined space in the discharge canal, and the potential of the lack of 'scatters' to yield stronger sound waves from the depths (especially at high relative velocities).

The volume of water in the tailwater where ADCP velocities could not be measured (Figure 22) was determined from the water depth of the four transects measured when all units were off-line and the depth of the valid data collected by the ADCP during pumping. The depth from each of the 4 transects revealed that the water depth decreased approximately 20 ft from the discharge bays to 100 ft downstream. Unfortunately, this volume of water represented the water velocities immediately in front of the discharge bays.

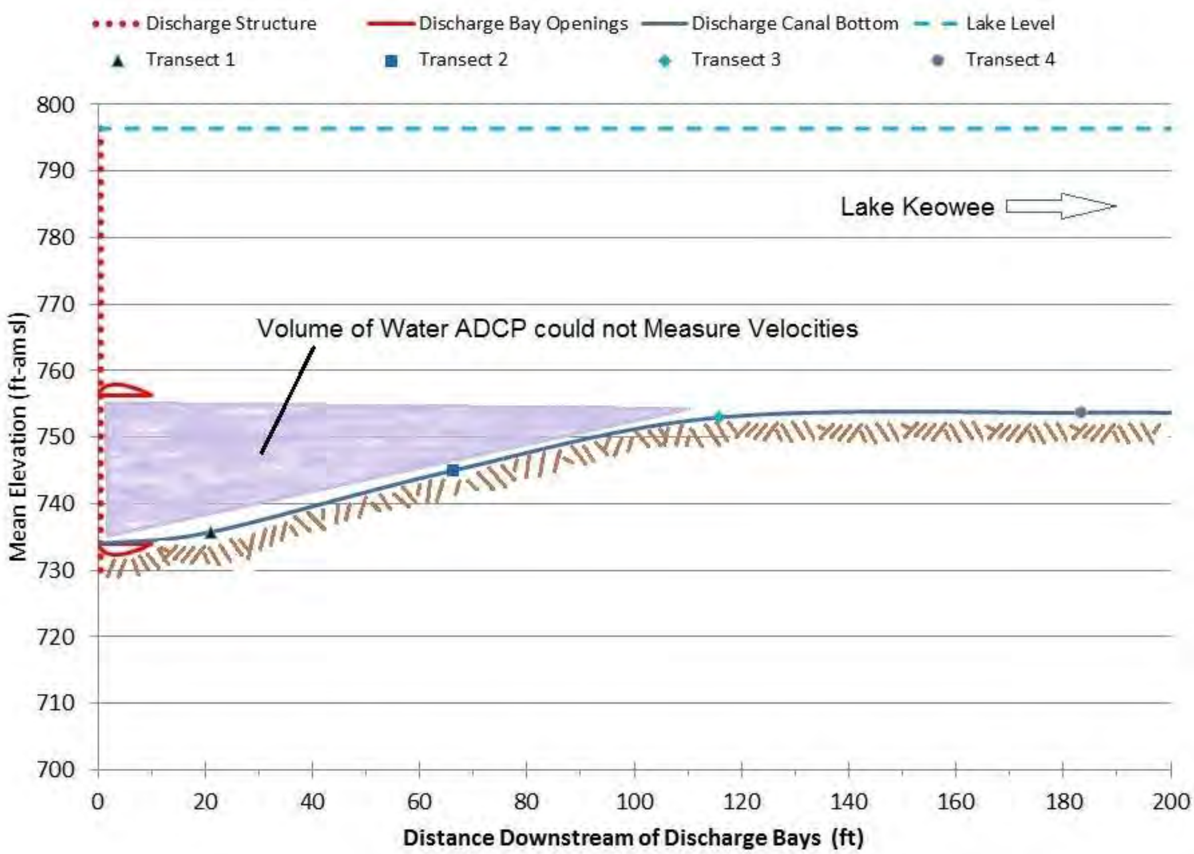

Figure 22. Jocassee Tailwater longitudinal river bottom elevation.

Since the water velocities could not be measured immediately in front of the discharge bay trash racks, a calculated water velocity though the racks was made by dividing the unit flows (from Table 2) and measured ADCP flows by the net open area of each trash rack[5] (Table 3). The measured flows were slightly greater than the calculated flows, but generally within 3%. The through-rack velocities calculated from each flow were approximately 4 ft/sec. The negative flow at no operation probably represented the total leakage flow from all of the units.

Table 3. Calculated and measured flow and through-rack water velocities during all pumping tests (see Table 2).

Unit Operation	Calculated Station Total Pumping Flow (cfs)	Calculated Station Average Through Rack Velocities (ft/sec)	ADCP Measured Station Total Pumping Flow (cfs)	Calculated from Station ADCP Average Through Rack Velocities (ft/sec)
No Pumping	0	-	-245	-0.03
Unit 1 pumping	7589	4.08	7770	4.18
Unit 2 pumping	7500	4.04	8406	4.52
Units 1 and 2 pumping	14902	4.01	16027	4.31
Unit 3 pumping	7485	4.03	7132	3.84
Unit 4 pumping	7449	4.01	7926	4.26
Units 3 and 4 pumping	14892	4.01	14055	3.78
Units 1, 3 and 4 pumping	22568	4.05	23091	4.14
Units 1, 2 and 3 pumping	22436	4.02	23271	4.17
Units 1, 2, 3, and 4 pumping	29769	4.00	30658	4.12

[5] The net area was determined by subtracting the total area of the grating from the total area of the trash racks, this net area = 206.5 ft^2 for each rack, each unit has 3 identical racks, yielding 619.5 ft^2 per unit

SUMMARY

Water velocities associated with the JPSS generation and pumping were measured under different combinations of unit operations. The water velocity data collected during generation revealed similar flow characteristics at both intake structures. Water column velocities at both intakes at 1-unit operation averaged 0.48 ft/sec and at a 2-unit operation averaged 1.08 ft/sec. However, maximum instantaneous velocities averaged 3.42 ft/sec. The high variability of velocities suggested an increase in turbulent water flow as generation increased. Operation of one intake had little, if any impact on water velocities in the immediate vicinity of the other intake. Multiple unit operation did alter the far-field velocity measurements.

The water velocity data collected in the tailwater was limited by the confined space, vertical concrete walls, and high turbulence at progressively higher flows. At any given flow rate, water velocities had little variability with depth, but a high degree of variability across the discharge bays. The highest velocities were usually measured along the west wing wall with the lowest velocities measured along the eastern riprapped shoreline. Each additional unit brought on-line caused increased velocities and increased turbulence throughout the tailwater. Unfortunately, water velocities directly in front of the discharge bays could not be measured; only velocities above the discharge bays could be measured. Therefore, a through-rack velocity was calculated from the unit flow and net trash rack area. Average water velocity though the trash racks averaged about 4 ft/sec, with little difference between units since all of the units and discharge bays were identical.

APPENDIX A –

CALCULATED VELOCITIES RESULTING FROM VARIOUS GENERATING SCENARIOS AT THE JPSS

Intake A - All Units Off (Unit 1, 2, 3, and 4 NOT Generating)
Northeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	0	-	-	-	-	23	-0.07	0.10	0.12	0.52	29	0.11	0.25	0.27	0.69
1083.2	2.0	0	-	-	-	-	23	-0.08	0.13	0.16	0.54	29	0.08	0.18	0.19	0.55
1082.8	2.3	0	-	-	-	-	23	-0.05	0.11	0.12	0.54	28	0.16	0.22	0.27	0.99
1082.5	2.6	0	-	-	-	-	24	-0.03	0.09	0.10	0.39	28	0.15	0.20	0.26	0.66
1082.2	3.0	0	-	-	-	-	23	-0.04	0.15	0.16	0.45	29	0.14	0.15	0.20	0.79
1080.7	4.4	0	-	-	-	-	24	0.06	0.16	0.17	0.82	29	0.17	0.17	0.24	0.77
1078.1	7.1	0	-	-	-	-	24	0.05	0.04	0.06	0.55	29	0.09	0.15	0.17	0.93
1075.4	9.7	0	-	-	-	-	24	0.01	0.06	0.06	0.89	29	0.09	0.10	0.14	1.03
1072.8	12.3	0	-	-	-	-	24	0.04	0.09	0.09	0.81	29	0.03	0.05	0.05	0.73
1070.2	14.9	0	-	-	-	-	24	-0.02	0.02	0.03	0.52	29	0.00	0.05	0.05	0.67
1067.6	17.6	0	-	-	-	-	24	-0.07	0.12	0.14	0.62	28	-0.07	0.07	0.10	0.90
1064.9	20.2	0	-	-	-	-	24	0.06	0.06	0.08	0.72	29	0.00	-0.03	0.03	0.53
1062.3	22.8	0	-	-	-	-	24	-0.02	-0.11	0.11	0.70	29	0.01	-0.03	0.03	0.62
1059.7	25.4	0	-	-	-	-	24	0.04	-0.25	0.26	1.06	29	-0.04	-0.07	0.08	0.66
1057.1	28.1	0	-	-	-	-	24	0.00	-0.23	0.23	0.71	29	-0.01	-0.05	0.05	0.68
1054.5	30.7	0	-	-	-	-	24	-0.05	-0.15	0.16	0.80	29	0.04	-0.18	0.18	0.99
1051.8	33.3	0	-	-	-	-	24	0.17	-0.30	0.34	1.84	29	0.08	-0.32	0.33	1.30
1049.2	35.9	0	-	-	-	-	24	0.22	-0.42	0.47	1.81	28	0.05	-0.54	0.55	1.84
1046.6	38.6	0	-	-	-	-	24	0.26	-0.44	0.52	1.43	23	0.18	-0.65	0.68	1.91
1044.0	41.2	0	-	-	-	-	22	0.35	-0.41	0.54	2.55	15	0.63	-0.65	0.90	2.70
1041.3	43.8	0	-	-	-	-	20	0.31	-0.34	0.46	1.90	5	-0.04	-0.48	0.48	1.51
1038.7	46.4	0	-	-	-	-	16	0.52	-0.50	0.72	2.07	4	-0.18	-0.34	0.39	0.89
1036.1	49.1	0	-	-	-	-	9	0.74	-0.86	1.13	2.43	4	0.15	-0.28	0.32	1.54
1033.5	51.7	0	-	-	-	-	8	0.73	-1.24	1.44	2.29	3	-0.22	-0.25	0.33	0.48
1030.8	54.3	0	-	-	-	-	3	0.60	-1.55	1.66	2.16	3	-0.27	-0.70	0.75	1.33
1028.2	56.9	0	-	-	-	-	2	0.79	-1.77	1.94	2.05	3	-0.23	-0.73	0.77	1.21

Blue color represents the opening to the intake bays

Intake A - All Units Off (Unit 1, 2, 3, and 4 NOT Generating)
Southeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	21	0.28	0.14	1.04	0.60	8	0.32	0.13	0.34	0.50	16	0.18	0.19	0.26	0.96
1083.2	2.0	21	0.29	0.18	1.12	0.61	8	0.31	0.17	0.36	0.59	16	0.22	0.28	0.36	1.03
1082.8	2.3	21	0.28	0.16	1.05	0.79	8	0.31	0.20	0.37	0.53	16	0.20	0.23	0.31	1.03
1082.5	2.6	21	0.29	0.20	1.14	0.91	8	0.30	0.18	0.35	0.48	16	0.20	0.23	0.30	0.88
1082.2	3.0	21	0.31	0.10	1.07	0.60	8	0.28	0.21	0.35	0.45	16	0.24	0.22	0.33	0.88
1080.7	4.4	21	0.26	0.07	0.87	0.80	8	0.41	0.17	0.45	0.85	16	0.37	0.27	0.46	0.95
1078.1	7.1	21	0.19	0.07	0.66	0.72	8	0.25	0.24	0.35	0.86	16	0.28	0.16	0.33	0.80
1075.4	9.7	21	0.16	0.06	0.55	0.71	8	0.11	0.22	0.25	0.59	16	0.24	0.06	0.25	0.95
1072.8	12.3	21	0.16	0.06	0.58	0.77	8	0.16	-0.03	0.16	0.50	16	0.24	0.03	0.24	1.04
1070.2	14.9	21	0.06	0.01	0.20	0.68	8	0.20	0.02	0.20	0.65	16	0.17	0.08	0.19	1.06
1067.6	17.6	21	0.01	-0.03	0.10	0.66	8	0.04	-0.07	0.08	0.67	16	0.17	0.05	0.18	0.89
1064.9	20.2	21	-0.06	-0.05	0.25	1.32	8	0.11	0.00	0.11	0.46	16	0.03	0.13	0.13	0.86
1062.3	22.8	21	-0.10	-0.11	0.47	0.56	8	0.02	-0.02	0.03	0.47	16	-0.03	0.05	0.06	0.67
1059.7	25.4	21	-0.08	-0.12	0.46	0.59	8	-0.07	0.04	0.08	0.52	16	-0.01	-0.09	0.09	0.75
1057.1	28.1	21	-0.13	-0.16	0.68	1.06	8	-0.14	-0.07	0.15	0.73	16	-0.08	-0.12	0.15	0.84
1054.5	30.7	21	-0.25	-0.19	1.02	1.17	8	-0.17	0.08	0.19	0.66	16	-0.22	-0.08	0.23	2.00
1051.8	33.3	21	-0.31	-0.20	1.20	1.17	8	-0.22	0.16	0.27	0.81	16	-0.34	-0.33	0.48	2.83
1049.2	35.9	21	-0.44	-0.33	1.79	1.25	8	-0.31	0.05	0.32	0.89	15	-0.47	-0.38	0.60	2.23
1046.6	38.6	21	-0.40	-0.35	1.76	1.79	8	-0.30	-0.34	0.46	1.21	14	-0.60	-0.35	0.70	2.28
1044.0	41.2	13	-0.58	-0.25	2.07	1.64	2	-0.86	0.10	0.87	1.38	6	-1.35	-0.44	1.42	3.26
1041.3	43.8	2	-0.23	-0.18	0.96	0.53	1	0.15	0.24	0.28	0.28	1	0.09	0.31	0.32	0.32
1038.7	46.4	2	-0.42	0.18	1.50	0.57	1	-0.10	0.16	0.19	0.19	1	-0.21	0.41	0.46	0.46
1036.1	49.1	2	-0.67	-0.06	2.21	0.86	1	0.00	-0.06	0.06	0.06	1	-0.32	0.20	0.38	0.38
1033.5	51.7	2	-1.25	0.27	4.21	1.82	1	-0.84	-0.05	0.84	0.84	1	-0.57	-0.46	0.73	0.73
1030.8	54.3	2	-1.70	-0.28	5.65	2.02	1	-0.15	0.54	0.56	0.56	0	-	-	-	-
1028.2	56.9	1	-1.09	-0.78	4.41	1.34	1	-1.44	-0.24	1.46	1.46	0	-	-	-	-

Blue color represents the opening to the intake bays

Intake A - All Units Off (Unit 1, 2, 3, and 4 NOT Generating)
Northwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	9	-0.03	0.33	0.33	0.65	19	0.19	0.32	0.37	1.07	18	0.30	0.19	0.36	0.87
1083.2	2.0	9	0.03	0.29	0.29	0.52	19	0.18	0.37	0.41	1.14	18	0.23	0.17	0.29	0.88
1082.8	2.3	9	-0.01	0.31	0.31	0.54	19	0.17	0.29	0.33	1.04	18	0.13	0.12	0.18	0.51
1082.5	2.6	9	0.03	0.26	0.26	0.58	19	0.08	0.32	0.33	0.89	16	0.16	0.06	0.18	0.59
1082.2	3.0	9	-0.01	0.30	0.30	0.46	19	0.09	0.27	0.28	1.14	18	0.14	0.08	0.16	0.60
1080.7	4.4	9	-0.08	0.30	0.31	0.50	19	0.02	0.24	0.24	0.73	18	-0.04	0.08	0.09	0.68
1078.1	7.1	9	-0.06	0.36	0.37	0.86	19	0.03	0.18	0.18	0.79	18	-0.04	0.04	0.05	0.71
1075.4	9.7	9	0.10	0.20	0.23	0.54	19	0.05	0.07	0.08	0.65	18	-0.05	-0.09	0.10	0.86
1072.8	12.3	9	0.07	0.17	0.18	0.53	19	-0.04	0.22	0.23	1.10	18	-0.14	-0.01	0.14	0.68
1070.2	14.9	9	0.08	0.11	0.13	0.47	19	-0.02	0.17	0.17	0.65	17	-0.13	-0.04	0.13	0.85
1067.6	17.6	9	0.00	0.12	0.12	0.40	18	-0.02	0.04	0.05	0.68	18	-0.16	0.01	0.16	0.76
1064.9	20.2	9	-0.10	0.00	0.10	0.48	19	-0.04	0.07	0.09	0.90	18	-0.11	-0.03	0.11	0.60
1062.3	22.8	9	-0.14	-0.03	0.14	0.46	19	-0.03	0.08	0.09	0.94	18	-0.12	-0.05	0.13	0.67
1059.7	25.4	9	-0.06	0.03	0.07	0.53	19	-0.02	0.11	0.11	0.79	18	-0.11	-0.09	0.14	0.72
1057.1	28.1	9	-0.05	0.10	0.11	0.51	19	0.10	0.11	0.15	1.07	18	-0.06	-0.06	0.09	0.60
1054.5	30.7	9	-0.05	0.13	0.14	0.46	19	0.23	0.09	0.25	1.56	18	0.08	-0.08	0.11	0.73
1051.8	33.3	9	-0.15	0.48	0.50	1.15	19	0.46	0.29	0.54	2.42	18	0.38	-0.12	0.40	1.38
1049.2	35.9	9	0.11	0.71	0.72	1.98	19	0.72	0.64	0.96	1.97	18	0.70	0.18	0.72	1.49
1046.6	38.6	9	0.61	1.01	1.18	2.35	19	0.88	0.51	1.02	2.21	17	0.99	0.30	1.03	2.50
1044.0	41.2	9	0.89	1.10	1.42	2.05	13	0.41	1.20	1.27	4.72	15	1.49	0.03	1.49	2.82
1041.3	43.8	2	0.20	0.86	0.88	1.14	4	0.51	0.35	0.62	1.79	5	1.59	1.28	2.04	2.96
1038.7	46.4	0	-	-	-	-	3	0.03	0.19	0.19	0.44	0	-	-	-	-
1036.1	49.1	0	-	-	-	-	3	-0.19	-0.04	0.19	0.44	0	-	-	-	-
1033.5	51.7	0	-	-	-	-	3	-0.05	0.08	0.09	0.28	0	-	-	-	-
1030.8	54.3	0	-	-	-	-	3	0.20	0.50	0.54	0.95	0	-	-	-	-
1028.2	56.9	0	-	-	-	-	3	0.67	0.40	0.78	1.41	0	-	-	-	-

Blue color represents the opening to the intake bays

Intake A - All Units Off (Unit 1, 2, 3, and 4 NOT Generating)
Southwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	24	-0.11	0.20	0.76	0.70	5	-0.06	0.19	0.20	0.34	11	-0.08	0.37	0.38	0.82
1083.2	2.0	23	-0.11	0.23	0.84	0.70	5	-0.06	0.24	0.25	0.35	11	-0.21	0.30	0.37	1.08
1082.8	2.3	24	-0.12	0.25	0.92	1.00	5	-0.09	0.14	0.16	0.21	11	-0.10	0.27	0.29	0.71
1082.5	2.6	24	-0.13	0.21	0.80	0.81	5	-0.10	0.24	0.26	0.47	10	-0.12	0.28	0.31	0.74
1082.2	3.0	24	-0.13	0.22	0.84	0.62	5	-0.15	0.25	0.29	0.39	11	-0.15	0.29	0.33	0.63
1080.7	4.4	24	-0.15	0.19	0.80	1.21	5	-0.18	0.10	0.21	0.61	11	0.04	0.15	0.15	0.55
1078.1	7.1	24	-0.06	0.13	0.46	0.74	5	-0.17	0.30	0.34	0.68	11	0.03	0.24	0.24	0.92
1075.4	9.7	24	-0.07	0.19	0.68	1.02	5	-0.08	0.21	0.23	0.55	11	0.05	0.21	0.21	0.80
1072.8	12.3	24	-0.14	0.11	0.57	0.98	5	-0.06	0.35	0.35	0.57	11	0.05	0.16	0.17	0.75
1070.2	14.9	23	-0.06	0.15	0.53	1.13	5	0.07	0.22	0.24	0.64	11	0.08	0.12	0.14	0.69
1067.6	17.6	24	-0.09	0.16	0.61	1.14	5	0.03	0.25	0.25	0.54	11	0.07	0.07	0.10	0.70
1064.9	20.2	24	-0.09	0.08	0.40	0.82	5	-0.02	0.18	0.18	0.31	11	0.04	-0.06	0.07	0.75
1062.3	22.8	24	-0.10	0.02	0.35	0.83	5	0.00	0.30	0.30	0.67	11	0.07	0.13	0.15	0.84
1059.7	25.4	24	-0.12	0.11	0.53	1.22	4	0.12	0.12	0.17	0.49	11	-0.03	0.08	0.09	0.77
1057.1	28.1	24	-0.18	-0.01	0.59	1.96	5	-0.20	0.08	0.21	0.59	11	-0.22	0.09	0.23	1.10
1054.5	30.7	24	-0.27	0.20	1.10	2.71	5	-0.50	0.40	0.64	2.09	10	-0.58	0.14	0.60	1.17
1051.8	33.3	24	-0.14	0.36	1.28	2.17	5	-0.43	0.49	0.65	1.69	11	-0.54	0.24	0.59	1.45
1049.2	35.9	22	-0.38	0.33	1.65	2.63	5	-0.76	0.55	0.94	1.75	11	-0.46	0.58	0.74	1.56
1046.6	38.6	20	-0.37	0.40	1.78	1.91	4	-1.14	0.57	1.27	1.87	11	-0.41	0.74	0.84	2.37
1044.0	41.2	20	-0.40	0.59	2.34	3.37	3	-1.65	0.71	1.80	2.95	11	-0.71	1.00	1.23	4.10
1041.3	43.8	13	-0.20	0.17	0.87	1.68	0	-	-	-	-	2	-0.73	0.25	0.78	1.21
1038.7	46.4	10	-0.52	0.26	1.89	1.75	0	-	-	-	-	1	-0.61	0.34	0.70	0.70
1036.1	49.1	6	-0.82	0.39	2.97	2.25	0	-	-	-	-	1	-1.31	0.90	1.59	1.59
1033.5	51.7	5	-0.67	-0.13	2.25	1.42	0	-	-	-	-	1	-0.52	0.40	0.66	0.66
1030.8	54.3	5	-0.63	-0.10	2.11	1.29	0	-	-	-	-	1	-0.41	0.04	0.41	0.41
1028.2	56.9	2	-1.76	0.30	5.84	1.90	0	-	-	-	-	1	-0.99	0.82	1.29	1.29

Blue color represents the opening to the intake bays

Intake A - One Unit Generating (Unit 1)

Northeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	112	0.31	-0.71	0.78	2.14	185	0.21	-0.55	0.59	1.72	83	0.33	-0.59	0.67	1.42
1083.2	2.0	110	0.33	-0.76	0.83	2.04	184	0.16	-0.52	0.54	1.83	83	0.28	-0.52	0.59	1.14
1082.8	2.3	112	0.31	-0.82	0.88	2.14	184	0.19	-0.52	0.55	1.97	83	0.29	-0.52	0.59	1.15
1082.5	2.6	111	0.30	-0.80	0.86	2.05	185	0.16	-0.53	0.55	2.25	83	0.24	-0.53	0.58	1.85
1082.2	3.0	112	0.28	-0.82	0.87	1.96	185	0.17	-0.49	0.52	2.60	83	0.28	-0.53	0.60	2.55
1080.7	4.4	112	0.33	-0.80	0.86	1.88	185	0.20	-0.51	0.55	1.99	83	0.29	-0.56	0.63	1.39
1078.1	7.1	112	0.35	-0.74	0.82	2.01	185	0.17	-0.54	0.57	2.19	83	0.22	-0.65	0.69	4.23
1075.5	9.7	112	0.35	-0.77	0.85	1.77	184	0.15	-0.57	0.59	1.68	83	0.15	-0.69	0.71	1.57
1072.8	12.3	112	0.29	-0.68	0.74	2.04	185	0.06	-0.57	0.57	1.85	81	0.06	-0.66	0.67	1.25
1070.2	14.9	112	0.24	-0.60	0.64	2.23	185	0.00	-0.59	0.59	2.02	83	-0.03	-0.73	0.73	1.48
1067.6	17.6	111	0.19	-0.55	0.58	1.89	184	-0.06	-0.55	0.55	1.81	83	-0.15	-0.79	0.81	1.82
1065.0	20.2	110	0.18	-0.47	0.50	1.66	182	-0.09	-0.60	0.61	1.62	83	-0.32	-0.84	0.90	1.86
1062.3	22.8	110	0.12	-0.43	0.44	1.59	182	-0.11	-0.56	0.57	1.67	83	-0.38	-0.81	0.89	1.78
1059.7	25.4	109	0.04	-0.46	0.46	1.54	181	-0.11	-0.54	0.55	1.65	83	-0.33	-0.74	0.81	1.56
1057.1	28.1	109	0.00	-0.41	0.41	1.50	182	-0.13	-0.52	0.53	1.58	83	-0.28	-0.70	0.75	1.56
1054.5	30.7	109	0.00	-0.37	0.37	1.81	182	-0.17	-0.57	0.59	1.74	83	-0.21	-0.68	0.71	1.86
1051.8	33.3	108	-0.03	-0.33	0.33	1.81	181	-0.14	-0.49	0.51	2.52	82	-0.06	-0.66	0.66	2.31
1049.2	35.9	105	-0.03	-0.34	0.34	1.80	168	-0.15	-0.45	0.47	1.98	77	0.02	-0.69	0.69	2.10
1046.6	38.6	102	0.00	-0.28	0.28	1.48	150	-0.20	-0.42	0.46	1.59	70	-0.05	-0.54	0.54	1.81
1044.0	41.2	91	0.03	-0.22	0.22	1.57	138	-0.15	-0.49	0.51	2.13	55	-0.08	-0.43	0.44	2.17
1041.3	43.8	73	-0.01	-0.12	0.12	1.83	102	-0.10	-0.43	0.44	1.96	22	-0.34	-0.44	0.56	2.00
1038.7	46.4	48	-0.09	-0.10	0.14	1.54	92	-0.05	-0.52	0.52	1.46	19	-0.37	-0.60	0.70	1.03
1036.1	49.1	25	-0.20	-0.18	0.27	1.66	83	-0.13	-0.41	0.44	1.52	16	-0.35	-0.49	0.60	0.92
1033.5	51.7	15	-0.20	-0.10	0.22	1.13	72	-0.16	-0.39	0.42	1.51	13	-0.39	-0.48	0.62	0.94
1030.8	54.3	13	-0.35	-0.45	0.57	1.33	52	-0.04	-0.45	0.46	1.75	12	-0.28	-0.74	0.80	1.00
1028.2	56.9	7	-0.25	-0.21	0.33	1.37	33	-0.01	-0.49	0.49	1.49	12	-0.19	-0.68	0.71	1.40

Blue color represents the opening to the intake bays

Intake A - One Unit Generating (Unit 1)

Southeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	9	-0.06	-0.06	0.26	2.57	1403	0.34	0.16	0.38	1.27	53	0.32	0.04	0.33	1.12
1083.2	2.0	8	0.13	0.07	0.46	1.76	1404	0.37	0.13	0.39	1.14	53	0.39	0.12	0.41	1.19
1082.8	2.3	9	-0.02	0.07	0.24	1.94	1412	0.39	0.13	0.41	1.15	53	0.40	0.12	0.42	0.95
1082.5	2.6	8	-0.10	0.00	0.34	2.14	1419	0.41	0.13	0.43	1.19	54	0.44	0.18	0.48	1.12
1082.2	3.0	9	0.35	-0.05	1.16	1.88	1419	0.41	0.14	0.44	1.16	54	0.38	0.16	0.41	1.29
1080.7	4.4	9	0.06	0.21	0.71	1.41	1427	0.45	0.11	0.46	1.18	54	0.40	0.29	0.49	1.32
1078.1	7.1	9	0.14	0.35	1.24	1.68	1425	0.49	-0.01	0.49	0.82	53	0.31	0.35	0.47	1.32
1075.5	9.7	9	0.26	0.26	1.20	1.48	1426	0.49	-0.02	0.49	0.90	54	0.20	0.39	0.44	1.34
1072.8	12.3	9	0.32	0.40	1.68	1.92	1423	0.46	-0.08	0.46	0.96	54	0.12	0.38	0.40	1.37
1070.2	14.9	9	0.21	0.20	0.97	1.61	1423	0.33	-0.04	0.33	1.25	54	0.04	0.46	0.46	1.36
1067.6	17.6	9	0.34	0.29	1.46	1.81	1423	0.27	-0.04	0.27	1.13	54	-0.03	0.51	0.51	1.34
1065.0	20.2	9	0.19	0.39	1.43	1.67	1397	0.26	-0.06	0.27	1.23	53	-0.17	0.49	0.52	1.94
1062.3	22.8	9	0.13	0.38	1.33	1.86	1403	0.24	-0.09	0.26	0.90	54	-0.12	0.51	0.53	1.15
1059.7	25.4	9	-0.02	0.39	1.28	1.71	1397	0.21	-0.10	0.23	1.52	54	-0.07	0.50	0.50	1.71
1057.1	28.1	9	-0.02	0.46	1.51	1.64	1396	0.20	-0.08	0.21	1.45	54	-0.08	0.40	0.41	2.07
1054.5	30.7	9	0.02	0.48	1.58	1.78	1395	0.21	-0.07	0.22	1.24	54	-0.10	0.37	0.39	2.70
1051.8	33.3	9	-0.11	0.52	1.74	2.17	1365	0.17	-0.06	0.18	1.16	53	-0.19	0.27	0.33	2.81
1049.2	35.9	7	-0.06	0.73	2.40	2.37	1313	0.10	0.02	0.10	1.39	50	-0.31	0.18	0.36	2.68
1046.6	38.6	7	-0.27	0.94	3.20	1.81	1241	0.06	0.04	0.07	1.11	45	-0.44	-0.01	0.44	2.06
1044.0	41.2	6	-0.17	1.02	3.39	2.42	1123	0.03	0.10	0.11	0.91	42	-0.57	0.01	0.57	1.29
1041.3	43.8	6	-0.05	0.68	2.24	1.76	567	0.04	0.11	0.12	1.22	6	-0.24	0.29	0.38	1.68
1038.7	46.4	6	-0.05	0.35	1.16	2.13	304	0.04	0.12	0.12	0.70	3	-0.23	-0.01	0.23	1.85
1036.1	49.1	6	-0.20	0.06	0.67	1.70	208	-0.06	0.12	0.14	0.90	3	0.19	-0.44	0.48	1.84
1033.5	51.7	6	-0.23	0.29	1.22	1.61	153	-0.02	0.13	0.14	1.35	3	-0.12	-0.16	0.20	1.60
1030.8	54.3	5	-0.32	0.05	1.05	1.27	109	-0.10	0.13	0.17	0.32	2	-0.44	0.21	0.48	1.19
1028.2	56.9	5	-0.23	-0.29	1.22	1.42	72	0.04	0.14	0.15	0.24	2	-1.26	-0.13	1.26	0.00

Blue color represents the opening to the intake bays

Intake A - One Unit Generating (Unit 1)

Northwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	598	0.38	0.12	0.39	1.14	312	0.46	0.20	0.50	1.33	107	0.58	0.21	0.62	1.05
1083.2	2.0	596	0.39	0.08	0.40	0.83	314	0.49	0.17	0.52	2.55	107	0.57	0.24	0.62	0.63
1082.8	2.3	596	0.42	0.06	0.42	0.95	319	0.46	0.19	0.50	2.37	113	0.66	0.24	0.70	0.66
1082.5	2.6	598	0.43	0.05	0.43	2.01	320	0.46	0.19	0.50	3.39	113	0.69	0.23	0.73	0.63
1082.2	3.0	594	0.44	0.06	0.44	1.03	320	0.46	0.21	0.51	1.94	114	0.74	0.23	0.78	0.64
1080.7	4.4	599	0.50	0.01	0.50	1.15	321	0.47	0.12	0.48	1.52	114	0.74	0.13	0.76	0.88
1078.1	7.1	598	0.57	-0.12	0.59	1.47	321	0.53	-0.13	0.55	1.21	114	0.71	-0.01	0.71	0.80
1075.5	9.7	598	0.62	-0.11	0.63	1.32	321	0.49	-0.24	0.54	1.42	114	0.67	-0.17	0.70	1.59
1072.8	12.3	596	0.57	-0.20	0.60	1.50	320	0.45	-0.29	0.54	1.68	114	0.61	-0.35	0.71	1.06
1070.2	14.9	597	0.38	-0.13	0.41	1.86	321	0.32	-0.25	0.41	1.36	113	0.54	-0.43	0.69	1.40
1067.6	17.6	597	0.30	-0.12	0.33	1.93	321	0.29	-0.29	0.41	1.66	114	0.49	-0.49	0.69	1.50
1065.0	20.2	593	0.30	-0.12	0.33	2.37	314	0.28	-0.38	0.47	1.44	114	0.41	-0.56	0.69	1.93
1062.3	22.8	594	0.30	-0.17	0.35	1.91	316	0.22	-0.41	0.46	1.39	114	0.39	-0.60	0.71	2.23
1059.7	25.4	591	0.25	-0.21	0.33	1.95	314	0.20	-0.41	0.45	1.43	114	0.39	-0.57	0.69	0.87
1057.1	28.1	590	0.24	-0.20	0.32	1.72	313	0.21	-0.33	0.39	1.65	114	0.38	-0.49	0.62	0.86
1054.5	30.7	592	0.28	-0.22	0.36	1.93	313	0.20	-0.29	0.35	1.56	113	0.32	-0.38	0.49	1.04
1051.8	33.3	583	0.23	-0.21	0.31	2.05	305	0.19	-0.24	0.31	1.63	113	0.26	-0.30	0.40	1.03
1049.2	35.9	567	0.14	-0.12	0.18	1.87	288	0.19	-0.17	0.25	1.60	112	0.24	-0.16	0.28	1.04
1046.6	38.6	538	0.19	-0.04	0.20	2.00	275	0.14	-0.16	0.21	2.23	106	0.20	-0.12	0.23	1.53
1044.0	41.2	501	0.21	0.03	0.21	1.89	228	0.16	-0.10	0.19	2.09	95	0.27	0.00	0.27	1.52
1041.3	43.8	218	0.22	0.00	0.22	1.29	154	0.11	-0.07	0.13	1.62	40	0.24	0.03	0.25	0.81
1038.7	46.4	114	0.28	-0.13	0.31	1.08	77	0.08	0.01	0.08	0.37	21	0.13	0.01	0.13	0.00
1036.1	49.1	67	0.22	-0.14	0.26	1.04	56	0.00	-0.13	0.13	0.89	12	0.30	0.43	0.53	0.00
1033.5	51.7	44	0.32	-0.17	0.37	0.79	50	0.06	-0.01	0.06	0.41	10	0.14	0.37	0.40	0.00
1030.8	54.3	30	0.20	-0.33	0.39	0.00	43	0.00	-0.05	0.05	0.55	5	0.39	0.47	0.61	0.00
1028.2	56.9	18	0.39	-0.45	0.59	0.00	29	0.13	0.00	0.13	1.66	3	0.39	0.55	0.67	0.00

Blue color represents the opening to the intake bays

Intake A - One Unit Generating (Unit 1)

Southwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	75	-0.03	0.17	0.56	1.83	123	0.13	0.24	0.27	1.52	100	0.22	0.18	0.28	0.88
1083.2	2.0	74	-0.01	0.08	0.27	1.68	123	0.16	0.20	0.26	1.22	102	0.32	0.15	0.35	1.46
1082.8	2.3	75	0.02	0.10	0.33	1.99	121	0.17	0.24	0.29	1.24	100	0.36	0.19	0.40	0.86
1082.5	2.6	74	0.12	0.16	0.65	2.02	123	0.23	0.24	0.34	1.37	102	0.33	0.18	0.38	1.58
1082.2	3.0	77	0.10	0.13	0.54	2.22	124	0.22	0.22	0.31	1.28	101	0.35	0.21	0.41	2.02
1080.7	4.4	77	0.10	0.14	0.57	1.88	125	0.28	0.23	0.36	1.54	102	0.39	0.28	0.48	1.54
1078.1	7.1	77	0.11	0.14	0.59	2.17	125	0.30	0.30	0.42	1.59	102	0.46	0.32	0.56	1.32
1075.5	9.7	77	0.07	0.23	0.78	2.01	125	0.33	0.36	0.49	1.26	102	0.41	0.42	0.59	1.12
1072.8	12.3	77	0.07	0.17	0.60	1.88	125	0.36	0.41	0.55	1.45	102	0.43	0.49	0.65	1.21
1070.2	14.9	77	-0.13	0.27	0.99	1.74	125	0.32	0.41	0.52	1.45	101	0.41	0.55	0.68	2.27
1067.6	17.6	76	-0.09	0.22	0.77	1.71	124	0.20	0.44	0.48	1.79	102	0.39	0.52	0.65	1.25
1065.0	20.2	67	0.04	0.27	0.88	2.02	122	0.16	0.47	0.49	1.79	100	0.42	0.53	0.68	1.24
1062.3	22.8	67	-0.02	0.26	0.85	2.00	124	0.22	0.47	0.52	2.17	100	0.34	0.58	0.67	1.72
1059.7	25.4	66	-0.07	0.32	1.08	1.91	124	0.18	0.48	0.51	1.81	100	0.32	0.60	0.68	1.85
1057.1	28.1	67	-0.11	0.29	1.00	1.74	124	0.16	0.48	0.51	1.97	100	0.29	0.60	0.67	1.56
1054.5	30.7	66	-0.06	0.23	0.77	2.19	124	0.14	0.48	0.51	1.77	99	0.24	0.54	0.59	1.54
1051.8	33.3	59	-0.06	0.14	0.49	2.31	122	0.14	0.48	0.50	2.07	98	0.17	0.59	0.61	1.60
1049.2	35.9	53	-0.17	0.34	1.25	2.47	119	0.00	0.54	0.54	2.31	92	0.00	0.65	0.65	1.71
1046.6	38.6	49	-0.37	0.29	1.54	2.62	114	-0.17	0.50	0.53	2.06	89	-0.26	0.59	0.65	1.95
1044.0	41.2	45	-0.42	0.38	1.86	2.51	105	-0.36	0.51	0.62	1.29	86	-0.46	0.59	0.75	1.87
1041.3	43.8	17	-0.30	0.46	1.81	2.22	69	-0.37	0.51	0.63	0.92	50	-0.31	0.57	0.65	1.12
1038.7	46.4	4	-0.01	1.93	6.35	1.89	39	-0.23	0.58	0.63	1.40	33	-0.40	0.54	0.67	1.83
1036.1	49.1	2	0.41	1.77	5.96	1.71	30	-0.51	0.78	0.93	1.15	28	-0.45	0.43	0.62	0.79
1033.5	51.7	0	-	-	-	-	21	-0.45	0.80	0.92	1.41	21	-0.50	0.43	0.66	1.05
1030.8	54.3	0	-	-	-	-	17	-0.74	0.93	1.19	1.16	12	-0.45	0.64	0.78	0.62
1028.2	56.9	0	-	-	-	-	12	-0.23	0.97	0.99	1.55	8	-0.46	0.66	0.81	1.14

Blue color represents the opening to the intake bays

Intake A - Two Units Generating (Unit 1 and 2)
Northeast Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1085.1	1.6	8	1.38	-0.97	1.68	2.42	13	-0.25	-1.47	1.49	2.46	64	0.26	-1.61	1.63	2.71
1084.8	2.0	8	0.52	-0.97	1.10	1.52	15	-0.12	-1.02	1.03	1.75	62	-0.02	-1.05	1.05	2.17
1084.4	2.3	8	0.35	-0.89	0.96	1.80	15	-0.35	-0.86	0.93	2.03	59	-0.13	-0.92	0.93	1.55
1084.1	2.6	7	0.14	-0.76	0.78	1.27	15	-0.24	-0.78	0.81	1.31	65	-0.27	-0.85	0.89	2.07
1083.8	3.0	8	0.05	-0.91	0.91	1.22	14	-0.22	-0.72	0.76	1.53	64	-0.29	-0.76	0.81	1.60
1082.3	4.4	8	0.14	-0.97	0.98	1.48	15	-0.32	-0.80	0.87	1.33	65	-0.29	-0.96	1.01	1.56
1079.7	7.1	8	0.03	-0.91	0.91	1.72	15	-0.30	-0.87	0.92	1.42	65	-0.31	-0.95	1.00	1.68
1077.1	9.7	7	0.12	-1.02	1.03	1.43	15	-0.20	-0.99	1.00	2.78	65	-0.36	-0.92	0.99	1.57
1074.4	12.3	8	-0.03	-1.14	1.14	1.67	15	-0.15	-0.92	0.93	2.39	65	-0.49	-0.99	1.10	1.84
1071.8	14.9	8	-0.02	-1.20	1.20	1.84	15	-0.50	-0.79	0.94	2.10	65	-0.61	-1.02	1.19	2.31
1069.2	17.6	8	0.33	-1.03	1.08	1.96	15	-0.38	-0.84	0.92	2.37	65	-0.64	-1.14	1.31	2.27
1066.6	20.2	8	0.65	-1.14	1.31	2.67	15	-0.40	-0.78	0.88	2.21	65	-0.70	-1.22	1.40	2.39
1063.9	22.8	8	0.73	-1.09	1.32	2.91	15	-0.42	-0.87	0.96	2.98	65	-0.47	-1.11	1.20	2.05
1061.3	25.4	8	0.69	-1.13	1.32	2.84	15	-0.61	-0.99	1.17	2.65	65	-0.17	-1.12	1.13	2.62
1058.7	28.1	8	0.89	-1.05	1.38	2.90	15	-0.39	-1.01	1.08	2.26	65	-0.10	-1.16	1.17	2.28
1056.1	30.7	8	1.35	-0.75	1.54	2.93	15	-0.37	-0.93	1.00	2.41	65	-0.05	-1.30	1.30	2.83
1053.4	33.3	8	1.32	-0.70	1.50	2.51	15	-0.28	-0.72	0.77	2.22	65	0.13	-1.46	1.47	3.05
1050.8	35.9	8	1.42	-0.75	1.60	2.67	15	-0.15	-0.83	0.84	2.16	61	0.18	-1.61	1.62	2.98
1048.2	38.6	8	1.57	-0.72	1.73	2.75	15	-0.24	-0.81	0.85	2.48	40	0.14	-1.44	1.45	2.94
1045.6	41.2	5	1.71	-0.72	1.86	2.73	13	-0.07	-0.63	0.63	2.40	25	0.20	-1.21	1.23	2.56
1042.9	43.8	5	1.95	-0.79	2.11	2.96	13	0.36	-1.18	1.23	3.22	15	0.60	-1.07	1.23	4.24
1040.3	46.4	4	1.72	-0.73	1.87	2.94	5	-0.21	-0.55	0.59	2.37	14	0.40	-1.32	1.38	2.78
1037.7	49.1	4	1.60	-0.81	1.80	2.79	5	-0.34	-0.96	1.02	2.25	11	0.25	-1.50	1.52	2.43
1035.1	51.7	3	0.90	-1.45	1.70	2.46	5	-0.58	-1.14	1.27	2.29	9	0.14	-1.60	1.61	2.71
1032.4	54.3	2	0.75	-0.93	1.19	2.93	4	-0.25	-1.33	1.36	2.46	5	-0.10	-1.42	1.42	2.46
1029.8	56.9	0	-	-	-	-	3	-1.39	-1.24	1.87	2.24	5	-0.10	-1.60	1.60	2.76

Blue color represents the opening to the intake bays

Intake A - Two Units Generating (Unit 1 and 2)
Southeast Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1085.1	1.6	9	-0.93	-0.73	3.87	1.59	4	-0.78	-0.87	1.17	1.81	28	0.17	-0.31	0.35	2.23
1084.8	2.0	8	-0.73	-0.27	2.55	1.73	3	-0.37	-0.37	0.52	1.29	27	0.67	0.09	0.68	2.26
1084.4	2.3	9	-0.76	-0.20	2.57	1.14	4	-0.64	-0.28	0.70	1.53	29	0.66	0.20	0.69	2.16
1084.1	2.6	9	-0.56	-0.10	1.87	1.08	4	-0.28	-0.16	0.33	1.26	29	0.74	0.20	0.76	2.12
1083.8	3.0	9	-0.62	-0.06	2.03	1.16	4	-0.08	-0.18	0.20	0.80	29	0.86	0.36	0.93	1.89
1082.3	4.4	9	-0.69	0.04	2.27	1.37	4	-0.37	0.04	0.37	1.58	29	0.82	0.39	0.91	2.20
1079.7	7.1	9	-0.71	0.25	2.48	1.17	4	-0.63	0.24	0.67	1.22	29	0.83	0.40	0.92	1.98
1077.1	9.7	9	-0.61	0.13	2.05	1.20	4	-0.57	0.33	0.66	1.46	29	0.77	0.37	0.85	2.10
1074.4	12.3	9	-0.77	0.06	2.54	1.80	4	-0.47	-0.12	0.48	1.58	29	0.59	0.36	0.70	1.96
1071.8	14.9	9	-0.65	0.01	2.14	1.77	4	-0.45	0.01	0.45	1.24	29	0.41	0.33	0.53	1.86
1069.2	17.6	9	-0.86	-0.04	2.81	2.08	4	-0.63	0.05	0.63	1.85	29	0.11	0.27	0.29	1.97
1066.6	20.2	9	-0.71	0.13	2.37	1.80	4	-0.97	0.41	1.05	1.97	29	0.07	0.45	0.46	2.53
1063.9	22.8	9	-0.87	0.05	2.85	1.89	4	-0.91	0.20	0.93	2.02	29	-0.05	0.38	0.38	2.89
1061.3	25.4	9	-1.19	-0.01	3.89	2.38	4	-1.15	0.04	1.15	2.15	29	-0.01	0.44	0.44	2.23
1058.7	28.1	9	-1.05	-0.27	3.56	2.46	4	-0.89	-0.19	0.91	1.86	29	-0.09	0.56	0.57	2.26
1056.1	30.7	9	-0.96	-0.78	4.07	2.44	4	-0.75	-0.47	0.88	1.68	29	-0.15	0.59	0.61	2.09
1053.4	33.3	9	-0.80	-0.84	3.81	1.87	4	-0.56	-0.56	0.80	1.19	29	-0.14	0.40	0.42	1.75
1050.8	35.9	9	-0.87	-1.02	4.40	2.19	4	-0.85	-0.70	1.10	1.91	29	-0.22	0.07	0.23	2.78
1048.2	38.6	9	-0.80	-1.14	4.57	2.27	4	-0.85	-0.90	1.24	1.99	27	-0.49	0.08	0.49	2.33
1045.6	41.2	9	-0.76	-1.17	4.59	1.93	4	-0.89	-0.89	1.26	1.78	23	-0.70	0.13	0.71	2.25
1042.9	43.8	9	-0.70	-1.43	5.21	2.34	4	-0.92	-1.18	1.49	2.24	13	-0.62	-0.04	0.62	2.24
1040.3	46.4	6	-0.81	-1.17	4.66	1.70	3	-0.89	-1.43	1.69	2.45	12	-0.79	-0.31	0.85	2.00
1037.7	49.1	9	-0.44	-0.86	3.17	0.98	3	-0.99	-2.15	2.37	3.24	10	-1.01	0.00	1.01	2.05
1035.1	51.7	7	-0.59	-0.69	2.97	1.49	2	-1.48	-1.93	2.44	2.75	8	-1.38	0.10	1.39	2.08
1032.4	54.3	8	-0.51	-0.35	2.04	2.81	1	-1.39	-2.00	2.44	2.44	7	-1.63	-0.42	1.68	2.09
1029.8	56.9	0	-	-	-	-	0	-	-	-	-	5	-1.70	-0.56	1.79	2.59

Blue color represents the opening to the intake bays

Intake A - Two Units Generating (Unit 1 and 2)
Northwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1085.1	1.6	25	1.36	-0.01	1.36	2.41	23	0.72	0.55	0.90	1.91	59	1.20	0.18	1.21	2.52
1084.8	2.0	24	0.83	-0.36	0.91	2.05	23	0.75	-0.03	0.75	1.21	58	0.86	-0.59	1.04	3.38
1084.4	2.3	25	0.69	-0.51	0.86	1.56	23	0.71	-0.41	0.82	1.27	60	0.74	-0.74	1.04	1.81
1084.1	2.6	25	0.57	-0.65	0.86	1.55	23	0.75	-0.48	0.89	1.21	62	0.64	-0.75	0.98	1.82
1083.8	3.0	26	0.53	-0.56	0.77	1.51	22	0.79	-0.56	0.97	1.72	61	0.59	-0.83	1.02	1.92
1082.3	4.4	26	0.65	-0.68	0.94	1.35	23	0.85	-0.55	1.01	1.84	62	0.68	-0.92	1.14	1.88
1079.7	7.1	26	0.69	-0.72	0.99	1.46	23	0.82	-0.59	1.00	1.60	62	0.74	-0.88	1.15	1.56
1077.1	9.7	26	0.85	-0.58	1.03	1.93	23	0.89	-0.54	1.04	1.63	62	0.84	-0.89	1.23	1.64
1074.4	12.3	26	0.91	-0.45	1.02	2.01	23	0.99	-0.55	1.13	1.80	62	0.92	-0.94	1.32	2.06
1071.8	14.9	26	0.82	-0.37	0.90	1.92	23	1.12	-0.42	1.20	1.86	62	1.03	-0.95	1.40	2.00
1069.2	17.6	26	1.03	-0.23	1.05	2.19	23	1.08	-0.19	1.10	1.95	62	1.16	-0.97	1.51	2.32
1066.6	20.2	26	1.13	-0.10	1.13	2.34	23	0.83	0.10	0.83	1.95	62	1.25	-0.96	1.58	2.48
1063.9	22.8	26	1.10	-0.27	1.13	2.48	23	0.92	-0.02	0.92	1.87	62	1.26	-0.60	1.39	2.24
1061.3	25.4	26	1.16	-0.26	1.19	2.26	23	1.03	0.02	1.03	2.30	62	1.17	-0.21	1.19	2.33
1058.7	28.1	26	1.03	-0.12	1.04	2.71	23	1.09	0.21	1.11	2.47	62	1.09	0.07	1.09	2.13
1056.1	30.7	26	1.14	0.08	1.15	2.03	23	1.04	0.36	1.10	2.07	62	1.17	0.24	1.19	2.42
1053.4	33.3	26	1.27	0.18	1.28	2.18	23	0.94	0.53	1.08	2.29	62	1.27	0.44	1.34	2.59
1050.8	35.9	26	1.44	0.09	1.44	2.48	22	0.85	0.56	1.02	2.12	60	1.46	0.55	1.56	2.46
1048.2	38.6	26	1.39	0.29	1.42	2.55	22	0.59	0.68	0.90	2.07	50	1.28	0.61	1.41	2.60
1045.6	41.2	21	1.36	0.38	1.41	2.52	21	0.59	0.82	1.01	1.86	29	1.43	0.26	1.45	2.86
1042.9	43.8	14	1.48	0.42	1.54	2.70	18	0.62	0.86	1.06	2.02	21	1.19	0.06	1.19	2.22
1040.3	46.4	12	1.26	0.43	1.33	2.37	16	0.63	0.92	1.12	1.81	11	0.98	0.11	0.98	2.74
1037.7	49.1	7	1.38	0.43	1.45	2.37	12	0.69	1.16	1.35	1.96	4	1.16	0.63	1.32	2.15
1035.1	51.7	5	1.53	0.61	1.65	2.31	10	0.83	1.47	1.69	2.22	3	0.89	0.58	1.06	1.86
1032.4	54.3	2	1.96	1.65	2.56	3.04	6	0.86	1.55	1.77	2.19	0	-	-	-	-
1029.8	56.9	0	-	-	-	-	3	1.19	1.40	1.84	2.40	0	-	-	-	-

Blue color represents the opening to the intake bays

Intake A - Two Units Generating (Unit 1 and 2)
Southwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1085.1	1.6	0	-	-	-	-	32	0.17	0.69	0.71	1.60	90	-0.11	0.55	0.57	2.26
1084.8	2.0	0	-	-	-	-	31	0.66	0.06	0.66	1.78	91	0.64	0.10	0.65	2.35
1084.4	2.3	0	-	-	-	-	32	0.72	-0.13	0.73	1.36	91	0.89	-0.03	0.89	5.20
1084.1	2.6	0	-	-	-	-	32	0.89	-0.19	0.91	1.32	92	1.05	-0.08	1.06	5.40
1083.8	3.0	0	-	-	-	-	32	0.89	-0.23	0.92	1.73	92	1.10	-0.07	1.10	4.05
1082.3	4.4	0	-	-	-	-	32	0.90	-0.26	0.94	1.92	94	1.16	-0.15	1.17	1.91
1079.7	7.1	0	-	-	-	-	32	0.96	-0.22	0.99	1.56	94	1.19	-0.07	1.19	1.93
1077.1	9.7	0	-	-	-	-	32	0.89	-0.11	0.90	1.38	94	1.19	0.04	1.19	1.90
1074.4	12.3	0	-	-	-	-	32	0.72	0.13	0.73	1.61	94	1.17	0.16	1.18	1.98
1071.8	14.9	0	-	-	-	-	32	0.69	0.35	0.78	1.75	94	1.20	0.35	1.25	2.41
1069.2	17.6	0	-	-	-	-	32	0.65	0.43	0.78	2.26	94	1.22	0.55	1.34	2.67
1066.6	20.2	0	-	-	-	-	32	0.66	0.53	0.85	2.40	94	1.10	0.79	1.35	3.05
1063.9	22.8	0	-	-	-	-	32	0.69	0.56	0.89	2.36	94	0.87	0.89	1.25	3.31
1061.3	25.4	0	-	-	-	-	32	0.54	0.72	0.90	1.99	94	0.51	0.80	0.94	2.42
1058.7	28.1	0	-	-	-	-	32	0.60	0.66	0.90	2.36	92	0.36	0.81	0.89	2.26
1056.1	30.7	0	-	-	-	-	32	0.61	0.79	1.00	3.02	94	0.32	0.89	0.94	2.74
1053.4	33.3	0	-	-	-	-	32	0.49	0.90	1.02	4.12	94	0.12	0.93	0.94	2.13
1050.8	35.9	0	-	-	-	-	30	0.32	0.91	0.97	3.07	90	-0.06	0.98	0.98	2.23
1048.2	38.6	0	-	-	-	-	28	0.28	1.02	1.06	2.82	86	-0.27	0.84	0.88	2.09
1045.6	41.2	0	-	-	-	-	26	-0.05	1.00	1.00	1.78	74	-0.43	0.71	0.83	2.48
1042.9	43.8	0	-	-	-	-	17	-0.01	1.12	1.12	1.77	35	-0.49	0.84	0.97	3.05
1040.3	46.4	0	-	-	-	-	17	-0.06	1.36	1.36	2.13	26	-0.13	0.83	0.84	1.69
1037.7	49.1	0	-	-	-	-	12	-0.09	1.35	1.35	1.92	25	-0.32	0.91	0.97	1.76
1035.1	51.7	0	-	-	-	-	11	-0.22	1.42	1.43	2.16	23	-0.49	0.95	1.07	1.91
1032.4	54.3	0	-	-	-	-	8	-0.31	1.23	1.27	2.02	17	-0.68	0.99	1.20	1.96
1029.8	56.9	0	-	-	-	-	7	-0.36	1.14	1.20	1.56	12	-0.61	1.19	1.34	2.41

Blue color represents the opening to the intake bays

Intake A - Two Units Generating (Unit 1 and 2) (Also Units 3 and 4 Generating)
Northeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.8	1.6	0	-	-	-	-	23	1.27	-0.79	1.50	2.59	104	0.15	-1.01	1.03	2.24
1084.4	2.0	0	-	-	-	-	23	0.72	-0.83	1.10	1.63	104	0.01	-0.49	0.49	1.97
1084.1	2.3	0	-	-	-	-	23	0.47	-0.87	0.99	1.25	105	-0.11	-0.33	0.35	2.35
1083.8	2.6	0	-	-	-	-	24	0.27	-0.84	0.88	1.49	106	-0.20	-0.33	0.39	1.47
1083.4	3.0	0	-	-	-	-	23	0.31	-0.85	0.90	1.21	105	-0.17	-0.30	0.35	3.19
1082.0	4.4	0	-	-	-	-	24	0.32	-0.94	0.99	2.05	106	-0.21	-0.36	0.42	1.51
1079.3	7.1	0	-	-	-	-	24	0.35	-1.03	1.09	1.75	108	-0.26	-0.44	0.51	1.40
1076.7	9.7	0	-	-	-	-	24	0.46	-0.95	1.06	1.65	107	-0.34	-0.50	0.60	1.54
1074.1	12.3	0	-	-	-	-	24	0.33	-1.09	1.14	1.89	108	-0.42	-0.57	0.70	1.57
1071.5	14.9	0	-	-	-	-	24	0.29	-1.15	1.19	1.93	108	-0.43	-0.58	0.72	1.57
1068.8	17.6	0	-	-	-	-	24	0.42	-1.27	1.34	2.40	108	-0.54	-0.67	0.86	1.84
1066.2	20.2	0	-	-	-	-	24	0.56	-1.23	1.35	2.24	108	-0.56	-0.73	0.93	1.99
1063.6	22.8	0	-	-	-	-	24	0.76	-1.25	1.46	2.78	108	-0.44	-0.86	0.96	2.14
1061.0	25.4	0	-	-	-	-	24	0.66	-1.31	1.46	2.72	108	-0.25	-1.02	1.05	2.02
1058.3	28.1	0	-	-	-	-	24	0.76	-1.34	1.54	2.64	108	-0.14	-1.15	1.16	2.41
1055.7	30.7	0	-	-	-	-	24	1.17	-1.15	1.64	3.03	108	-0.13	-1.29	1.30	2.40
1053.1	33.3	0	-	-	-	-	24	1.42	-1.00	1.74	2.91	108	-0.12	-1.29	1.30	2.47
1050.5	35.9	0	-	-	-	-	24	1.58	-0.88	1.81	4.12	104	-0.16	-1.37	1.38	2.54
1047.8	38.6	0	-	-	-	-	24	1.77	-0.66	1.89	4.19	92	-0.11	-1.25	1.26	2.93
1045.2	41.2	0	-	-	-	-	22	1.70	-0.78	1.87	3.69	68	0.15	-1.22	1.23	3.64
1042.6	43.8	0	-	-	-	-	20	1.89	-0.92	2.10	2.81	38	0.70	-1.12	1.32	2.38
1040.0	46.4	0	-	-	-	-	16	2.34	-0.98	2.54	3.28	22	0.68	-0.90	1.13	2.44
1037.3	49.1	0	-	-	-	-	9	2.29	-0.93	2.47	3.44	21	0.94	-1.24	1.55	3.30
1034.7	51.7	0	-	-	-	-	8	2.40	-0.89	2.56	3.57	21	0.94	-1.31	1.62	3.41
1032.1	54.3	0	-	-	-	-	3	2.86	-1.99	3.49	4.22	18	1.12	-1.39	1.79	3.70
1029.5	56.9	0	-	-	-	-	2	3.09	-1.03	3.26	4.10	13	1.10	-1.57	1.92	4.05

Blue color represents the opening to the intake bays

Intake A - Two Units Generating (Unit 1 and 2) (Also Units 3 and 4 Generating)
Southeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	9	-0.06	-0.06	0.26	2.57	1403	0.34	0.16	0.38	1.27	53	0.32	0.04	0.33	1.12
1083.2	2.0	8	0.13	0.07	0.46	1.76	1404	0.37	0.13	0.39	1.14	53	0.39	0.12	0.41	1.19
1082.8	2.3	9	-0.02	0.07	0.24	1.94	1412	0.39	0.13	0.41	1.15	53	0.40	0.12	0.42	0.95
1082.5	2.6	8	-0.10	0.00	0.34	2.14	1419	0.41	0.13	0.43	1.19	54	0.44	0.18	0.48	1.12
1082.2	3.0	9	0.35	-0.05	1.16	1.88	1419	0.41	0.14	0.44	1.16	54	0.38	0.16	0.41	1.29
1080.7	4.4	9	0.06	0.21	0.71	1.41	1427	0.45	0.11	0.46	1.18	54	0.40	0.29	0.49	1.32
1078.1	7.1	9	0.14	0.35	1.24	1.68	1425	0.49	-0.01	0.49	0.82	53	0.31	0.35	0.47	1.32
1075.5	9.7	9	0.26	0.26	1.20	1.48	1426	0.49	-0.02	0.49	0.90	54	0.20	0.39	0.44	1.34
1072.8	12.3	9	0.32	0.40	1.68	1.92	1423	0.46	-0.08	0.46	0.96	54	0.12	0.38	0.40	1.37
1070.2	14.9	9	0.21	0.20	0.97	1.61	1423	0.33	-0.04	0.33	1.25	54	0.04	0.46	0.46	1.36
1067.6	17.6	9	0.34	0.29	1.46	1.81	1423	0.27	-0.04	0.27	1.13	54	-0.03	0.51	0.51	1.34
1065.0	20.2	9	0.19	0.39	1.43	1.67	1397	0.26	-0.06	0.27	1.23	53	-0.17	0.49	0.52	1.94
1062.3	22.8	9	0.13	0.38	1.33	1.86	1403	0.24	-0.09	0.26	0.90	54	-0.12	0.51	0.53	1.15
1059.7	25.4	9	-0.02	0.39	1.28	1.71	1397	0.21	-0.10	0.23	1.52	54	-0.07	0.50	0.50	1.71
1057.1	28.1	9	-0.02	0.46	1.51	1.64	1396	0.20	-0.08	0.21	1.45	54	-0.08	0.40	0.41	2.07
1054.5	30.7	9	0.02	0.48	1.58	1.78	1395	0.21	-0.07	0.22	1.24	54	-0.10	0.37	0.39	2.70
1051.8	33.3	9	-0.11	0.52	1.74	2.17	1365	0.17	-0.06	0.18	1.16	53	-0.19	0.27	0.33	2.81
1049.2	35.9	7	-0.06	0.73	2.40	2.37	1313	0.10	0.02	0.10	1.39	50	-0.31	0.18	0.36	2.68
1046.6	38.6	7	-0.27	0.94	3.20	1.81	1241	0.06	0.04	0.07	1.11	45	-0.44	-0.01	0.44	2.06
1044.0	41.2	6	-0.17	1.02	3.39	2.42	1123	0.03	0.10	0.11	0.91	42	-0.57	0.01	0.57	1.29
1041.3	43.8	6	-0.05	0.68	2.24	1.76	567	0.04	0.11	0.12	1.22	6	-0.24	0.29	0.38	1.68
1038.7	46.4	6	-0.05	0.35	1.16	2.13	304	0.04	0.12	0.12	0.70	3	-0.23	-0.01	0.23	1.85
1036.1	49.1	6	-0.20	0.06	0.67	1.70	208	-0.06	0.12	0.14	0.90	3	0.19	-0.44	0.48	1.84
1033.5	51.7	6	-0.23	0.29	1.22	1.61	153	-0.02	0.13	0.14	1.35	3	-0.12	-0.16	0.20	1.60
1030.8	54.3	5	-0.32	0.05	1.05	1.27	109	-0.10	0.13	0.17	0.32	2	-0.44	0.21	0.48	1.19
1028.2	56.9	5	-0.23	-0.29	1.22	1.42	72	0.04	0.14	0.15	0.24	2	-1.26	-0.13	1.26	0.00

Blue color represents the opening to the intake bays

Intake A - Two Units Generating (Unit 1 and 2) (Also Units 3 and 4 Generating)
Northwest Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	598	0.38	0.12	0.39	1.14	312	0.46	0.20	0.50	1.33	107	0.58	0.21	0.62	1.05
1083.2	2.0	596	0.39	0.08	0.40	0.83	314	0.49	0.17	0.52	2.55	107	0.57	0.24	0.62	0.63
1082.8	2.3	596	0.42	0.06	0.42	0.95	319	0.46	0.19	0.50	2.37	113	0.66	0.24	0.70	0.66
1082.5	2.6	598	0.43	0.05	0.43	2.01	320	0.46	0.19	0.50	3.39	113	0.69	0.23	0.73	0.63
1082.2	3.0	594	0.44	0.06	0.44	1.03	320	0.46	0.21	0.51	1.94	114	0.74	0.23	0.78	0.64
1080.7	4.4	599	0.50	0.01	0.50	1.15	321	0.47	0.12	0.48	1.52	114	0.74	0.13	0.76	0.88
1078.1	7.1	598	0.57	-0.12	0.59	1.47	321	0.53	-0.13	0.55	1.21	114	0.71	-0.01	0.71	0.80
1075.5	9.7	598	0.62	-0.11	0.63	1.32	321	0.49	-0.24	0.54	1.42	114	0.67	-0.17	0.70	1.59
1072.8	12.3	596	0.57	-0.20	0.60	1.50	320	0.45	-0.29	0.54	1.68	114	0.61	-0.35	0.71	1.06
1070.2	14.9	597	0.38	-0.13	0.41	1.86	321	0.32	-0.25	0.41	1.36	113	0.54	-0.43	0.69	1.40
1067.6	17.6	597	0.30	-0.12	0.33	1.93	321	0.29	-0.29	0.41	1.66	114	0.49	-0.49	0.69	1.50
1065.0	20.2	593	0.30	-0.12	0.33	2.37	314	0.28	-0.38	0.47	1.44	114	0.41	-0.56	0.69	1.93
1062.3	22.8	594	0.30	-0.17	0.35	1.91	316	0.22	-0.41	0.46	1.39	114	0.39	-0.60	0.71	2.23
1059.7	25.4	591	0.25	-0.21	0.33	1.95	314	0.20	-0.41	0.45	1.43	114	0.39	-0.57	0.69	0.87
1057.1	28.1	590	0.24	-0.20	0.32	1.72	313	0.21	-0.33	0.39	1.65	114	0.38	-0.49	0.62	0.86
1054.5	30.7	592	0.28	-0.22	0.36	1.93	313	0.20	-0.29	0.35	1.56	113	0.32	-0.38	0.49	1.04
1051.8	33.3	583	0.23	-0.21	0.31	2.05	305	0.19	-0.24	0.31	1.63	113	0.26	-0.30	0.40	1.03
1049.2	35.9	567	0.14	-0.12	0.18	1.87	288	0.19	-0.17	0.25	1.60	112	0.24	-0.16	0.28	1.04
1046.6	38.6	538	0.19	-0.04	0.20	2.00	275	0.14	-0.16	0.21	2.23	106	0.20	-0.12	0.23	1.53
1044.0	41.2	501	0.21	0.03	0.21	1.89	228	0.16	-0.10	0.19	2.09	95	0.27	0.00	0.27	1.52
1041.3	43.8	218	0.22	0.00	0.22	1.29	154	0.11	-0.07	0.13	1.62	40	0.24	0.03	0.25	0.81
1038.7	46.4	114	0.28	-0.13	0.31	1.08	77	0.08	0.01	0.08	0.37	21	0.13	0.01	0.13	0.00
1036.1	49.1	67	0.22	-0.14	0.26	1.04	56	0.00	-0.13	0.13	0.89	12	0.30	0.43	0.53	0.00
1033.5	51.7	44	0.32	-0.17	0.37	0.79	50	0.06	-0.01	0.06	0.41	10	0.14	0.37	0.40	0.00
1030.8	54.3	30	0.20	-0.33	0.39	0.00	43	0.00	-0.05	0.05	0.55	5	0.39	0.47	0.61	0.00
1028.2	56.9	18	0.39	-0.45	0.59	0.00	29	0.13	0.00	0.13	1.66	3	0.39	0.55	0.67	0.00

Blue color represents the opening to the intake bays

Intake A - Two Units Generating (Unit 1 and 2) (Also Units 3 and 4 Generating)
Southwest Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	75	-0.03	0.17	0.56	1.83	123	0.13	0.24	0.27	1.52	100	0.22	0.18	0.28	0.88
1083.2	2.0	74	-0.01	0.08	0.27	1.68	123	0.16	0.20	0.26	1.22	102	0.32	0.15	0.35	1.46
1082.8	2.3	75	0.02	0.10	0.33	1.99	121	0.17	0.24	0.29	1.24	100	0.36	0.19	0.40	0.86
1082.5	2.6	74	0.12	0.16	0.65	2.02	123	0.23	0.24	0.34	1.37	102	0.33	0.18	0.38	1.58
1082.2	3.0	77	0.10	0.13	0.54	2.22	124	0.22	0.22	0.31	1.28	101	0.35	0.21	0.41	2.02
1080.7	4.4	77	0.10	0.14	0.57	1.88	125	0.28	0.23	0.36	1.54	102	0.39	0.28	0.48	1.54
1078.1	7.1	77	0.11	0.14	0.59	2.17	125	0.30	0.30	0.42	1.59	102	0.46	0.32	0.56	1.32
1075.5	9.7	77	0.07	0.23	0.78	2.01	125	0.33	0.36	0.49	1.26	102	0.41	0.42	0.59	1.12
1072.8	12.3	77	0.07	0.17	0.60	1.88	125	0.36	0.41	0.55	1.45	102	0.43	0.49	0.65	1.21
1070.2	14.9	77	-0.13	0.27	0.99	1.74	125	0.32	0.41	0.52	1.45	101	0.41	0.55	0.68	2.27
1067.6	17.6	76	-0.09	0.22	0.77	1.71	124	0.20	0.44	0.48	1.79	102	0.39	0.52	0.65	1.25
1065.0	20.2	67	0.04	0.27	0.88	2.02	122	0.16	0.47	0.49	1.79	100	0.42	0.53	0.68	1.24
1062.3	22.8	67	-0.02	0.26	0.85	2.00	124	0.22	0.47	0.52	2.17	100	0.34	0.58	0.67	1.72
1059.7	25.4	66	-0.07	0.32	1.08	1.91	124	0.18	0.48	0.51	1.81	100	0.32	0.60	0.68	1.85
1057.1	28.1	67	-0.11	0.29	1.00	1.74	124	0.16	0.48	0.51	1.97	100	0.29	0.60	0.67	1.56
1054.5	30.7	66	-0.06	0.23	0.77	2.19	124	0.14	0.48	0.51	1.77	99	0.24	0.54	0.59	1.54
1051.8	33.3	59	-0.06	0.14	0.49	2.31	122	0.14	0.48	0.50	2.07	98	0.17	0.59	0.61	1.60
1049.2	35.9	53	-0.17	0.34	1.25	2.47	119	0.00	0.54	0.54	2.31	92	0.00	0.65	0.65	1.71
1046.6	38.6	49	-0.37	0.29	1.54	2.62	114	-0.17	0.50	0.53	2.06	89	-0.26	0.59	0.65	1.95
1044.0	41.2	45	-0.42	0.38	1.86	2.51	105	-0.36	0.51	0.62	1.29	86	-0.46	0.59	0.75	1.87
1041.3	43.8	17	-0.30	0.46	1.81	2.22	69	-0.37	0.51	0.63	0.92	50	-0.31	0.57	0.65	1.12
1038.7	46.4	4	-0.01	1.93	6.35	1.89	39	-0.23	0.58	0.63	1.40	33	-0.40	0.54	0.67	1.83
1036.1	49.1	2	0.41	1.77	5.96	1.71	30	-0.51	0.78	0.93	1.15	28	-0.45	0.43	0.62	0.79
1033.5	51.7	0	-	-	-	-	21	-0.45	0.80	0.92	1.41	21	-0.50	0.43	0.66	1.05
1030.8	54.3	0	-	-	-	-	17	-0.74	0.93	1.19	1.16	12	-0.45	0.64	0.78	0.62
1028.2	56.9	0	-	-	-	-	12	-0.23	0.97	0.99	1.55	8	-0.46	0.66	0.81	1.14

Blue color represents the opening to the intake bays

Intake B - All Units Off (Unit 1, 2, 3, and 4 NOT Generating)
Northeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	0	-	-	-	-	33	0.29	0.19	0.34	1.07	30	-0.17	-0.21	0.27	1.80
1083.1	2.0	0	-	-	-	-	33	0.13	0.15	0.20	0.81	30	0.02	-0.03	0.03	1.59
1082.8	2.3	0	-	-	-	-	32	0.13	0.13	0.19	0.91	30	0.04	-0.11	0.12	1.78
1082.5	2.6	0	-	-	-	-	32	0.14	0.20	0.24	0.94	28	0.08	-0.10	0.13	1.69
1082.1	3.0	0	-	-	-	-	32	0.08	0.15	0.17	0.93	29	0.11	-0.12	0.16	2.00
1080.7	4.4	0	-	-	-	-	33	-0.01	0.20	0.20	0.86	30	0.04	-0.12	0.13	2.38
1078.0	7.1	0	-	-	-	-	33	-0.03	0.09	0.10	0.92	30	0.03	-0.15	0.15	1.86
1075.4	9.7	0	-	-	-	-	33	-0.03	0.17	0.18	0.77	30	-0.01	-0.16	0.16	2.19
1072.8	12.3	0	-	-	-	-	33	0.01	0.16	0.16	1.20	29	-0.03	-0.24	0.24	2.26
1070.2	14.9	0	-	-	-	-	33	-0.04	0.09	0.09	0.72	30	-0.07	-0.20	0.21	1.62
1067.5	17.6	0	-	-	-	-	33	-0.12	0.10	0.16	0.80	30	-0.02	-0.35	0.35	1.93
1064.9	20.2	0	-	-	-	-	33	-0.13	0.09	0.16	0.96	29	-0.07	-0.32	0.32	1.98
1062.3	22.8	0	-	-	-	-	33	-0.10	0.01	0.10	0.89	30	-0.03	-0.28	0.28	1.60
1059.7	25.4	0	-	-	-	-	33	-0.07	0.02	0.07	1.08	29	-0.05	-0.40	0.40	2.11
1057.0	28.1	0	-	-	-	-	32	-0.04	-0.14	0.15	1.84	30	-0.14	-0.43	0.45	2.02
1054.4	30.7	0	-	-	-	-	32	-0.05	-0.13	0.13	1.80	30	-0.14	-0.43	0.45	1.73
1051.8	33.3	0	-	-	-	-	33	-0.02	-0.09	0.09	1.50	30	-0.35	-0.45	0.57	1.83
1049.2	35.9	0	-	-	-	-	33	0.19	0.10	0.21	1.61	27	-0.97	-0.35	1.03	2.08
1046.5	38.6	0	-	-	-	-	32	0.13	0.08	0.16	1.62	18	-0.97	-0.35	1.03	2.22
1043.9	41.2	0	-	-	-	-	23	0.61	0.03	0.61	3.37	7	-0.35	-0.45	0.56	1.12
1041.3	43.8	0	-	-	-	-	8	0.05	0.58	0.58	1.54	4	-0.32	-0.35	0.47	2.17
1038.7	46.4	0	-	-	-	-	8	-0.15	0.64	0.66	1.31	4	-0.36	-0.45	0.58	0.00
1036.0	49.1	0	-	-	-	-	5	-0.02	0.14	0.14	0.61	4	-0.41	-0.66	0.78	0.00
1033.4	51.7	0	-	-	-	-	4	-0.15	0.00	0.15	0.47	3	-0.26	-0.78	0.82	0.00
1030.8	54.3	0	-	-	-	-	2	0.07	-0.67	0.67	0.00	2	-0.25	-0.65	0.69	0.00
1028.2	56.9	0	-	-	-	-	3	-0.11	-0.66	0.67	0.00	1	-0.59	-0.58	0.82	0.00

Blue color represents the opening to the intake bays

Intake B - All Units Off (Unit 1, 2, 3, and 4 NOT Generating)
Southeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	5	-0.01	0.26	0.87	0.51	1	0.03	0.45	0.45	0.45	1	-0.03	0.71	0.71	0.71
1083.2	2.0	6	0.18	0.22	0.92	0.41	1	0.34	0.49	0.60	0.60	1	-0.01	0.66	0.66	0.66
1082.8	2.3	6	0.52	0.27	1.90	2.06	1	0.44	0.30	0.53	0.53	1	0.04	0.76	0.77	0.77
1082.5	2.6	6	0.05	0.22	0.75	0.43	1	0.24	0.35	0.42	0.42	1	0.46	0.57	0.73	0.73
1082.2	3.0	6	0.18	0.22	0.93	0.53	1	0.50	0.18	0.53	0.53	1	0.06	0.63	0.64	0.64
1080.7	4.4	6	0.26	0.34	1.42	0.78	1	0.52	0.36	0.63	0.63	1	0.12	0.65	0.66	0.66
1078.1	7.1	6	0.22	0.36	1.39	0.64	1	0.48	0.15	0.50	0.50	1	0.46	0.69	0.83	0.83
1075.4	9.7	6	0.25	0.25	1.14	0.42	1	0.44	-0.12	0.46	0.46	1	0.31	0.60	0.67	0.67
1072.8	12.3	6	0.11	0.22	0.82	0.31	1	0.38	-0.05	0.38	0.38	1	0.41	0.59	0.71	0.71
1070.2	14.9	6	0.10	0.29	0.99	0.63	1	0.31	0.05	0.31	0.31	1	0.46	0.55	0.72	0.72
1067.6	17.6	6	-0.09	0.09	0.43	0.51	1	0.36	-0.03	0.36	0.36	1	0.10	0.24	0.26	0.36
1064.9	20.2	6	-0.03	0.01	0.10	0.32	1	0.63	-0.24	0.68	0.68	1	-0.20	0.18	0.27	0.68
1062.3	22.8	6	-0.13	0.03	0.43	0.51	1	0.21	0.25	0.32	0.32	1	0.02	0.12	0.12	0.32
1059.7	25.4	6	0.05	-0.10	0.36	0.71	1	0.46	-0.38	0.59	0.59	1	0.01	-0.01	0.01	0.59
1057.1	28.1	6	0.03	-0.06	0.21	0.41	1	0.08	0.06	0.09	0.09	1	-0.04	0.14	0.14	0.14
1054.5	30.7	6	-0.14	-0.12	0.61	0.70	1	0.38	-0.38	0.54	0.54	1	-0.15	0.23	0.28	0.54
1051.8	33.3	6	-0.28	-0.03	0.91	0.88	1	0.10	-0.47	0.48	0.48	1	-0.10	0.14	0.17	0.48
1049.2	35.9	5	-0.39	0.13	1.34	1.04	1	-0.01	-0.21	0.21	0.21	1	-0.64	0.35	0.73	0.73
1046.6	38.6	4	-0.47	0.38	1.98	1.46	1	-0.75	-0.39	0.85	0.85	1	-0.48	0.21	0.52	0.85
1044.0	41.2	4	-0.25	-0.15	0.96	0.88	1	-1.19	2.13	2.44	2.44	1	-0.39	2.06	2.10	2.44
1041.3	43.8	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-
1038.7	46.4	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-
1036.1	49.1	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-
1033.5	51.7	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-
1030.8	54.3	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-
1028.2	56.9	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-

Blue color represents the opening to the intake bays

Intake B - All Units Off (Unit 1, 2, 3, and 4 NOT Generating)
Northwest Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	0	-	-	-	-	11	0.51	0.14	0.53	1.26	23	0.40	0.47	0.62	1.64
1083.2	2.0	0	-	-	-	-	11	0.41	0.03	0.41	1.05	23	0.15	0.21	0.26	0.96
1082.8	2.3	0	-	-	-	-	11	0.29	-0.05	0.30	1.10	23	0.15	0.17	0.23	1.20
1082.5	2.6	0	-	-	-	-	11	0.16	-0.04	0.16	1.09	22	0.27	0.16	0.32	1.44
1082.2	3.0	0	-	-	-	-	11	0.16	-0.11	0.19	1.82	22	0.05	0.18	0.19	1.01
1080.7	4.4	0	-	-	-	-	11	0.18	0.12	0.22	0.67	23	0.17	0.11	0.20	1.47
1078.1	7.1	0	-	-	-	-	11	0.10	0.09	0.13	0.75	23	0.30	0.12	0.33	1.35
1075.4	9.7	0	-	-	-	-	11	0.16	0.20	0.26	1.05	23	0.18	0.12	0.22	1.69
1072.8	12.3	0	-	-	-	-	11	0.14	0.08	0.16	0.98	23	0.11	0.07	0.13	1.55
1070.2	14.9	0	-	-	-	-	11	0.28	0.02	0.28	1.28	23	0.30	0.01	0.30	1.90
1067.6	17.6	0	-	-	-	-	11	0.23	-0.03	0.24	0.63	23	0.34	0.04	0.34	1.97
1064.9	20.2	0	-	-	-	-	11	0.18	0.15	0.23	0.94	23	0.17	0.10	0.20	1.68
1062.3	22.8	0	-	-	-	-	11	0.14	0.05	0.15	0.89	23	0.24	0.01	0.24	1.91
1059.7	25.4	0	-	-	-	-	11	0.12	-0.04	0.13	0.85	23	0.12	-0.02	0.12	1.98
1057.1	28.1	0	-	-	-	-	11	0.15	-0.09	0.18	0.98	23	0.20	0.02	0.20	1.76
1054.5	30.7	0	-	-	-	-	11	0.16	-0.18	0.24	0.68	23	0.20	0.05	0.20	2.47
1051.8	33.3	0	-	-	-	-	11	0.32	-0.13	0.34	0.67	22	0.31	0.35	0.47	2.80
1049.2	35.9	0	-	-	-	-	11	0.38	-0.03	0.38	1.23	23	0.44	0.40	0.59	2.91
1046.6	38.6	0	-	-	-	-	11	0.76	0.53	0.92	1.82	21	0.49	1.11	1.22	3.00
1044.0	41.2	0	-	-	-	-	10	0.88	1.01	1.34	2.80	20	0.61	1.63	1.74	3.59
1041.3	43.8	0	-	-	-	-	7	0.65	0.50	0.82	2.36	14	0.37	1.43	1.48	2.75
1038.7	46.4	0	-	-	-	-	5	0.19	-0.29	0.35	0.73	12	0.35	0.57	0.67	1.80
1036.1	49.1	0	-	-	-	-	5	0.44	-0.56	0.71	1.22	9	0.35	0.45	0.57	0.00
1033.5	51.7	0	-	-	-	-	4	0.92	0.52	1.06	2.08	8	0.78	0.98	1.26	0.00
1030.8	54.3	0	-	-	-	-	4	0.90	0.15	0.91	1.14	8	0.57	1.31	1.43	0.00
1028.2	56.9	0	-	-	-	-	2	0.94	0.03	0.94	1.19	7	0.46	2.30	2.34	0.00

Blue color represents the opening to the intake bays

Intake B - All Units Off (Unit 1, 2, 3, and 4 NOT Generating)
Southwest Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	0	-	-	-	-	0	-	-	-	-	20	-0.04	0.19	0.19	0.80
1083.2	2.0	0	-	-	-	-	0	-	-	-	-	21	0.03	0.24	0.24	0.75
1082.8	2.3	0	-	-	-	-	0	-	-	-	-	21	0.18	0.22	0.29	0.82
1082.5	2.6	0	-	-	-	-	0	-	-	-	-	21	0.10	0.21	0.23	0.90
1082.2	3.0	0	-	-	-	-	0	-	-	-	-	21	0.01	0.22	0.22	0.87
1080.7	4.4	0	-	-	-	-	0	-	-	-	-	21	0.00	0.09	0.09	1.47
1078.1	7.1	0	-	-	-	-	0	-	-	-	-	21	-0.14	0.10	0.17	1.84
1075.4	9.7	0	-	-	-	-	0	-	-	-	-	20	-0.16	0.00	0.16	1.07
1072.8	12.3	0	-	-	-	-	0	-	-	-	-	21	0.00	-0.02	0.02	1.32
1070.2	14.9	0	-	-	-	-	0	-	-	-	-	21	-0.01	0.07	0.07	1.35
1067.6	17.6	0	-	-	-	-	0	-	-	-	-	21	-0.12	0.00	0.12	1.66
1064.9	20.2	0	-	-	-	-	0	-	-	-	-	21	-0.18	-0.08	0.20	1.14
1062.3	22.8	0	-	-	-	-	0	-	-	-	-	21	-0.22	-0.15	0.27	1.04
1059.7	25.4	0	-	-	-	-	0	-	-	-	-	21	-0.28	-0.11	0.30	1.27
1057.1	28.1	0	-	-	-	-	0	-	-	-	-	21	-0.38	-0.14	0.40	2.31
1054.5	30.7	0	-	-	-	-	0	-	-	-	-	21	-0.40	-0.10	0.41	1.60
1051.8	33.3	0	-	-	-	-	0	-	-	-	-	21	-0.46	-0.16	0.49	1.84
1049.2	35.9	0	-	-	-	-	0	-	-	-	-	20	-0.53	-0.10	0.54	2.03
1046.6	38.6	0	-	-	-	-	0	-	-	-	-	19	-0.55	-0.15	0.57	2.09
1044.0	41.2	0	-	-	-	-	0	-	-	-	-	16	-0.74	-0.12	0.75	2.68
1041.3	43.8	0	-	-	-	-	0	-	-	-	-	11	-0.50	-0.26	0.56	1.39
1038.7	46.4	0	-	-	-	-	0	-	-	-	-	7	-0.59	0.30	0.66	0.00
1036.1	49.1	0	-	-	-	-	0	-	-	-	-	5	-1.21	0.13	1.21	0.00
1033.5	51.7	0	-	-	-	-	0	-	-	-	-	3	-0.91	-0.60	1.09	0.00
1030.8	54.3	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-
1028.2	56.9	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-

Blue color represents the opening to the intake bays

Intake B - One Unit Generating (Unit 3)
Northeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	63	-0.08	0.30	0.32	2.68	48	0.22	0.09	0.24	2.33	32	0.18	-0.12	0.22	1.22
1083.1	2.0	62	-0.05	0.27	0.28	1.61	49	0.17	0.10	0.19	1.51	32	0.21	-0.14	0.25	1.09
1082.8	2.3	62	-0.11	0.31	0.33	4.47	50	0.15	0.04	0.15	1.46	32	0.18	-0.06	0.19	0.68
1082.5	2.6	62	-0.13	0.27	0.30	4.48	51	0.21	0.06	0.22	1.84	32	0.18	-0.07	0.19	0.78
1082.1	3.0	64	-0.12	0.22	0.25	5.71	50	0.16	0.04	0.17	0.87	32	0.20	-0.10	0.22	0.79
1080.7	4.4	64	-0.01	0.23	0.23	1.32	50	0.15	0.04	0.16	1.87	32	0.17	-0.16	0.23	1.10
1078.0	7.1	64	-0.06	0.05	0.08	1.16	51	0.17	-0.07	0.18	1.42	31	0.10	-0.28	0.30	1.32
1075.4	9.7	64	-0.12	0.01	0.12	2.10	51	0.01	-0.11	0.11	1.16	32	0.03	-0.42	0.42	1.23
1072.8	12.3	64	-0.18	-0.04	0.19	1.76	51	-0.06	-0.19	0.20	1.32	32	-0.05	-0.37	0.38	1.75
1070.2	14.9	64	-0.21	-0.11	0.24	2.20	51	-0.18	-0.20	0.26	1.05	30	-0.12	-0.48	0.50	1.33
1067.5	17.6	64	-0.18	-0.18	0.25	2.82	51	-0.31	-0.33	0.45	1.42	32	-0.26	-0.53	0.59	1.32
1064.9	20.2	59	-0.23	-0.15	0.28	2.38	49	-0.24	-0.41	0.47	1.57	32	-0.29	-0.62	0.69	1.43
1062.3	22.8	59	-0.22	-0.14	0.26	1.90	49	-0.27	-0.41	0.49	1.49	32	-0.34	-0.67	0.75	1.49
1059.7	25.4	59	-0.22	-0.26	0.34	1.60	49	-0.32	-0.46	0.56	1.35	32	-0.23	-0.68	0.72	1.52
1057.0	28.1	59	-0.15	-0.27	0.31	1.77	49	-0.29	-0.56	0.63	2.33	32	-0.18	-0.76	0.79	1.65
1054.4	30.7	59	-0.07	-0.40	0.41	1.97	49	-0.33	-0.48	0.59	2.20	32	-0.16	-0.73	0.75	2.14
1051.8	33.3	52	-0.05	-0.44	0.44	2.00	47	-0.15	-0.59	0.60	2.36	32	0.01	-0.65	0.65	1.94
1049.2	35.9	49	-0.14	-0.46	0.49	2.34	43	-0.01	-0.55	0.55	2.44	32	0.09	-0.65	0.66	1.90
1046.5	38.6	41	0.09	-0.55	0.56	1.94	39	-0.03	-0.38	0.38	2.41	31	0.11	-0.64	0.65	2.05
1043.9	41.2	32	0.16	-0.68	0.70	1.94	31	-0.26	-0.66	0.71	2.52	29	0.21	-0.64	0.67	1.72
1041.3	43.8	20	0.09	-0.77	0.77	1.63	19	-0.17	-0.90	0.91	2.07	11	-0.20	-0.54	0.58	2.49
1038.7	46.4	7	-0.12	-0.74	0.75	2.30	15	-0.03	-0.89	0.89	2.68	10	-0.34	-0.52	0.62	1.78
1036.0	49.1	4	-0.98	-0.15	0.99	1.30	12	-0.20	-0.79	0.81	2.58	9	-0.04	-0.53	0.53	1.72
1033.4	51.7	3	-1.21	0.27	1.24	1.57	7	0.08	-0.90	0.91	1.97	6	-0.58	-0.64	0.87	1.84
1030.8	54.3	1	-1.59	-0.04	1.59	1.59	6	0.02	-1.13	1.13	2.15	3	-0.70	-0.48	0.84	0.92
1028.2	56.9	0	-	-	-	-	5	-0.08	-1.19	1.19	2.20	3	-0.18	-0.81	0.83	1.05

Blue color represents the opening to the intake bays

Intake B - One Unit Generating (Unit 3)
Southeast Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (10-15 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Distance from Intake A (15-20 ft) Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	55	0.43	0.27	1.65	4.16	4	0.05	0.30	0.31	0.59	15	0.16	0.25	0.30	0.59
1083.1	2.0	54	0.49	0.26	1.83	3.47	4	0.18	0.39	0.43	0.76	16	0.23	0.32	0.39	0.83
1082.8	2.3	55	0.52	0.17	1.79	2.50	4	0.10	0.33	0.35	0.68	16	0.30	0.32	0.44	0.85
1082.5	2.6	53	0.59	0.17	2.01	3.00	4	0.23	0.39	0.45	0.67	16	0.24	0.37	0.45	1.00
1082.1	3.0	56	0.57	0.17	1.94	3.89	4	0.17	0.40	0.43	0.70	16	0.31	0.28	0.41	0.92
1080.7	4.4	56	0.35	0.11	1.21	1.58	4	0.11	0.34	0.36	0.88	16	0.32	0.39	0.51	1.23
1078.0	7.1	55	0.20	0.18	0.88	1.31	4	-0.28	0.14	0.31	0.65	16	0.22	0.33	0.39	1.01
1075.4	9.7	56	0.07	0.05	0.28	1.87	4	-0.01	0.19	0.19	0.85	16	0.13	0.44	0.46	1.10
1072.8	12.3	56	0.02	0.03	0.13	1.59	4	-0.14	0.34	0.37	0.82	16	0.04	0.50	0.51	1.25
1070.2	14.9	56	-0.27	0.00	0.88	2.24	4	-0.29	0.11	0.31	0.80	16	0.04	0.31	0.31	1.19
1067.5	17.6	54	-0.21	0.01	0.69	2.68	4	-0.50	0.24	0.55	1.41	16	-0.20	0.02	0.20	0.99
1064.9	20.2	49	-0.06	0.17	0.58	1.88	4	-0.42	0.33	0.54	1.32	16	-0.44	-0.09	0.45	1.33
1062.3	22.8	47	-0.11	0.14	0.59	1.40	4	-0.26	-0.05	0.27	1.01	16	-0.33	-0.10	0.35	1.00
1059.7	25.4	49	-0.22	0.10	0.79	1.26	4	-0.70	0.22	0.73	1.30	16	-0.24	-0.03	0.24	0.94
1057.0	28.1	48	-0.14	0.12	0.60	1.34	4	-0.43	0.16	0.46	1.29	16	-0.26	-0.16	0.31	1.21
1054.4	30.7	48	-0.23	0.02	0.75	1.15	4	-0.24	0.02	0.24	1.31	16	-0.21	-0.09	0.22	0.96
1051.8	33.3	46	-0.30	0.05	1.01	1.37	4	-0.48	0.11	0.49	1.50	14	-0.32	0.06	0.33	1.34
1049.2	35.9	45	-0.56	0.03	1.83	1.65	4	-0.63	0.12	0.64	1.30	13	-0.49	0.03	0.50	0.87
1046.5	38.6	42	-0.58	-0.17	1.98	1.80	4	-0.49	0.26	0.55	1.27	13	-0.36	-0.11	0.38	1.23
1043.9	41.2	41	-0.82	-0.20	2.78	1.93	4	-0.71	0.09	0.72	1.62	12	-0.48	-0.04	0.49	1.15
1041.3	43.8	15	-0.62	-0.07	2.05	1.16	3	-0.47	0.53	0.71	1.52	9	-0.51	-0.12	0.52	1.24
1038.7	46.4	9	-0.64	0.07	2.12	1.58	3	-0.25	0.01	0.25	0.92	6	-0.15	0.01	0.15	1.24
1036.0	49.1	6	0.02	0.02	0.09	0.65	3	-0.59	-0.02	0.59	1.51	5	-0.56	-0.26	0.62	1.79
1033.4	51.7	6	-0.20	-0.21	0.94	0.70	2	-1.30	0.99	1.64	3.60	5	-0.59	0.14	0.61	1.38
1030.8	54.3	3	-0.28	-0.25	1.24	1.06	1	-0.10	-1.35	1.35	1.35	2	-0.88	0.11	0.89	1.83
1028.2	56.9	3	-0.47	-0.27	1.79	0.75	1	-0.24	-0.64	0.68	0.68	1	-1.24	0.38	1.29	1.29

Blue color represents the opening to the intake bays

Intake B - One Unit Generating (Unit 3)
Northwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	47	0.40	0.31	0.51	1.15	60	0.61	0.20	0.65	1.37	13	0.79	0.22	0.82	1.57
1083.1	2.0	47	0.43	0.32	0.54	1.72	60	0.61	0.20	0.65	1.11	13	0.73	0.10	0.73	1.11
1082.8	2.3	47	0.49	0.20	0.53	3.22	60	0.63	0.16	0.65	1.20	13	0.81	0.02	0.81	1.15
1082.5	2.6	47	0.52	0.21	0.56	1.96	59	0.63	0.11	0.64	1.16	12	0.64	-0.06	0.64	0.85
1082.1	3.0	44	0.45	0.33	0.56	2.90	59	0.66	0.05	0.66	1.27	13	0.69	-0.05	0.69	1.00
1080.7	4.4	47	0.51	0.12	0.52	1.88	60	0.68	-0.07	0.68	1.46	13	0.59	-0.15	0.61	1.16
1078.0	7.1	47	0.48	0.00	0.48	1.57	60	0.66	-0.24	0.70	1.39	13	0.59	-0.18	0.62	1.19
1075.4	9.7	47	0.53	0.07	0.53	2.13	60	0.60	-0.25	0.64	1.26	13	0.50	-0.26	0.56	1.14
1072.8	12.3	47	0.47	0.01	0.47	1.54	60	0.50	-0.42	0.65	1.30	13	0.43	-0.52	0.68	1.02
1070.2	14.9	47	0.45	0.05	0.45	2.25	59	0.42	-0.42	0.59	1.34	13	0.40	-0.65	0.77	1.12
1067.5	17.6	47	0.42	-0.02	0.42	1.81	60	0.40	-0.44	0.60	1.32	13	0.27	-0.68	0.73	1.33
1064.9	20.2	47	0.40	-0.19	0.44	2.38	60	0.40	-0.52	0.65	1.56	13	0.21	-0.85	0.87	1.44
1062.3	22.8	47	0.36	-0.25	0.43	2.71	60	0.43	-0.55	0.70	1.57	13	0.17	-0.75	0.77	1.30
1059.7	25.4	47	0.43	-0.25	0.50	1.88	60	0.43	-0.58	0.73	2.00	13	0.20	-0.74	0.77	1.47
1057.0	28.1	47	0.45	-0.27	0.53	1.89	60	0.48	-0.48	0.68	2.60	13	0.28	-0.62	0.68	1.79
1054.4	30.7	47	0.38	-0.13	0.41	1.88	60	0.57	-0.38	0.69	2.75	13	0.42	-0.39	0.57	1.41
1051.8	33.3	47	0.37	-0.05	0.38	2.01	60	0.65	-0.37	0.75	2.57	13	0.71	-0.08	0.71	1.91
1049.2	35.9	47	0.55	-0.03	0.55	2.26	57	0.74	-0.26	0.78	2.68	11	0.88	-0.30	0.93	2.15
1046.5	38.6	47	0.53	0.18	0.56	2.62	54	0.62	-0.09	0.63	2.75	9	0.88	-0.33	0.94	2.87
1043.9	41.2	44	0.57	0.17	0.60	2.73	47	0.82	-0.03	0.82	2.71	7	0.42	-0.48	0.64	2.15
1041.3	43.8	24	0.71	-0.10	0.72	2.94	27	0.65	0.46	0.80	3.39	4	0.10	-0.47	0.49	1.51
1038.7	46.4	14	0.80	0.24	0.84	2.31	18	0.57	0.39	0.69	3.28	4	0.20	-0.59	0.62	1.74
1036.0	49.1	7	0.89	0.14	0.90	1.73	14	0.57	0.62	0.85	2.93	3	0.18	-0.10	0.21	0.79
1033.4	51.7	4	1.24	0.13	1.25	2.01	7	0.14	1.00	1.01	2.07	3	0.57	0.17	0.59	1.69
1030.8	54.3	4	1.18	0.41	1.25	2.30	6	0.42	0.79	0.90	1.89	3	1.05	0.45	1.14	1.64
1028.2	56.9	1	0.14	0.46	0.48	0.48	5	0.71	0.61	0.94	1.62	1	1.31	-0.34	1.35	1.35

Blue color represents the opening to the intake bays

Intake B - One Unit Generating (Unit 3)
Southwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1083.5	1.6	92	0.10	0.33	1.12	1.60	28	0.15	0.48	0.50	0.99	40	0.40	0.31	0.51	0.98
1083.1	2.0	93	0.18	0.31	1.18	1.10	28	0.30	0.40	0.50	0.95	40	0.43	0.32	0.54	1.24
1082.8	2.3	94	0.17	0.29	1.10	2.47	28	0.34	0.44	0.55	1.52	40	0.49	0.20	0.53	1.74
1082.5	2.6	94	0.24	0.30	1.26	2.87	28	0.35	0.33	0.48	0.89	39	0.52	0.21	0.56	3.50
1082.1	3.0	93	0.20	0.21	0.95	3.71	28	0.37	0.27	0.46	1.06	40	0.45	0.33	0.56	3.57
1080.7	4.4	95	0.09	0.32	1.08	2.13	28	0.35	0.41	0.54	1.32	40	0.51	0.12	0.52	1.27
1078.0	7.1	95	0.08	0.23	0.79	1.28	28	0.18	0.40	0.44	1.25	40	0.48	0.00	0.48	1.41
1075.4	9.7	95	0.03	0.23	0.77	1.50	28	0.10	0.39	0.40	1.42	40	0.53	0.07	0.53	1.30
1072.8	12.3	95	-0.12	0.30	1.07	1.84	28	0.27	0.41	0.49	1.75	40	0.47	0.01	0.47	1.22
1070.2	14.9	94	-0.35	0.36	1.64	2.18	28	0.15	0.42	0.45	1.63	40	0.45	0.05	0.45	1.37
1067.5	17.6	94	-0.30	0.22	1.22	2.02	28	-0.28	0.45	0.53	1.38	40	0.42	-0.02	0.42	1.47
1064.9	20.2	76	-0.18	0.21	0.90	2.05	28	-0.40	0.45	0.60	2.61	35	0.40	-0.19	0.44	1.57
1062.3	22.8	76	-0.29	0.32	1.41	1.87	28	-0.40	0.44	0.60	2.31	35	0.36	-0.25	0.43	1.88
1059.7	25.4	76	-0.35	0.39	1.72	1.92	28	-0.42	0.37	0.56	1.77	35	0.43	-0.25	0.50	1.76
1057.0	28.1	76	-0.45	0.34	1.85	1.85	27	-0.34	0.40	0.53	2.02	35	0.45	-0.27	0.53	2.18
1054.4	30.7	76	-0.43	0.27	1.68	2.18	27	-0.36	0.44	0.57	2.09	35	0.38	-0.13	0.41	1.76
1051.8	33.3	70	-0.45	0.29	1.76	2.65	27	-0.45	0.68	0.81	2.47	34	0.37	-0.05	0.38	1.70
1049.2	35.9	65	-0.63	0.26	2.25	2.26	26	-0.59	0.72	0.93	2.26	28	0.55	-0.03	0.55	1.49
1046.5	38.6	54	-0.78	0.10	2.58	3.82	23	-0.91	0.70	1.15	2.42	25	0.53	0.18	0.56	1.72
1043.9	41.2	42	-0.85	0.11	2.82	2.82	19	-1.23	1.05	1.62	3.94	25	0.57	0.17	0.60	2.01
1041.3	43.8	24	-0.46	0.05	1.52	1.47	7	-0.71	0.54	0.89	2.22	17	0.71	-0.10	0.72	1.07
1038.7	46.4	13	-0.33	0.18	1.23	2.14	2	-0.96	0.77	1.23	2.36	15	0.80	0.24	0.84	1.30
1036.0	49.1	7	-0.54	-0.02	1.77	1.35	2	-0.95	0.82	1.25	2.19	11	0.89	0.14	0.90	1.34
1033.4	51.7	6	-0.43	0.28	1.68	1.16	2	-0.90	0.86	1.24	1.84	3	1.24	0.13	1.25	1.22
1030.8	54.3	5	-0.35	0.19	1.31	1.40	2	-0.96	0.91	1.32	2.19	2	1.18	0.41	1.25	0.63
1028.2	56.9	5	-0.49	0.26	1.82	1.42	0	-	-	-	-	1	0.14	0.46	0.48	0.26

Blue color represents the opening to the intake bays

Intake B - Two Units Generating (Units 3 and 4)
Northeast Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.1	1.6	16	0.34	-0.76	0.83	1.44	54	0.15	-0.38	0.41	2.45	111	0.38	0.44	0.58	2.13
1083.8	2.0	15	0.06	-0.65	0.65	1.18	55	0.02	-0.32	0.33	4.03	111	0.40	0.51	0.65	2.01
1083.4	2.3	16	0.00	-0.64	0.64	1.22	56	0.00	-0.28	0.28	3.64	110	0.39	0.57	0.69	2.05
1083.1	2.6	16	0.19	-0.56	0.59	1.87	56	0.03	-0.32	0.32	1.69	111	0.40	0.64	0.75	2.66
1082.8	3.0	13	-0.11	-0.67	0.68	3.28	57	0.05	-0.22	0.22	4.30	111	0.35	0.59	0.68	2.03
1081.3	4.4	16	0.09	-0.70	0.71	1.76	57	-0.03	-0.34	0.34	1.61	112	0.26	0.71	0.76	2.60
1078.7	7.1	16	0.21	-0.76	0.79	1.86	57	-0.04	-0.34	0.34	1.57	112	0.16	0.71	0.72	2.36
1076.1	9.7	16	0.17	-0.91	0.93	2.08	57	-0.19	-0.31	0.37	1.87	112	-0.02	0.75	0.75	2.29
1073.4	12.3	16	0.19	-1.21	1.22	1.97	57	-0.18	-0.32	0.37	2.05	112	-0.18	0.74	0.76	2.56
1070.8	14.9	16	0.21	-1.15	1.17	2.19	57	-0.03	-0.44	0.45	1.87	111	-0.30	0.76	0.82	2.59
1068.2	17.6	16	0.71	-0.90	1.15	2.14	57	-0.13	-0.46	0.48	2.56	111	-0.47	0.80	0.92	3.13
1065.6	20.2	16	0.80	-1.01	1.29	2.38	57	-0.12	-0.52	0.53	2.81	112	-0.55	0.78	0.96	3.24
1062.9	22.8	16	0.78	-0.95	1.23	2.58	57	-0.02	-0.65	0.65	2.48	112	-0.63	0.60	0.87	3.31
1060.3	25.4	16	0.78	-1.22	1.45	2.40	57	-0.02	-0.78	0.78	2.58	112	-0.56	0.44	0.72	3.46
1057.7	28.1	15	1.07	-1.03	1.49	2.30	57	-0.01	-0.82	0.82	2.71	111	-0.40	0.15	0.43	2.94
1055.1	30.7	15	0.96	-0.98	1.38	2.40	57	0.18	-0.70	0.72	2.98	112	-0.36	-0.04	0.36	2.98
1052.4	33.3	15	1.05	-1.21	1.60	2.33	57	0.43	-0.56	0.70	2.84	112	-0.27	-0.26	0.37	3.15
1049.8	35.9	15	0.87	-1.12	1.42	2.46	57	0.56	-0.60	0.83	2.80	97	-0.25	-0.24	0.34	3.49
1047.2	38.6	14	1.08	-0.87	1.38	2.10	54	0.81	-0.72	1.09	2.54	72	-0.21	-0.02	0.21	2.92
1044.6	41.2	12	1.24	-0.99	1.59	2.33	48	1.08	-0.69	1.28	2.59	52	-0.29	0.03	0.29	3.37
1041.9	43.8	6	0.96	-0.98	1.37	1.75	45	1.18	-0.78	1.41	3.04	45	-0.34	0.10	0.35	3.71
1039.3	46.4	2	1.16	-0.89	1.47	1.68	36	1.14	-0.56	1.27	2.75	42	-0.50	-0.11	0.51	3.65
1036.7	49.1	2	0.61	-1.24	1.38	1.58	29	1.09	-0.64	1.26	2.85	38	-0.54	-0.32	0.63	3.70
1034.1	51.7	2	0.50	-1.05	1.16	1.49	19	0.80	-0.76	1.10	2.90	35	-0.46	-0.19	0.49	2.42
1031.4	54.3	2	0.78	-2.00	2.15	2.56	9	0.23	-0.71	0.74	3.00	30	-0.56	-0.29	0.63	2.68
1028.8	56.9	2	0.76	-2.31	2.44	2.45	5	0.14	-0.98	0.99	2.56	24	-0.42	-0.10	0.43	2.98

Blue color represents the opening to the intake bays

Intake B - Two Units Generating (Units 3 and 4)
Southeast Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.1	1.6	21	0.90	0.35	3.16	2.55	30	0.64	0.78	1.01	2.92	61	0.61	0.53	0.81	3.36
1083.8	2.0	22	1.06	0.47	3.81	1.67	29	1.06	0.75	1.30	2.73	63	1.00	0.76	1.25	2.61
1083.4	2.3	22	1.10	0.53	4.01	2.03	29	1.07	0.88	1.39	2.70	63	1.01	0.79	1.28	3.46
1083.1	2.6	21	1.09	0.54	4.00	1.83	29	1.07	0.89	1.40	2.53	65	1.06	0.87	1.37	2.79
1082.8	3.0	22	1.06	0.60	3.99	1.74	29	1.05	0.91	1.39	2.55	62	1.01	0.84	1.31	2.47
1081.3	4.4	22	1.07	0.81	4.42	2.18	30	1.07	1.04	1.49	3.08	65	1.05	0.89	1.37	2.84
1078.7	7.1	22	0.90	0.99	4.38	1.90	30	0.98	1.03	1.42	2.83	65	0.83	0.85	1.19	2.14
1076.1	9.7	22	0.87	1.07	4.53	2.01	30	0.70	0.99	1.22	3.64	65	0.62	0.64	0.89	2.26
1073.4	12.3	21	0.67	1.27	4.69	2.08	30	0.29	0.96	1.01	2.61	65	0.53	0.64	0.83	2.88
1070.8	14.9	22	0.72	1.39	5.13	2.44	30	0.38	1.17	1.23	2.65	65	0.55	0.62	0.83	2.89
1068.2	17.6	22	0.68	1.58	5.66	2.45	30	0.41	1.20	1.27	2.85	65	0.36	0.62	0.71	3.29
1065.6	20.2	22	0.65	1.48	5.30	2.47	30	0.36	1.24	1.29	3.05	65	0.27	0.62	0.67	3.26
1062.9	22.8	22	0.38	1.31	4.47	2.18	30	0.03	1.07	1.07	2.80	65	0.22	0.62	0.66	3.10
1060.3	25.4	22	0.11	1.06	3.51	2.16	30	-0.11	0.93	0.94	2.64	64	0.14	0.63	0.64	3.14
1057.7	28.1	22	-0.02	0.92	3.01	1.76	30	-0.31	0.90	0.95	3.04	64	0.06	0.60	0.60	4.01
1055.1	30.7	22	-0.05	0.68	2.22	2.02	30	-0.48	0.66	0.82	2.65	64	-0.04	0.62	0.62	4.01
1052.4	33.3	22	-0.40	0.65	2.49	2.19	30	-0.51	0.72	0.88	2.48	64	-0.12	0.61	0.62	3.98
1049.8	35.9	21	-0.40	0.65	2.51	1.91	29	-0.59	0.72	0.93	3.02	64	-0.30	0.51	0.60	3.73
1047.2	38.6	17	-0.28	0.98	3.34	1.99	28	-0.54	0.50	0.74	3.00	60	-0.35	0.61	0.70	4.43
1044.6	41.2	14	-0.30	1.22	4.12	2.00	26	-0.59	0.14	0.60	2.12	54	-0.44	0.54	0.70	3.80
1041.9	43.8	11	0.00	1.12	3.66	1.98	18	-0.39	-0.17	0.43	1.90	33	-0.48	0.84	0.96	2.95
1039.3	46.4	11	-0.09	0.83	2.73	1.50	14	-0.26	-0.42	0.50	1.82	24	-0.48	0.78	0.92	2.72
1036.7	49.1	10	-0.32	0.70	2.51	1.45	13	-0.58	-0.30	0.65	1.85	22	-0.43	0.53	0.68	2.29
1034.1	51.7	10	-0.63	0.64	2.93	1.59	12	-0.92	-0.22	0.95	2.54	21	-0.38	0.44	0.58	1.73
1031.4	54.3	10	-0.23	0.06	0.77	1.79	7	-1.07	-0.45	1.16	2.17	19	-0.51	0.20	0.54	2.26
1028.8	56.9	10	-0.96	0.10	3.18	2.40	4	-1.01	-0.15	1.02	1.57	19	-0.70	-0.09	0.71	3.16

Blue color represents the opening to the intake bays

Intake B - Two Units Generating (Units 3 and 4)
Northwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.1	1.6	56	0.72	-0.08	0.72	2.06	111	0.78	-0.18	0.80	2.37	26	0.58	-0.12	0.59	1.74
1083.8	2.0	55	0.47	-0.39	0.61	2.36	112	0.43	-0.58	0.72	2.95	23	0.27	-0.52	0.59	2.02
1083.4	2.3	57	0.36	-0.51	0.62	1.66	110	0.38	-0.61	0.72	2.81	24	0.23	-0.73	0.76	1.94
1083.1	2.6	53	0.31	-0.55	0.63	1.44	109	0.28	-0.60	0.66	3.64	24	0.09	-0.89	0.90	3.58
1082.8	3.0	57	0.27	-0.58	0.63	1.33	111	0.28	-0.61	0.67	4.15	25	0.07	-0.92	0.93	3.65
1081.3	4.4	57	0.16	-0.75	0.77	1.80	114	0.16	-0.80	0.82	1.45	26	0.33	-0.79	0.85	1.59
1078.7	7.1	57	0.19	-0.72	0.74	1.75	113	0.28	-0.70	0.75	1.77	26	0.37	-0.88	0.95	1.64
1076.1	9.7	57	0.48	-0.61	0.77	1.99	114	0.48	-0.60	0.77	1.99	26	0.51	-0.77	0.92	1.55
1073.4	12.3	57	0.53	-0.70	0.88	2.01	114	0.56	-0.59	0.81	2.12	26	0.62	-0.64	0.89	1.89
1070.8	14.9	57	0.83	-0.26	0.87	2.36	114	0.69	-0.44	0.82	2.21	26	0.67	-0.35	0.76	1.99
1068.2	17.6	57	1.10	0.13	1.11	2.36	114	0.85	-0.12	0.86	2.52	26	0.82	-0.03	0.82	2.14
1065.6	20.2	57	1.11	0.20	1.13	2.40	114	0.95	-0.08	0.95	2.70	25	0.84	0.08	0.84	1.98
1062.9	22.8	57	1.05	0.22	1.07	2.61	114	0.96	-0.06	0.96	2.52	25	0.90	0.21	0.92	2.00
1060.3	25.4	57	1.05	0.20	1.07	3.84	114	1.01	-0.09	1.01	2.77	25	0.94	0.17	0.95	2.34
1057.7	28.1	57	1.00	0.26	1.03	2.21	114	0.92	0.05	0.92	2.75	25	0.86	0.21	0.88	1.96
1055.1	30.7	57	1.06	0.26	1.10	2.51	113	0.92	0.21	0.94	2.75	25	1.03	0.27	1.07	2.33
1052.4	33.3	57	1.01	0.23	1.04	2.94	113	0.91	0.23	0.94	2.33	23	1.13	0.37	1.19	2.59
1049.8	35.9	56	1.01	0.21	1.03	2.57	110	1.01	0.27	1.05	2.35	19	1.14	0.29	1.17	2.68
1047.2	38.6	55	0.97	0.43	1.07	2.47	111	1.10	0.42	1.18	2.29	14	0.98	0.17	0.99	1.97
1044.6	41.2	45	1.23	0.50	1.33	3.22	98	1.20	0.58	1.33	3.06	14	0.89	0.39	0.98	1.72
1041.9	43.8	25	1.12	0.54	1.24	3.06	70	1.38	0.63	1.51	3.08	11	0.89	0.31	0.94	1.80
1039.3	46.4	8	1.35	-0.12	1.36	3.12	46	1.32	0.57	1.43	2.88	7	1.04	0.24	1.07	1.74
1036.7	49.1	4	1.76	0.18	1.77	2.68	36	1.34	0.51	1.44	2.71	6	1.32	0.14	1.32	1.78
1034.1	51.7	1	2.21	-0.46	2.26	2.26	18	1.31	0.44	1.38	2.88	6	1.20	0.12	1.21	1.71
1031.4	54.3	1	1.40	-1.37	1.96	1.96	8	1.14	0.77	1.38	2.60	6	1.33	0.17	1.34	1.87
1028.8	56.9	0	-	-	-	-	4	0.45	0.66	0.80	1.57	6	1.65	0.22	1.66	2.12

Blue color represents the opening to the intake bays

Intake B - Two Units Generating (Units 3 and 4)
Southwest Quadrat

Elevation (ft-AMSL)	Depth (ft)	Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
		Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.1	1.6	40	0.69	0.33	2.52	5.27	124	0.29	0.15	0.32	5.24	108	0.50	0.13	0.51	3.82
1083.8	2.0	38	0.84	0.12	2.77	2.95	125	0.74	-0.15	0.76	3.97	110	0.99	0.01	0.99	3.89
1083.4	2.3	40	0.88	0.15	2.93	8.03	123	0.90	-0.33	0.95	5.87	109	1.15	-0.12	1.16	5.41
1083.1	2.6	42	0.80	0.11	2.65	6.68	125	0.99	-0.36	1.05	3.43	110	1.10	-0.24	1.12	4.05
1082.8	3.0	41	0.83	0.10	2.73	4.17	131	0.93	-0.42	1.02	4.86	113	1.12	-0.32	1.17	5.76
1081.3	4.4	42	0.97	-0.12	3.22	3.06	133	0.93	-0.47	1.04	2.46	114	1.20	-0.31	1.24	2.71
1078.7	7.1	42	0.76	-0.05	2.48	2.24	133	0.87	-0.45	0.97	2.58	114	1.20	-0.33	1.25	2.29
1076.1	9.7	42	0.67	0.13	2.24	1.92	133	0.75	-0.28	0.80	2.51	114	1.11	-0.26	1.14	2.39
1073.4	12.3	42	0.48	0.27	1.82	1.89	133	0.69	-0.11	0.70	2.39	114	0.93	-0.19	0.95	2.22
1070.8	14.9	42	0.33	0.49	1.95	1.85	133	0.64	0.05	0.64	2.83	114	0.94	0.07	0.94	2.50
1068.2	17.6	42	0.27	0.60	2.17	2.30	132	0.54	0.26	0.60	3.33	114	0.88	0.31	0.94	2.47
1065.6	20.2	42	0.09	0.67	2.22	1.96	132	0.43	0.36	0.56	3.17	114	0.88	0.56	1.04	2.86
1062.9	22.8	42	0.08	0.76	2.52	2.22	133	0.39	0.45	0.59	2.48	113	0.76	0.63	0.98	3.57
1060.3	25.4	42	0.10	0.77	2.56	2.03	133	0.36	0.55	0.66	3.04	114	0.44	0.46	0.64	2.46
1057.7	28.1	42	-0.02	0.71	2.34	2.19	133	0.28	0.63	0.69	2.58	113	0.32	0.51	0.60	3.10
1055.1	30.7	41	-0.21	0.68	2.34	2.27	133	0.27	0.61	0.67	2.90	114	0.32	0.61	0.69	3.01
1052.4	33.3	41	-0.17	0.77	2.58	2.37	133	0.21	0.59	0.62	3.06	114	0.31	0.62	0.70	3.14
1049.8	35.9	39	-0.22	0.69	2.39	2.30	130	0.06	0.59	0.59	2.84	106	0.12	0.63	0.64	3.62
1047.2	38.6	36	-0.26	0.60	2.15	1.94	128	-0.10	0.48	0.49	2.78	96	0.08	0.53	0.54	3.13
1044.6	41.2	28	-0.25	0.73	2.53	2.10	117	-0.28	0.58	0.64	3.08	89	-0.15	0.55	0.57	3.28
1041.9	43.8	16	-0.37	0.61	2.33	2.81	86	-0.34	0.48	0.59	3.87	57	-0.21	0.43	0.48	3.48
1039.3	46.4	10	-0.62	0.89	3.57	2.65	67	-0.27	0.40	0.48	2.02	47	-0.17	0.44	0.47	2.24
1036.7	49.1	8	-0.52	0.68	2.82	1.60	57	-0.23	0.49	0.54	2.48	41	-0.28	0.53	0.59	2.12
1034.1	51.7	6	-0.46	0.73	2.82	2.27	50	-0.28	0.45	0.53	2.46	37	-0.23	0.60	0.64	2.10
1031.4	54.3	5	-0.78	0.71	3.46	2.26	36	-0.35	0.48	0.60	2.63	32	-0.32	0.58	0.66	4.17
1028.8	56.9	3	-0.15	0.05	0.53	2.09	23	-0.24	0.36	0.44	2.55	22	-0.08	0.76	0.77	2.08

Blue color represents the opening to the intake bays

Intake B - Two Units Generating (Unit 3 and 4) (Also Units 1 and 2 Generating)
Northeast Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.6	1.6	9	0.99	0.10	1.00	2.20	17	0.10	0.86	0.86	3.64	74	0.53	0.04	0.53	2.96
1084.3	2.0	10	1.12	0.56	1.26	3.79	17	-0.01	0.87	0.87	4.01	75	0.20	0.21	0.29	2.85
1083.9	2.3	10	1.58	0.88	1.81	5.37	17	-0.03	0.73	0.73	4.13	75	0.09	0.27	0.29	3.50
1083.6	2.6	10	1.83	1.00	2.08	6.31	17	0.12	0.94	0.95	3.44	76	0.01	0.23	0.23	3.64
1083.3	3.0	10	1.91	1.13	2.22	5.82	17	-0.21	0.66	0.69	3.53	77	0.01	0.17	0.17	3.76
1081.8	4.4	10	1.50	0.82	1.71	2.61	17	-0.12	0.75	0.76	3.09	78	0.04	0.18	0.19	3.07
1079.2	7.1	10	1.63	0.99	1.91	3.09	17	-0.03	0.76	0.76	3.04	78	0.07	0.09	0.11	2.93
1076.6	9.7	10	1.68	0.72	1.83	2.87	17	0.26	0.60	0.65	2.70	78	0.08	-0.01	0.08	3.14
1073.9	12.3	10	1.48	0.54	1.57	2.27	17	0.37	0.36	0.51	3.43	77	0.09	-0.11	0.14	2.84
1071.3	14.9	10	1.70	0.55	1.79	3.92	17	0.33	0.03	0.33	3.33	78	0.11	-0.18	0.21	3.16
1068.7	17.6	10	1.57	0.51	1.65	2.37	17	0.09	-0.35	0.36	2.94	77	0.05	-0.37	0.38	2.57
1066.1	20.2	10	1.48	0.46	1.55	2.47	17	-0.03	-0.55	0.55	2.53	78	0.07	-0.51	0.51	2.58
1063.4	22.8	10	1.34	0.53	1.44	2.17	17	0.21	-0.74	0.77	2.96	78	0.09	-0.55	0.56	2.43
1060.8	25.4	10	1.23	0.65	1.39	2.16	17	0.05	-0.93	0.93	2.76	78	0.24	-0.63	0.67	2.32
1058.2	28.1	10	1.00	0.56	1.15	1.61	16	0.31	-0.86	0.91	2.51	78	0.34	-0.71	0.79	2.52
1055.6	30.7	10	0.87	0.78	1.16	1.79	17	0.28	-0.73	0.79	1.88	78	0.33	-0.76	0.83	2.47
1052.9	33.3	10	0.86	1.08	1.38	2.58	17	0.33	-0.59	0.67	1.90	78	0.43	-0.87	0.97	3.26
1050.3	35.9	10	0.95	1.05	1.42	2.68	16	0.30	-0.60	0.67	2.59	75	0.51	-0.85	0.99	3.34
1047.7	38.6	10	0.89	0.97	1.31	2.45	11	0.45	-0.87	0.98	2.33	60	0.54	-0.73	0.91	3.06
1045.1	41.2	10	0.51	0.53	0.74	2.01	10	0.04	-0.98	0.98	2.83	51	0.54	-0.63	0.83	3.94
1042.4	43.8	10	-0.01	0.48	0.48	3.17	7	0.59	-0.55	0.80	2.01	36	0.74	-0.59	0.94	3.87
1039.8	46.4	10	-0.05	0.56	0.56	2.89	5	0.34	-0.76	0.83	1.77	27	0.68	-0.56	0.88	2.16
1037.2	49.1	10	0.07	0.10	0.12	2.39	4	0.68	-0.76	1.02	1.87	26	0.61	-0.68	0.91	2.84
1034.6	51.7	10	0.05	-0.04	0.06	2.42	4	0.95	-0.60	1.13	1.81	17	0.60	-0.79	0.99	2.00
1031.9	54.3	7	0.21	-0.66	0.70	2.02	3	0.97	-0.73	1.21	2.03	15	0.64	-0.68	0.94	2.12
1029.3	56.9	5	-0.01	-0.99	0.99	2.07	2	0.54	-0.57	0.79	1.78	10	0.87	-0.58	1.05	2.73

Blue color represents the opening to the intake bays

Intake B - Two Units Generating (Unit 3 and 4) (Also Units 1 and 2 Generating)
Southeast Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.6	1.6	1	1.24	0.89	4.99	1.52	21	1.64	0.64	1.76	5.67	26	1.35	0.62	1.48	3.31
1084.3	2.0	1	1.14	0.67	4.34	1.32	22	1.95	0.72	2.08	6.24	27	1.60	0.62	1.72	3.22
1083.9	2.3	1	1.17	0.73	4.53	1.38	22	2.03	0.66	2.13	6.67	28	1.70	0.77	1.86	2.89
1083.6	2.6	1	1.16	1.11	5.28	1.61	22	1.98	0.61	2.08	8.42	28	1.81	0.77	1.97	2.98
1083.3	3.0	1	1.18	1.28	5.71	1.74	22	2.11	0.63	2.20	6.47	28	1.72	0.64	1.84	2.84
1081.8	4.4	1	1.30	0.77	4.96	1.51	22	2.13	0.52	2.19	4.03	28	1.77	0.60	1.87	2.88
1079.2	7.1	1	1.78	-0.13	5.84	1.78	22	2.17	0.37	2.20	3.72	28	1.73	0.55	1.82	2.82
1076.6	9.7	1	1.04	0.79	4.29	1.31	22	2.14	0.40	2.17	3.81	28	1.42	0.49	1.50	2.84
1073.9	12.3	1	0.32	0.63	2.34	0.71	22	1.89	0.18	1.90	3.46	28	1.68	0.58	1.77	3.43
1071.3	14.9	1	1.24	1.25	5.78	1.76	22	1.85	0.25	1.87	3.63	28	1.55	0.60	1.66	3.08
1068.7	17.6	1	1.28	0.62	4.66	1.42	22	1.82	0.67	1.94	3.48	28	1.16	0.65	1.34	3.00
1066.1	20.2	1	1.23	1.03	5.26	1.60	22	1.56	0.92	1.81	3.57	28	1.03	0.58	1.18	3.33
1063.4	22.8	1	0.80	1.10	4.45	1.36	22	0.99	0.76	1.25	3.52	28	0.68	0.41	0.80	3.08
1060.8	25.4	1	1.32	-0.09	4.34	1.32	22	0.42	0.42	0.59	3.91	28	0.63	0.35	0.72	2.41
1058.2	28.1	1	0.94	0.54	3.57	1.09	22	-0.02	0.23	0.23	3.58	28	0.40	0.28	0.49	2.94
1055.6	30.7	1	1.22	0.40	4.23	1.29	22	-0.28	0.32	0.43	4.47	28	0.24	0.24	0.34	2.20
1052.9	33.3	1	0.99	0.49	3.62	1.10	22	-0.27	0.28	0.39	4.19	28	0.12	0.24	0.27	1.73
1050.3	35.9	1	0.37	0.05	1.23	0.37	22	-0.51	0.46	0.69	3.18	27	0.00	0.38	0.38	2.58
1047.7	38.6	1	0.47	0.33	1.89	0.58	19	-0.51	0.46	0.68	2.66	27	-0.31	0.26	0.40	2.66
1045.1	41.2	1	0.17	-0.33	1.23	0.38	19	-0.74	0.40	0.84	2.60	22	-0.36	0.05	0.36	2.23
1042.4	43.8	1	0.43	-0.75	2.83	0.86	9	-0.93	0.13	0.94	4.94	13	-0.21	0.25	0.32	2.27
1039.8	46.4	1	0.15	-0.09	0.59	0.18	5	-0.62	0.28	0.68	2.78	11	-0.26	0.18	0.32	2.59
1037.2	49.1	1	-0.64	-0.94	3.74	1.14	5	-0.81	0.32	0.87	2.62	10	-0.34	0.05	0.34	2.58
1034.6	51.7	1	-0.23	-0.22	1.04	0.32	4	-0.93	0.42	1.02	2.81	8	-0.79	0.23	0.83	2.81
1031.9	54.3	0	-	-	-	-	4	-0.96	0.39	1.04	2.61	4	-0.72	0.41	0.83	2.61
1029.3	56.9	0	-	-	-	-	3	-1.36	0.54	1.47	2.82	2	-0.73	0.66	0.98	1.47

Blue color represents the opening to the intake bays

Intake B - Two Units Generating (Unit 3 and 4) (Also Units 1 and 2 Generating)
Northwest Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.6	1.6	4	0.36	0.22	0.42	5.50	128	0.61	-0.04	0.61	5.50	114	0.97	0.05	0.97	3.84
1084.3	2.0	1	0.49	-0.23	0.54	5.96	127	0.21	-0.45	0.50	4.82	111	0.25	-0.68	0.72	5.96
1083.9	2.3	4	-0.65	-0.26	0.70	6.34	131	-0.09	-0.65	0.66	5.17	115	0.11	-0.78	0.78	6.34
1083.6	2.6	2	-0.09	-0.86	0.87	6.60	131	-0.06	-0.80	0.81	5.77	112	-0.01	-0.91	0.91	6.60
1083.3	3.0	4	-0.77	-0.28	0.82	6.47	128	-0.07	-0.82	0.82	4.63	110	0.00	-0.96	0.96	6.47
1081.8	4.4	4	-0.07	-0.73	0.73	2.31	141	-0.17	-0.98	1.00	1.99	121	-0.02	-1.09	1.09	2.31
1079.2	7.1	4	-0.31	-0.97	1.02	2.09	140	-0.12	-1.00	1.01	2.00	121	0.03	-1.16	1.16	2.09
1076.6	9.7	4	-0.09	-1.03	1.03	2.47	141	0.05	-0.90	0.90	2.13	121	0.16	-1.24	1.25	2.47
1073.9	12.3	4	0.11	-1.01	1.01	2.54	141	0.27	-0.93	0.97	2.54	121	0.32	-1.27	1.31	2.48
1071.3	14.9	4	0.12	-0.82	0.83	3.07	141	0.46	-1.11	1.20	3.07	121	0.47	-1.25	1.33	2.58
1068.7	17.6	4	0.05	-0.89	0.89	3.48	140	0.66	-1.08	1.27	3.48	121	0.68	-1.19	1.37	2.89
1066.1	20.2	4	0.32	-0.74	0.81	3.49	141	0.60	-0.89	1.07	3.49	121	0.74	-1.01	1.25	3.00
1063.4	22.8	4	0.32	-0.64	0.71	3.29	141	0.52	-0.66	0.84	3.29	121	0.79	-0.73	1.07	2.91
1060.8	25.4	4	0.48	-0.49	0.69	2.97	141	0.49	-0.54	0.73	2.97	121	0.74	-0.46	0.87	2.53
1058.2	28.1	4	0.22	-0.76	0.80	3.08	141	0.50	-0.39	0.63	3.08	121	0.73	-0.29	0.79	2.43
1055.6	30.7	4	0.31	-0.28	0.42	3.76	141	0.56	-0.28	0.63	3.76	121	0.79	-0.20	0.82	2.61
1052.9	33.3	4	0.48	-0.10	0.49	4.19	141	0.64	-0.15	0.65	4.19	121	0.95	-0.09	0.95	2.75
1050.3	35.9	4	0.74	0.22	0.78	2.83	131	0.63	-0.05	0.63	2.48	118	1.04	0.13	1.05	2.83
1047.7	38.6	4	0.80	0.08	0.80	2.47	123	0.68	0.10	0.69	2.47	92	0.91	0.18	0.93	2.33
1045.1	41.2	4	0.89	0.17	0.91	2.60	113	0.77	0.16	0.79	2.26	77	0.93	0.18	0.95	2.60
1042.4	43.8	3	0.77	0.08	0.77	4.15	75	0.97	0.30	1.02	4.15	51	1.11	0.38	1.17	4.08
1039.8	46.4	3	0.89	0.04	0.90	2.78	56	1.05	0.11	1.05	2.25	28	0.95	0.11	0.96	2.78
1037.2	49.1	2	0.92	1.61	1.85	2.62	49	1.09	0.21	1.11	2.43	21	1.00	0.09	1.00	2.22
1034.6	51.7	0	-	-	-	-	30	0.94	0.18	0.96	2.40	19	1.32	0.17	1.33	2.59
1031.9	54.3	0	-	-	-	-	21	0.85	0.21	0.88	2.56	15	1.17	0.25	1.20	2.52
1029.3	56.9	0	-	-	-	-	16	0.96	0.00	0.96	2.62	12	1.22	0.33	1.26	2.82

Blue color represents the opening to the intake bays

Intake B - Two Units Generating (Unit 3 and 4) (Also Units 1 and 2 Generating)
Southwest Quadrat

		Distance from Intake A (0-10 ft)					Distance from Intake A (10-15 ft)					Distance from Intake A (15-20 ft)				
Elevation (ft-AMSL)	Depth (ft)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Resultant Velocity (ft/sec)	Count (n)	Mean East Velocity (ft/sec)	Mean North Velocity (ft/sec)	Mean Resultant Velocity (ft/sec)	Maximum Velocity (ft/sec)
1084.6	1.6	0	-	-	-	-	53	0.36	-0.03	0.36	5.67	54	0.42	-0.01	0.42	4.49
1083.1	2.0	0	-	-	-	-	50	0.83	-0.88	1.20	4.02	54	1.05	-0.86	1.36	6.24
1082.8	2.3	0	-	-	-	-	51	0.96	-0.97	1.36	6.67	58	1.36	-1.03	1.71	6.57
1082.5	2.6	0	-	-	-	-	54	1.24	-1.35	1.83	8.42	55	1.32	-1.26	1.83	8.31
1082.1	3.0	0	-	-	-	-	53	1.25	-1.19	1.72	4.76	57	1.47	-1.18	1.89	5.17
1080.7	4.4	0	-	-	-	-	59	1.28	-1.27	1.81	3.80	60	1.58	-1.08	1.92	4.03
1078.0	7.1	0	-	-	-	-	59	1.24	-1.20	1.72	3.10	60	1.73	-0.94	1.97	3.72
1075.4	9.7	0	-	-	-	-	59	1.14	-0.98	1.50	3.81	60	1.63	-0.75	1.79	3.22
1072.8	12.3	0	-	-	-	-	59	1.01	-0.63	1.19	3.46	60	1.56	-0.51	1.64	3.07
1070.2	14.9	0	-	-	-	-	59	1.11	-0.58	1.25	3.63	59	1.57	-0.25	1.59	3.21
1067.5	17.6	0	-	-	-	-	59	0.93	-0.31	0.98	3.43	60	1.26	0.00	1.26	2.78
1064.9	20.2	0	-	-	-	-	59	0.67	-0.11	0.68	3.57	59	1.04	0.16	1.05	2.64
1062.3	22.8	0	-	-	-	-	59	0.63	0.02	0.63	3.52	60	0.91	0.24	0.94	2.94
1059.7	25.4	0	-	-	-	-	59	0.56	0.18	0.59	3.91	60	0.81	0.28	0.86	2.53
1057.0	28.1	0	-	-	-	-	59	0.45	0.19	0.49	3.58	60	0.66	0.39	0.76	2.58
1054.4	30.7	0	-	-	-	-	59	0.27	0.33	0.43	4.47	60	0.51	0.36	0.63	3.64
1051.8	33.3	0	-	-	-	-	59	0.03	0.40	0.40	3.54	60	0.33	0.51	0.60	3.59
1049.2	35.9	0	-	-	-	-	57	-0.11	0.46	0.47	2.31	60	0.15	0.54	0.56	3.18
1046.5	38.6	0	-	-	-	-	52	-0.10	0.53	0.54	2.25	55	0.01	0.63	0.63	2.02
1043.9	41.2	0	-	-	-	-	47	-0.27	0.69	0.74	1.51	50	0.12	0.73	0.74	2.24
1041.3	43.8	0	-	-	-	-	35	-0.31	0.70	0.76	2.04	36	-0.09	0.75	0.76	4.94
1038.7	46.4	0	-	-	-	-	27	-0.29	0.71	0.76	1.60	25	-0.11	0.46	0.47	2.47
1036.0	49.1	0	-	-	-	-	23	-0.15	0.64	0.66	1.74	23	-0.19	0.44	0.48	1.54
1033.4	51.7	0	-	-	-	-	19	-0.15	0.54	0.56	1.38	19	-0.27	0.55	0.61	1.67
1030.8	54.3	0	-	-	-	-	11	-0.19	0.43	0.47	1.58	15	-0.34	0.49	0.60	1.71
1028.2	56.9	0	-	-	-	-	6	-0.24	0.56	0.61	1.15	10	-0.56	0.27	0.62	1.50

Blue color represents the opening to the intake bays

APPENDIX C

FISH COMMUNITY ASSESSMENT STUDY PLAN

PURSE SEINE SUMMARY FROM LAKES JOCASSEE AND KEOWEE, 2012 & 2013

KEOWEE-TOXAWAY PROJECT

FERC NO. 2503

by

David J. Coughlan and Barry K. Baker

Duke Energy Carolinas, LLC
Environmental Department
Water Resources

July 31, 2013

APPENDIX C

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I. EXECUTIVE SUMMARY

On January 27, 2012, the Federal Energy Regulatory Commission (FERC) recommended Duke Energy conduct an evaluation of fish entrainment at the Jocassee Pumped Storage Station (JPSS) as part of relicensing of the Keowee-Toxaway Hydroelectric Project, FERC No. 2503 (Project). One part of this three-part evaluation was the use of hydroacoustic monitoring near the intakes to estimate numbers of fish entrained under the range of Project operations to provide critical data used in estimating entrainment-related fish morality. To verify the species composition and size distribution of the pelagic forage fish observed by the hydroacoustics in Lakes Jocassee and Keowee, nighttime purse seine collections were made in both lakes on three dates during the year-long entrainment study.

In order to provide *in situ* data on forage fish species in Lakes Jocassee and Keowee, nighttime collections were made with a 400- x 30-ft purse seine. The pelagic fish communities observed in purse seine collections on Lakes Jocassee and Keowee were dominated by threadfin shad and blueback herring. Rodriguez (2013a and 2013b) found similar results in an examination of purse seine data dating back to 1997 for both reservoirs and surmised this the prevailing condition since introduction of both species into Lake Jocassee in the 1970's (Prince and Barwick 1981). These two pelagic alosine species are small with upwards of 99% of the individuals collected in both lakes being < 6 in. Their small size and residence in open water would make them prime species of concern for fish entrainment during generation or pumping at the Project.

II. PROJECT INTRODUCTION AND BACKGROUND

In a January 27, 2012 letter, the Federal Energy Regulatory Commission (FERC) directed Duke Energy to conduct an evaluation of fish entrainment at the Jocassee Pumped Storage Station (JPSS) as part of relicensing of the Keowee-Toxaway Hydroelectric Project, FERC No. 2503 (Project). This evaluation was to consist of three parts and include: (1) use of Acoustic Doppler Current Profiler (ADCP) to describe the velocity around the JPSS intakes across operational scenarios to allow Duke Energy to relate velocity data to historical generation and pumping rates; (2) use of hydroacoustic monitoring near the intakes to estimate numbers of fish entrained under the range of Project operations to provide critical data used in estimating entrainment-related fish morality; and (3) desktop entrainment mortality estimation, based on pump-turbine characteristics and the species and sizes of fish being entrained, to provide a mortality rate for fish entrained to apply to the rate of fish entrainment to estimate fish mortality.

The hydroacoustic assessment (conducted from July 2012 though June 2013) relies on sound to enumerate fish targets entrained by JPSS but provides no information on the species composition of the forage community nor an independent assessment of the lengths of fish likely to be entrained. In order to provide *in situ* data on forage fish species in Lakes Jocassee and Keowee, nighttime collections were made with a purse seine on three occasions in September and November 2012 and March 2013. Epilimnetic forage fish species typically cease schooling after dark and rise to the water surface where they distribute randomly and become vulnerable to active sampling gear like the purse seine.

III. STUDY AREA

Pelagic forage fish collections, via nighttime purse seine hauls, occurred in Lakes Jocassee and Keowee (Figure 1). Ongoing annual purse seine surveys occur in November at two and three unique locations in Jocassee and Keowee, respectively. Additionally, to supplement the collection of forage fish data during this year-long entrainment study, purse seine samples were collected on two dates at one location near the JPSS forebay in Lake Jocassee and one location downstream of JPSS in Lake Keowee. This downstream location in Lake Keowee was identical to the one immediately downstream of JPSS sampled annually each November.

IV. METHODOLOGY

Purse seine samples were collected in September and November 2012 and March 2013. The purse seine measured 122.0 x 9.1 m (400- x 30-ft), with a mesh size of 4.8 mm (3/16 in). To collect a sample, the net is pulled from the back of the purse seine boat by a smaller boat and dragged (or seined) through the water column, eventually enclosing a rough circle as the smaller boat returns the end ropes to the purse boat. The bottom 'purse' line of the net is retrieved, completely trapping the pelagic fish community down to a depth of approximately 6 m. The net is hauled aboard the purse boat by hand, the forage fish collected, and a labeled sample preserved for later laboratory analysis. The fish from each haul were identified to species (Menhinick 1991, Rohde et al. 2009) to estimate taxa composition and measured (TL, mm) to determine size distribution. Water temperature (°C) was measured at each sampling location with a calibrated thermistor.

V. RESULTS

Species Composition - Purse seine collections on Lakes Jocassee (Figure 2) and Keowee (Figure 3) documented a pelagic forage fish community dominated by threadfin shad (*Dorosoma petenense*) and blueback herring (*Alosa aesitvalis*). Of the 2,491 fish collected in the purse hauls, 99.84% (n=2,487) were alosines.

Species composition in the hauls varied dramatically from September 2012 to March 2013. Threadfin shad dominated the September 2012 catches in the JPSS forebay and downstream of JPSS in Lake Keowee and then only the November 2012 collection near Oconee Nuclear Station (ONS). Rodriguez (2013b) has documented an affinity of threadfin shad for the thermally enhanced regions of Lake Keowee near the ONS during the cooler periods of the year. Purse samples collected from both reservoirs in November 2012 and March 2013 near JPSS were composed almost entirely of blueback herring.

Length Frequency – Based on visual inspection of the purse seine distributions, most of the fish collected in the September and November 2012 hauls were less than 4 in (102 mm), while most collected in March 2013 were less than 6 in. (152 mm). When data for the entire series of hauls from both lakes was combined and tabulated, 88.72% of all fish collected were less than 4 in, while 99.92% were less than 6 in (Table 1).

Analysis of fish lengths collected only in Lake Jocassee indicated that 86.26% of all fish collected were less than 4 in, while 99.90% were less than 6 in (Table 2 and Figure 4). Analysis of fish lengths collected only in Lake Keowee indicated that 90.48% of all fish collected were less than 4 in, while 99.93% were less than 6 in.

VI. DISCUSSION AND ANALYSIS

The pelagic fish communities observed in purse seine collections on Lakes Jocassee and Keowee were dominated by threadfin shad and blueback herring. Rodriguez (2013a and 2013b) found similar results in an examination of purse seine data dating back to 1997 for both reservoirs and surmised this the prevailing condition since introduction of both species into Lake Jocassee in the 1970's (Prince and Barwick 1981). These two pelagic alosine species are small with upwards of 99% of the individuals collected in both lakes being < 6 in. Their small size and residence in open water would make them prime species of concern for fish entrainment during generation or pumping at JPSS.

VII. TABLES

Table 1. Length frequency distribution (2 inch size groups) of all fish collected in purse seine samples from both Lakes Jocassee and Keowee in September and November 2012 and March 2013. Additional non-alosine fish captured were white catfish (255 mm), bluegill (98 and 124 mm), and black crappie (337 mm).

mm range	inch range	Number	Frequency (%)
1 - 51	0 - 2	18	0.72
52 - 102	2 - 4	2192	88.00
103 - 152	4 - 6	279	11.20
153 - 203	6 - 8	0	0.00
204 - 254	8 - 10	0	0.00
255 - 305	10 - 12	1	0.04
306 - 457	12 - 18	1	0.04

Table 2. Length frequency distribution (2 inch size groups) of fish collected from either Lake Jocassee or Lake Keowee in September and November 2012 and March 2013.

		Frequency (%)	
mm range	inch range	Jocassee	Keowee
1 - 51	0 - 2	0.94	0.56
52 - 102	2 - 4	85.32	89.92
103 - 152	4 - 6	13.64	9.45
153 - 203	6 - 8	0.00	0.00
204 - 254	8 - 10	0.00	0.00
255 - 305	10 - 12	0.09	0.00
306 - 457	12 - 18	0.00	0.07

VIII. LOCATION MAPS AND FIGURES

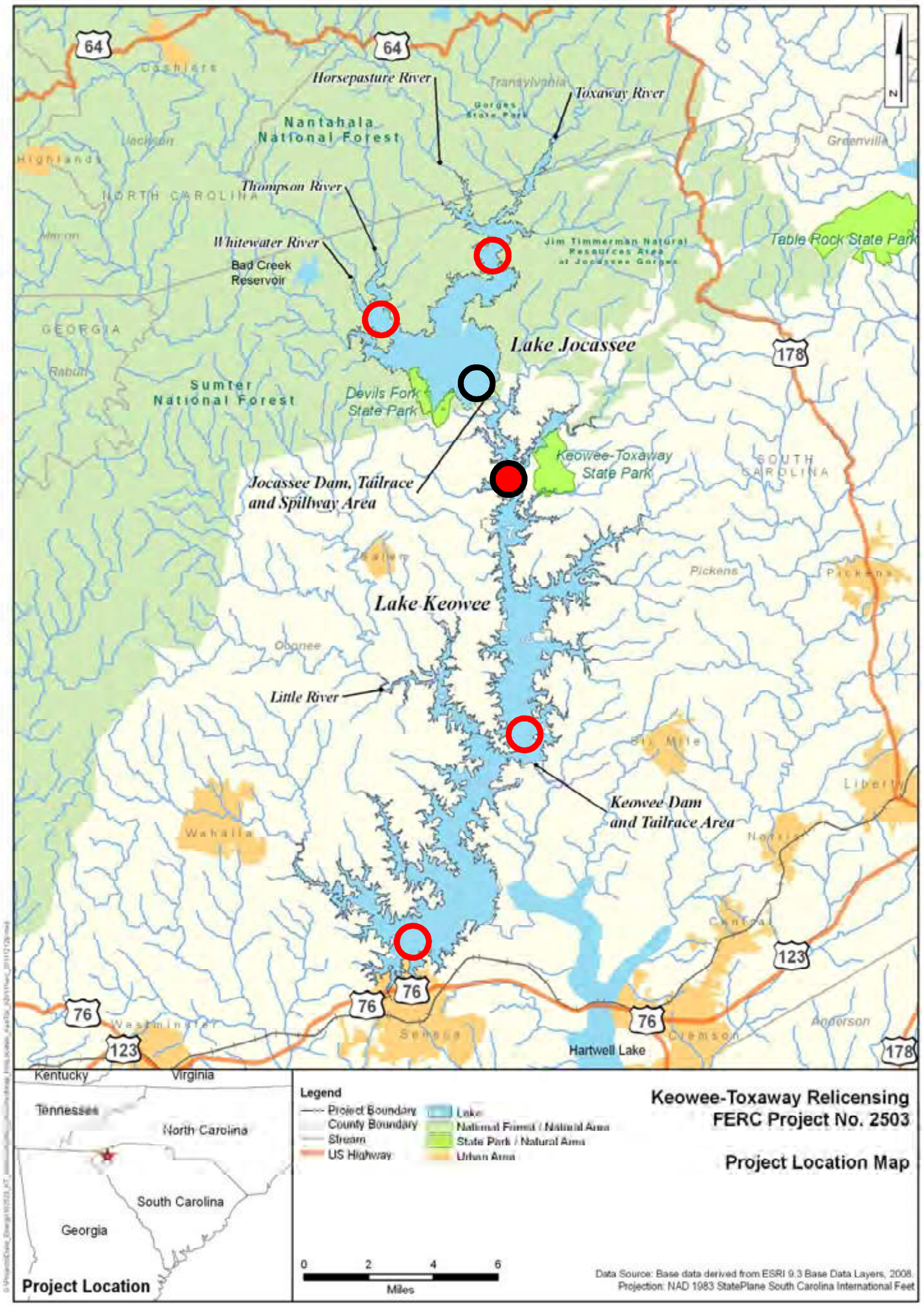

Figure 1. Map of the Keowee-Toxaway Project with special reference to purse seine locations described in this report. Black circles - locations sampled in September 2012 and March 2013; red circles – locations sampled in November 2012 (includes the black circle with red fill).

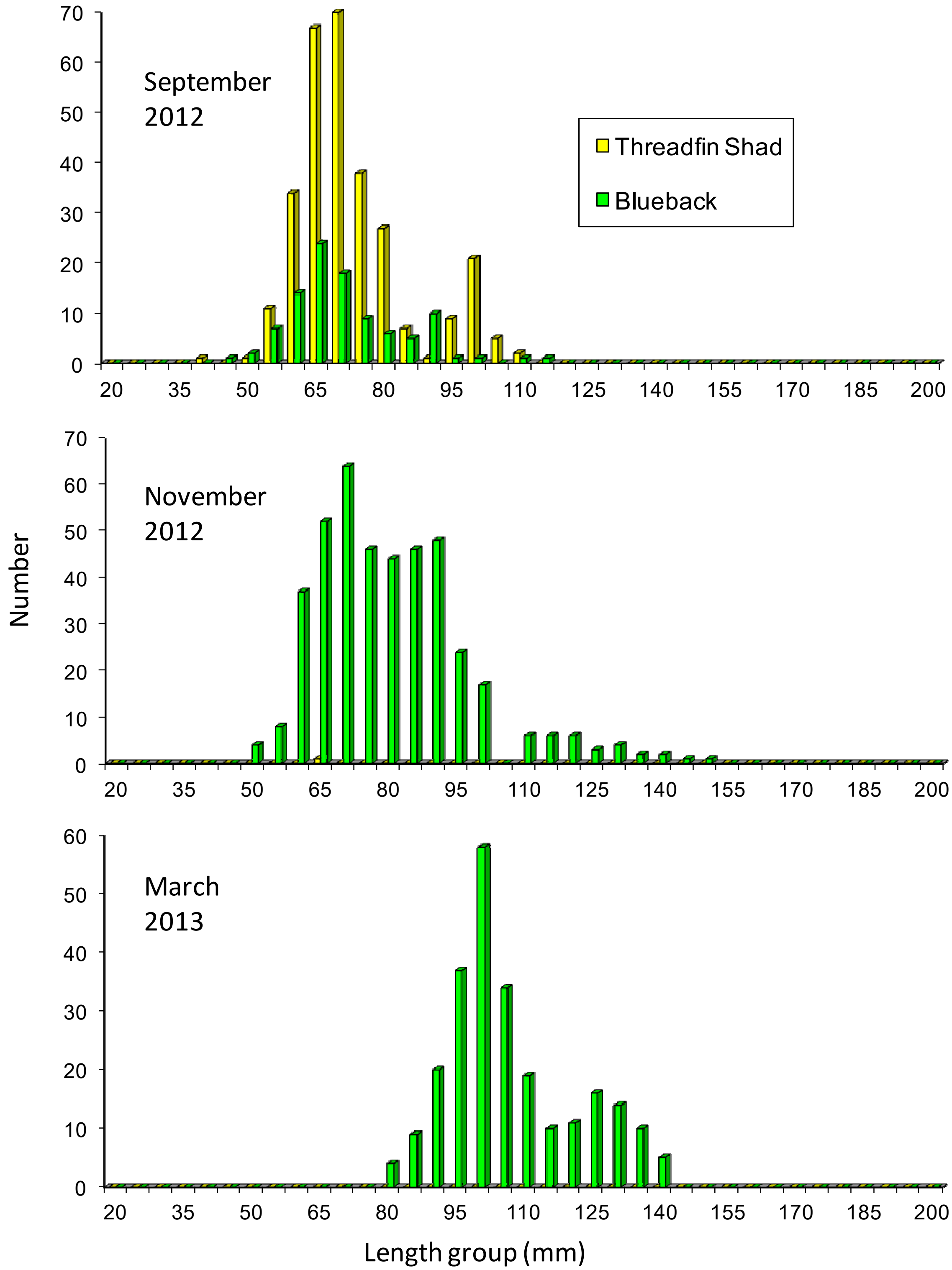

Figure 2. Length frequency distributions of forage fish collected in purse seine hauls in September and November 2012 and March 2013 in Lake Jocassee.

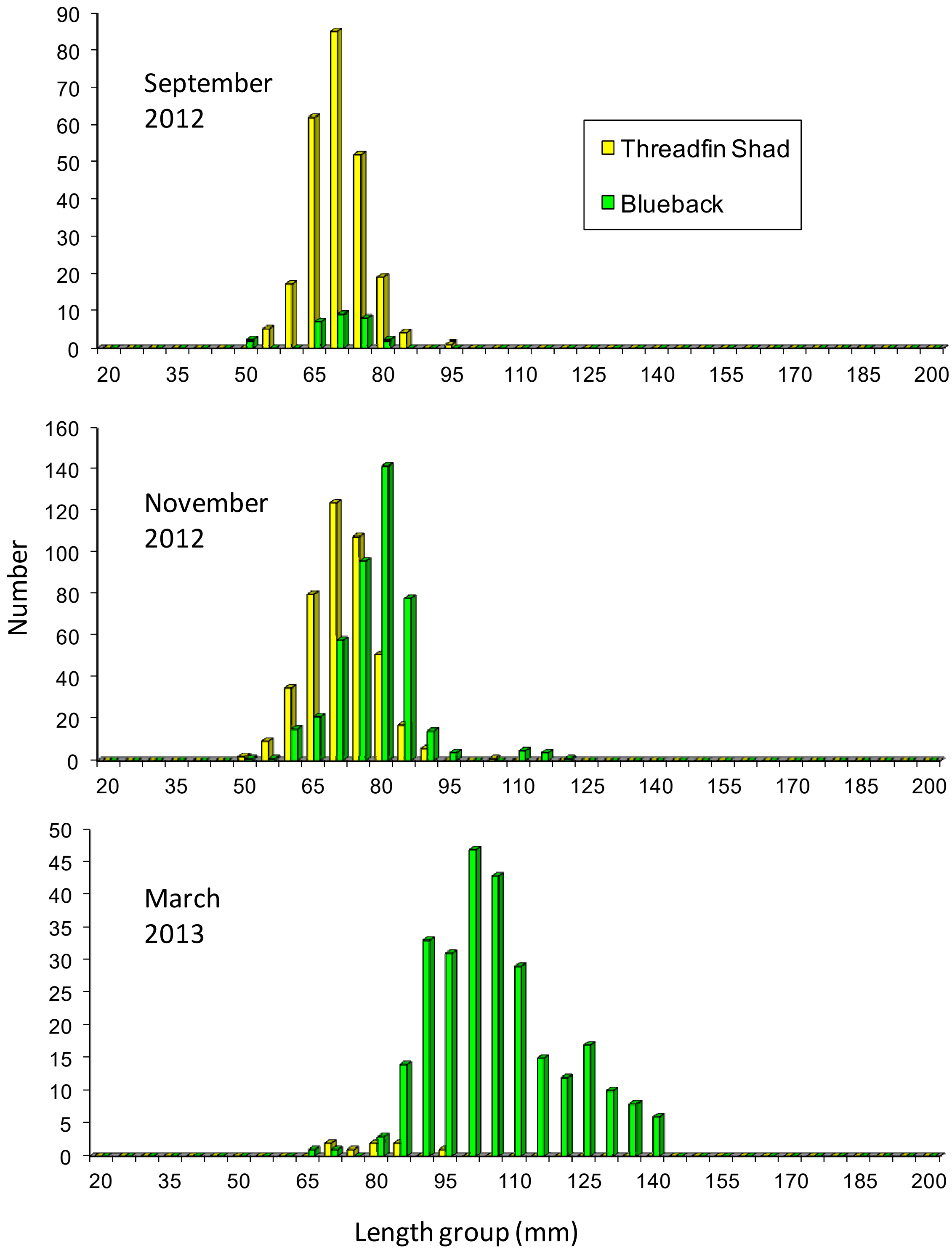

Figure 3. Length frequency distributions of forage fish collected in purse seine hauls in September and November 2012 and March 2013 in Lake Keowee.

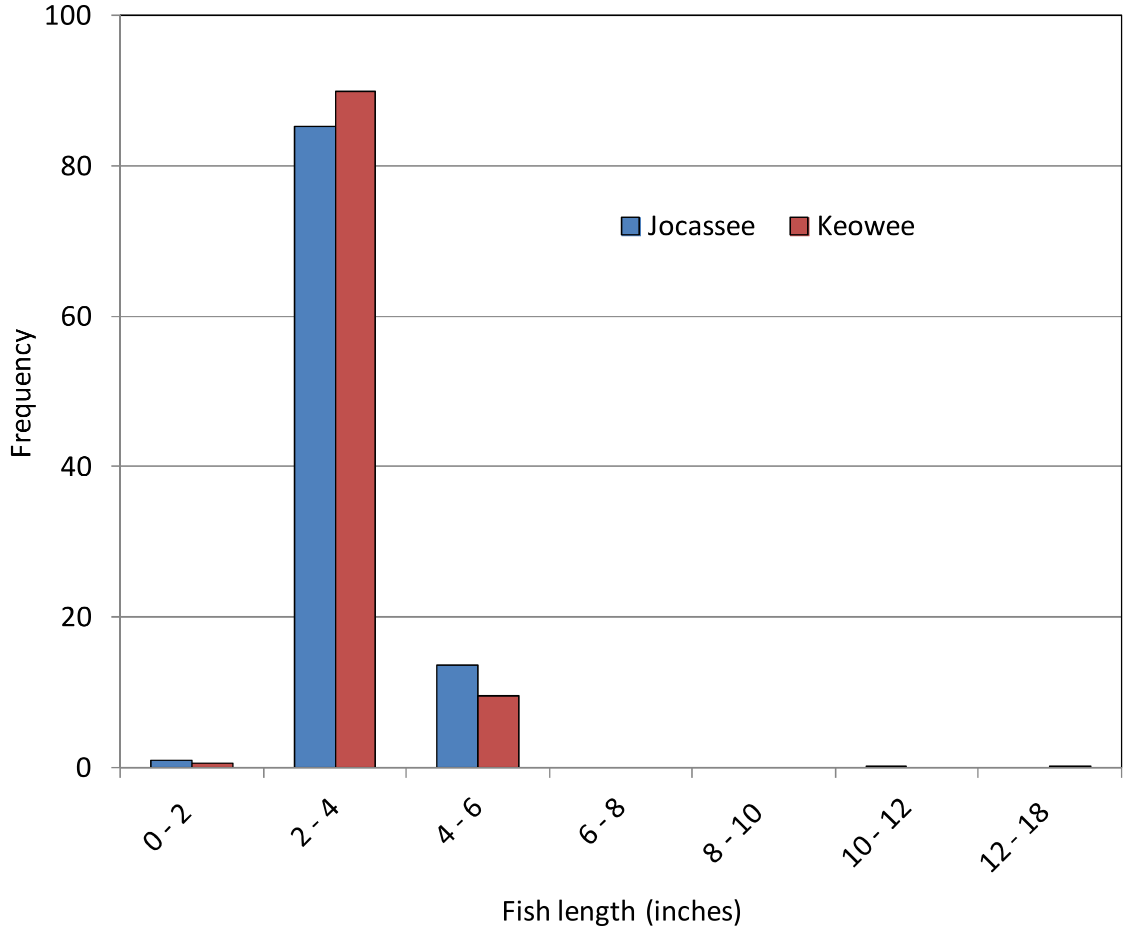

Figure 4. Length frequency distribution (2-inch size groups) of all fish collected in purse seine samples from either Lake Jocassee or Lake Keowee in September and November 2012 and March 2013.

IX. LITERATURE CITATIONS

Menhinick, E.F. 1991. The freshwater fishes of North Carolina. North Carolina Wildlife Resources Commission. Raleigh, NC. 227 p.

Prince, E.D. and D.H. Barwick. 1981. Landlocked blueback herring in two South Carolina reservoirs: reproduction and suitability as stocked prey. North American Journal of Fisheries Management 1:41-45.

Rodriguez, M.S. 2013a. The pelagic forage fish community of Lake Jocassee, South Carolina. Report to Duke Energy, LLC by M.S. Rodriguez, Greensboro, NC.

Rodriguez, M.S. 2013b. The pelagic forage fish community of Lake Keowee, South Carolina. Report to Duke Energy, LLC by M.S. Rodriguez, Greensboro, NC.

Rohde, F.C., R.G. Arndt, J.W. Foltz, and J.M. Quattro. 2009. Freshwater Fishes of South Carolina. University of South Carolina Press. Columbia, SC. 430 pp.

APPENDIX D

CONSULTATION RECORD

Barwick, Hugh

From: Barwick, Hugh
Sent: Thursday, August 15, 2013 12:39 PM
To: Dan Rankin (rankind@dnr.sc.gov); Bill Marshall (marshallb@dnr.sc.gov); Mark Cantrell (mark_a_cantrell@fws.gov)
Cc: Dave Van Lear (vanlear1940@bellsouth.net); Keith Finley (Keith.Finley@duke-energy.com); Mark Scott (scottm@dnr.sc.gov); Vivianne Vejdani (VejdaniV@dnr.sc.gov); Huff, Jennifer R; Lineberger, Jeff; Jessen, Nancy S
Subject: 20130813_Fish Community Assessment Study_Final Draft

The above report regarding KT fish entrainment is available at http://www.ktrel.com/default.aspx (under the Aquatics RC tab and in the Study Plan Reports folder) for your review and comment. If possible, I would like to have your track-change edits and comments no later than September 16. You can return your comments by adding your initials to the document and saving it in the Study Plan Report folder. If you have questions or concerns with this report, please do not hesitate to let me know.

You will recall, we have an Aquatics RC Meeting scheduled on August 26 (1:00-4:00 PM at the Anderson Operations Conference Room) to discuss this report.

Hugh Barwick
Duke Energy
Water Strategy & Hydro Licensing
704.382.0805

Barwick, Hugh

From:	Bill Marshall [MarshallB@dnr.sc.gov]
Sent:	Monday, September 16, 2013 4:45 PM
To:	Barwick, Hugh
Cc:	Bob Perry
Subject:	RE: 20130813_Fish Community Assessment Study_Final Draft
Attachments:	DNR Comments KT Entrainment Study (Sep 16, 2013).docx

Hugh,

The attachment presents SCDNR comments on the KT fish entrainment study report. Thank you for providing this information and giving us another opportunity to provide our input.

Bill Marshall
SC Department of Natural Resources
PO Box 167, 1000 Assembly Street
Columbia, SC 29202
803-734-9096 - office
803-331-2608 - mobile

Coordinator, FERC Hydroproject Review

From: Barwick, Hugh [mailto:Hugh.Barwick@duke-energy.com]
Sent: Thursday, August 15, 2013 12:39 PM
To: Dan Rankin; Bill Marshall; Mark Cantrell (mark_a_cantrell@fws.gov)
Cc: Dave Van Lear (vanlear1940@bellsouth.net); Finley, Keith A; Mark Scott; Vivianne Vejdani; Huff, Jennifer R; Lineberger, Jeff; Jessen, Nancy S
Subject: 20130813_Fish Community Assessment Study_Final Draft

The above report regarding KT fish entrainment is available at http://www.ktrel.com/default.aspx (under the Aquatics RC tab and in the Study Plan Reports folder) for your review and comment. If possible, I would like to have your track-change edits and comments no later than September 16. You can return your comments by adding your initials to the document and saving it in the Study Plan Report folder. If you have questions or concerns with this report, please do not hesitate to let me know.

You will recall, we have an Aquatics RC Meeting scheduled on August 26 (1:00-4:00 PM at the Anderson Operations Conference Room) to discuss this report.

Hugh Barwick
Duke Energy
Water Strategy & Hydro Licensing
704.382.0805

SCDNR Comments Regarding the Fish Entrainment Study Report of August 2013 for the Keowee-Toxaway Hydro Project

September 16, 2013

Staff with the South Carolina Department of Natural Resources (DNR) have reviewed the August 2013 report produced by Duke Energy entitled "Fish Community Assessment Study, FERC Required Fish Entrainment Modification" (Study Report), which addresses entrainment at Jocassee Pump Storage Station (JPSS), and we offer the following comments for consideration.

Chapter 1 - Numbers of Fish Entrained

Chapter 1 of the Study Report presents estimated numbers of fish entrained at JPSS and the related mortality for the period of July 2012 through June 2013. Duke Energy reports an estimated 1,519,102 fish were entrained during pumpback mode and 552,894 were entrained during conventional generation mode. While we do not dispute these numbers, it is appropriate to recognize these estimates do not include the entrainment of larval and juvenile fish under about 1.5 to 2 inches in size, since hydroacoustic equipment is not able to count these smaller fish.

Duke Energy hired the consultant Normandeau Associates, Inc. to estimate the mortality of entrained fish considering the nature of the turbines and other factors. As presented in Appendix A of the Study Report, Normandeau applied the Franke et al (1997) model to estimate mortality of entrained fish. The Franke model factors in physical parameters of the turbines (i.e. fish size, blade strike, turbine velocity, etc.) in order to estimate mortality. The Franke model was applied to the estimates of entrained fish (of Chapter 1) to yield estimates of entrainment mortality as follows: 24,328 fish during pumpback mode and 13,253 during generation mode.

While we do not have data to dispute these estimates of mortality, we question the apparent assumptions used in estimating mortality in this situation. The Normandeau entrainment survival report points out that "reliable field studies using fish acclimated to depth have not been conducted", yet the Study Report apparently assumes pressure-related mortality to be zero, and calculates a mortality estimate using only the Franke model. The Normandeau report further recognizes the lack of data for how decompression trauma impacts threadfin shad and blueback herring, yet makes the assumption that these species are just as "hardy" as other physostomous species to overcoming decompression trauma, which is another untested assumption of the Normandeau report. The assumptions of the Normandeau survival report related to pressure effects are lacking in empirical data and thus the overall estimates of entrainment mortality may be substantially incomplete.

Regardless of the issue of survival of entrained fish, we recognize that entrainment (minus larval and juvenile fishes) as estimated for July 2012 through June 2013 was moderate in comparison with lakewide population estimates of shad and herring conducted during fall 2012. Entrainment during pumpback mode at JPSS was approximately 21% of the total lakewide population as presented for Lake Keowee. Entrainment during generation mode was only about 4% of the

2012 total lakewide population estimate in Lake Jocassee; however, it is appropriate to note the forage fish population estimate for Jocassee in 2012 came in over 300% higher than the recent average population estimates for the reservoir, and was considered a "statistical outlier" in Duke Energy's statistical analyses. Excluding the 2012 estimate, average fall population levels for Jocassee in recent years have been approximately 4 million forage fish. Jocassee entrainment (during generation) in the study compared to 4 million fish would equate to approximately 14% of the total lakewide forage fish population.

Chapters 2 and 3 - Forage Fish Population Analyses

Chapters 2 and 3 present Duke Energy's updated statistical analyses of forage fish populations and the potential effects of JPSS operations. Most of this data was presented in earlier reports and this update includes the addition of 2011-2013 data. Analyses include simple linear regression and multivariate analyses of 15 and 16 years of historic data for Lakes Keowee and Jocassee, respectively. The analyses continue to present negative effects of JPSS operations on forage fish populations.

In Chapter 3, the data for Lake Keowee continues to indicate that JPSS project operation has a negative effect on both the Keowee Basin (1/2 of Lake Keowee) *and* lakewide forage population levels during pump-back mode (95% confidence level). This relationship is highly influenced by one very "influential" data point during 2000, when low pumpback was realized at JPSS, which complicates interpretation of the data. In addition, Figure 3-4, a graphic of Fall Forage Fish in Lake Keowee, continues to present a downward trend in forage fish abundance.

As presented in Chapter 2, the data for Lake Jocassee continues to indicate that JPSS project operation has a negative effect on fall forage fish densities in Zone 1 of Lake Jocassee (~1/3 of lake adjacent to forebay) during conventional generation. One statistical outlier data point (fall 2012 forage estimate) also was "non-conforming" to the relationship. When 2012 data were excluded from the analysis, JPSS generation flows for May through October present a negative effect on the fall forage fish lakewide numbers.

Forage fish population levels in the Keowee-Toxaway lakes are clearly highly variable and potentially affected by many factors, including entrainment. While the one year entrainment study does offer insight into the magnitude of entrainment at JPSS, it does not define the relationship between entrainment and forage populations through the wide range of population levels experienced in the lakes. We do not know if the level of entrainment is proportional to lakewide population levels or if it is static.

From DNR's perspective, the relative impact of entrainment remains questionable because we see that historic data indicates negative population effects related to JPSS operations; however, the one-year entrainment study provides a less compelling cause for concern particularly given the rebound in estimated total population numbers.

Because of the uncertainties related to entrainment impacts, we believe it is appropriate to employ all reasonable operational adjustments that are expected to result in reduced entrainment rates. Operational modifications to reduce entrainment at Unit 4 during pumping mode would appear to present the greatest opportunity to reduce overall entrainment because entrainment rates for Unit 4 were 2 to 4 times the other units between September and March, and Unit 4 rates were highest during most other months as well.

We also believe, based on fish protection measures tested at Richard B. Russell dam, that modification and use of lighting is a practical and effective means to reduce entrainment; therefore, we suggest lighting modification to include the reduction of lighting at hydroplant facilities so as to reduce the attraction of fish to intake areas. Additionally, we would suggest use of lighting to include installation of lights positioned downstream of the Jocassee tailrace to draw fish away from the intake areas at JPSS; however, we understand Duke Energy has reasons for not wanting to install this type of lighting.

Finally, DNR recommends Duke Energy continue to support the monitoring of fish populations in the Keowee-Toxaway Lakes to enable Duke Energy and DNR to assess the potential future effects of hydro operations on the fisheries going forward through the life of a new license.

Submitted by
Bill Marshall
SC Department of Natural Resources

Comment	Duke Energy Response
Chapter 1. The population estimate for the 2012 Lake Jocassee fall survey was considered a "statistical outlier" and numbers of fish entrained during generation at the JPSS should have been more appropriately compared to the estimates noted in the historical fall surveys (e.g., approximately 4 million fish).	Duke Energy disagrees with this statement. Even though the Lake Jocassee 2012 forage fish population estimate was a statistical outlier when compared to data collected in previous years, the fish were nevertheless present. In addition, it would appear logical to expect the numbers of fish entrained from a reservoir to be somewhat proportional to their abundance in the reservoir during the year sampled. Thus, the suggestion of comparing 2012 fish entrainment at the Jocassee Station to periods when fish abundance was much lower would appear inappropriate.
Chapters 2 and 3. The analyses demonstrate negative effects of JPSS operations on forage fish populations.	In any statistical analyses where significance is dependent on only one data point, such a relationship is suspect. In the case of Lake Jocassee, deleting the 2012 forage fish population estimate from the 17-year data set resulted in a statistically-significant negative relation between JPSS generation and Lake Jocassee forage fish populations. For Lake Keowee, deleting the 2000 forage fish population estimate from the 15-year data set resulted in a statistically-insignificant relationship between JPSS pumping operations and Keowee forage fish populations. Furthermore, there were numerous other non-operational relationships (e.g., meteorological conditions, nutrients, food, and predation) noted in Chapters 2 and 3 resulting in both positive and negative relationships as well. So, while SCDNR's statement there is a statistically-significant relationship between JPSS operations and fish populations is correct, these significant relationships were always related to the inclusion of or the deletion of one data point. Further, it's unclear whether this relationship is due to entrainment or some other currently unknown effect. Overall, both Lakes Jocassee and Keowee supported forage fish populations similar to other nearby reservoirs with similar levels of fertility.

Comment	Duke Energy Response
Duke Energy should monitor fish populations at the Project for the duration of the New License.	Duke Energy has collected various types of ecological data from Lakes Jocassee and Keowee for over 30 years. As presented in Chapters 2 and 3 of the study report, little impact has been noted on fish populations associated with the operation of the Project during this last 15-17 years period. Therefore, continuous data collection is not needed and should not be required in the New License.

Appendix D

Relicensing Agreement for the Keowee-Toxaway Hydroelectric Project FERC No. 2503

Relicensing Agreement

for the

Keowee-Toxaway Hydroelectric Project
FERC Project No. 2503

September 18, 2013

Signature Copy

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AGREEMENT

APPENDICES

APPENDIX A: PROPOSED LICENSE ARTICLES

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STATE OF NORTH CAROLINA
COUNTY OF MECKLENBURG

DUKE ENERGY CAROLINAS, LLC

AGREEMENT

THIS AGREEMENT ("Agreement" or "Relicensing Agreement"), made and entered into as of November 29, 2013, by and between DUKE ENERGY CAROLINAS, LLC, with its principal place of business in Mecklenburg County, North Carolina (the "Licensee"); ADVOCATES FOR QUALITY DEVELOPMENT, INC.; ANDERSON AREA CHAMBER OF COMMERCE; CITY OF SENECA; COMMISSIONERS OF PUBLIC WORKS OF THE CITY OF GREENVILLE; FRIENDS OF LAKE KEOWEE SOCIETY, INC.; OCONEE COUNTY, SOUTH CAROLINA; PICKENS COUNTY, SOUTH CAROLINA; PICKENS COUNTY WATER AUTHORITY; SOUTH CAROLINA DEPARTMENT OF ARCHIVES AND HISTORY; SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES; SOUTH CAROLINA DEPARTMENT OF PARKS, RECREATION AND TOURISM; SOUTH CAROLINA WILDLIFE FEDERATION; THE CLIFFS AT KEOWEE VINEYARDS COMMUNITY ASSOCIATION, INC.; THE RESERVE AT LAKE KEOWEE; UPSTATE FOREVER; and WARPATH DEVELOPMENT, INC.; (collectively "Stakeholders"), (all referenced Stakeholders and the Licensee collectively "Parties" provided the duly authorized representative of each signs this Agreement), provides as follows:

WITNESSETH

WHEREAS, pursuant to a license issued by the Federal Energy Regulatory Commission (“FERC" or “Commission”) (FERC Project No. 2503), the Licensee operates a hydroelectric power project, known as the Keowee-Toxaway Hydroelectric Project (the "Project") which is situated on the Keowee and Little Rivers in the South Carolina counties of Oconee and Pickens with a small portion extending into Transylvania County, North Carolina, the Project consisting primarily of the following major components. (See the Exhibit K drawings for the Existing License for the Project, which describe the Project Boundaries in more specific detail.)

a) The Jocassee Development consisting principally of a powerhouse, two saddle dikes, two intake structures, water conveyance tunnels, a gated spillway, and the Jocassee Dam impounding the Keowee River to form Lake Jocassee; and

b) The Keowee Development consisting principally of a powerhouse, an intake structure, gated concrete ogee spillway, four saddle dikes, the Keowee Dam impounding the Keowee River and the Little River Dam impounding the Little River, both of which form Lake Keowee; and

WHEREAS, beginning in August 2009, the Licensee and the Stakeholders, plus EASTERN BAND OF CHEROKEE INDIANS, formally met as the Keowee-Toxaway Hydroelectric Project Stakeholder Team (“Team”) to begin the process of developing a non-binding Agreement-in-Principle ("AIP") with regard to the issues related to the relicensing of the Project; and

WHEREAS, on March 11, 2011, the Licensee filed a timely Notice of Intent with the FERC to apply for a new license ("New License") for the Project; and

WHEREAS, by July 25, 2013, the Licensee and the Stakeholders signed the non-binding AIP concerning most substantive matters of interest to them related to the relicensing of the Project, and the Licensee and the Stakeholders indicated in said AIP their desire to work together to convert the AIP into this binding Agreement; and

WHEREAS, EASTERN BAND OF CHEROKEE INDIANS, by electing not to sign the AIP was not afforded the opportunity to participate in the development of this Agreement but was afforded the opportunity to become a Party; and

WHEREAS, SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL, UNITED STATES ARMY CORPS OF ENGINEERS, and UNITED STATES FISH AND WILDLIFE SERVICE also participated in many of the meetings of the Team and were afforded the opportunity to become Parties to this Agreement; and

WHEREAS, on or before August 31, 2014, the Licensee will file an application, consistent with this Agreement in all respects, with the FERC for a New License for the Project; and

WHEREAS, the Licensee will include this Agreement and the accompanying Explanatory Statement in its Application for New License; and

WHEREAS, within 60 days following the FERC's issuance of its Notice of Ready for Environmental Analysis, the Licensee will file an application, consistent with this Agreement in all respects, with the South Carolina Department of Health and Environmental Control ("SCDHEC") for a Water Quality Certification for the Project pursuant to §401 of the Clean Water Act ("401 WQC"), as amended; and

WHEREAS, the Licensee, the United States Army Corps of Engineers ("USACE"), and the Southeastern Power Administration ("SEPA") are currently parties to a water storage balancing agreement ("1968 Agreement") requiring flow releases from the Keowee Development under certain circumstances and the 1968 Agreement will be replaced by a new agreement ("New Operating Agreement" or "NOA") to be negotiated in conjunction with relicensing of the Project and said NOA will not be inconsistent with this Agreement; and

WHEREAS, the Parties agree that generating power at the Project's powerhouses and managing the reservoirs' levels and flows for public water supply support, fish habitat, public recreation, and other purposes are all important uses of the limited waters of the Keowee and Little rivers and their tributaries, and that the terms of this Agreement strike a reasonable balance among these uses and provide a basis for the Parties' concurrence in the issuance of a New License for the Project to the Licensee, subject to the applicable terms, covenants, and provisions of this Agreement; and

WHEREAS, the Licensee's Application for New License will include proposed facilities and actions to protect, mitigate, or enhance: public recreational opportunities at the Project's reservoirs ("Project Reservoirs"), cultural resources, fish and wildlife resources, the regional economy, and other resource enhancement initiatives; and

WHEREAS, there are terms, phrases, and abbreviations specific to the Stakeholder Process that led to this Agreement and the significant terms, phrases, and abbreviations are defined in Appendix C; and

WHEREAS, the Parties agree that sharing the burden during periods of low inflow and maintenance and emergency conditions is important, and that the Low Inflow Protocol ("LIP") for the Keowee-Toxaway Hydroelectric Project (Appendix D) and the Maintenance and Emergency Protocol ("MEP") for the Keowee-Toxaway Hydroelectric Project (Appendix E) are reasonable compromises by the Parties to define operational changes during these time periods; and

WHEREAS, the maps included in Appendix F are intended solely to assist in describing the locations and boundaries of specific tracts of land, but are not of survey quality; and

WHEREAS, the Parties understand that certain governmental Parties have independent statutory responsibilities and processes that may result in mandates that are not consistent with the terms of this Agreement, and that it is nonetheless necessary to preserve the integrity and independence of those responsibilities and processes, and this Agreement specifically does so; and

WHEREAS, this Agreement is the culmination of the Parties' desires, as set forth in the July 25, 2013, AIP, to draft from the AIP a binding agreement that embodies the intent of the Parties; and

WHEREAS, this Agreement faithfully sets forth in more detail and specificity, in contractual terms, the concepts described and to which the Parties agreed to in the AIP, with mutually agreeable adjustments as negotiated by the Parties after the AIP was signed; and

WHEREAS, the Parties have now reached full agreement on the resolution of all the material resource matters identified and at issue in the New License for the Project, specifically including but not limited to hydropower generation; watershed and hydro operation practices that protect and sustain the quality and quantity of the waters of the Keowee-Toxaway River Basin; a well-managed and adequate water supply to serve the region for years to come; safe and sufficient access for users of motorized and non-motorized boats and safe and sufficient areas for fishing, hiking, sightseeing, camping, and other public recreation opportunities; opportunities to support tourism; balanced shoreline uses to accommodate diverse interests including undisturbed areas; conservation of the fish and wildlife resources as well as the habitats supporting those resources; and protection of Historic Properties, all of which result in the Parties relinquishing certain arguments and potential outcomes in exchange for the certainty of the agreed-upon terms and conditions;

NOW, THEREFORE, IN CONSIDERATION of all other actions and undertakings as set forth herein below, the Parties contract and agree as follows.

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RESOURCE AGREEMENTS

The Parties agree that, except for the provisions in Appendix A, the provisions in this Agreement should not be incorporated into the terms of the New License that the FERC is expected to issue for the Project. The Parties have listed their proposed License Articles in each relevant section and have provided the specific language of the proposed License Articles in Appendix A.

1.0 Agreements on Full Consensus

1.1 The Parties acknowledge that: (i) they have participated fully in the activities of the Keowee-Toxaway Stakeholder Process and have a good understanding of the issues resolved herein; (ii) this Agreement is developed from and is consistent with the AIP signed by the Parties by July 25, 2013, except to the extent that it contains mutually agreeable adjustments as negotiated by the Parties after the AIP was signed; (iii) they are requesting that the FERC issue a license for the Project with a term of at least 40 years; (iv) they are in agreement with the entirety of this Agreement; (v) they understand the Licensee will file this Agreement with the FERC and the SCDHEC for these agencies' consideration as they process applications for the New License and the 401 WQC for the Project; and (vi) the Licensee will also request that the FERC and the SCDHEC act consistently with the terms of this Agreement in issuing their licenses, certifications, and orders for the Project.

1.2 Actions of the Licensee

1.2.1 Application for New License – The Licensee shall develop and submit the Application for New License in a manner consistent with this Agreement and submit this Agreement with the Application for New License.

1.2.2 401 WQC – The Licensee shall submit its 401 WQC Request in a manner consistent with this Agreement and include this Agreement with the 401 WQC Request.

1.2.3 NOA – The Licensee shall negotiate with the USACE and the SEPA to replace the 1968 Agreement with a NOA that is not inconsistent with this Agreement.

1.2.4 Other Relicensing Filings – The Licensee shall ensure all other filings it makes as may be required for relicensing the Project are consistent with this Agreement.

1.3 Actions of Parties to this Agreement other than the Licensee

The Parties to this Agreement, excepting the Licensee, shall advocate for New License conditions, a 401 WQC, a NOA with the USACE and SEPA, and all other agency findings and documents associated with relicensing of the Project or implementation of the New License consistent with this Agreement by:

1.3.1 Submitting statements, individually or collectively, within open public comment periods for the Licensee's submittals identified in Section 1.2 above requesting the relevant agencies take actions wholly consistent with this Agreement;

1.3.2 Undertaking reasonable efforts to obtain regulatory agency actions wholly consistent with this Agreement in a timely manner; and

1.3.3 Not supporting in any way entities seeking to obtain regulatory actions inconsistent with this Agreement or seeking to delay regulatory actions associated with relicensing of the Project.

2.0 Normal Operating Ranges for Reservoir Levels Agreements

Reservoir Elevations Article – The Parties recommend the proposed Reservoir Elevations License Article, the full text of which is provided in Appendix A of this Agreement, be incorporated verbatim into any New License the FERC may issue for the Project.

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3.0 Actions to Support Water User Needs Agreements

3.1 Low Inflow Protocol ("LIP") License Article – The Parties recommend the proposed Low Inflow Protocol for the Keowee-Toxaway Hydroelectric Project License Article, the full text of which is provided in Appendix A of this Agreement, be incorporated verbatim into any New License the FERC may issue for the Project.

3.2 Support of Relicensing Study Findings for Evaluating Proposed Increases in Water Withdrawal Amounts – The Parties acknowledge the water quantity effects of water intakes located in the Upper Savannah River Basin have been evaluated during the relicensing process based on the available facts, assumptions, and analytical methods and reported in the Water Supply Study, Final Report and Addenda, Keowee-Toxaway Hydroelectric Relicensing Project, December 5, 2012. This evaluation considered the capacities of existing water intakes and projected increases in withdrawals through the Year 2066. The Parties shall consider the results of this study when evaluating proposals for additional water use from the Project.

3.3 Protecting and Enhancing Usable Water Storage – The Licensee shall require all lake use permit applicants for new, expanded, or rebuilt water intakes (public, industrial, or power generation) to design and construct their water intakes to operate at full capacity with the lake drawn down to the hydro station operational limit (70 feet ("ft") local datum / 1080 ft above Mean Sea Level ("AMSL") for Lake Jocassee and 75 ft local datum / 775 ft AMSL for Lake Keowee). If a lake use permit applicant is unable to comply with this requirement, the Licensee shall require the lake use permit applicant to justify, to the satisfaction of the Licensee, a more shallow water intake with a feasibility evaluation conducted by a licensed professional engineer with water resources expertise, but the Licensee shall not authorize a new, expanded, or rebuilt water intake (public, industrial, or power generation) that requires a lake elevation to operate at full withdrawal capacity higher than the new Critical Reservoir Elevations defined in the LIP (Appendix D).

3.4 LIP

3.4.1 The Licensee shall file the LIP provided in Appendix D of this Agreement with its Application for New License and request the FERC incorporate it verbatim into the New License.

3.4.2 Importance of Human Health and Safety and the Integrity of the Public Water Supply and Electric Systems – Nothing in the LIP will limit the Licensee's ability to take any and all lawful actions necessary at its hydro projects to protect human health and safety, to protect its equipment from damage, to ensure the stability of the regional electric grid, to protect the equipment of the Large Water Intake owners from damage, and to ensure the stability of public water supply systems; provided that nothing in this Agreement or LIP will obligate the Licensee to take any actions to protect the equipment of Large Water Intake owners from damage or to ensure the stability of the public water supply systems. It is recognized the Licensee may take such actions to provide this protection without prior consultation or notification.

3.4.3 Effective Date for LIP – The Parties agree to fully implement their water management responsibilities as applicable under the LIP beginning on the Effective Date of this Agreement.

3.4.4 As a condition of the Licensee's written approval, the Licensee shall require all owners of new, expanded, or rebuilt water intakes who install an intake on Lake Keowee to comply with the requirements of the LIP.

3.4.5 Rainfall Data Collection – Within one year following the issuance of the New License, the Licensee shall upgrade its rainfall data collection and reporting system so rainfall amounts recorded at the Keowee and Jocassee Developments and the Bad Creek Project can be used on an updated daily basis for the purposes of the LIP.

3.4.6 Regional Drought Response – When the Project is operating in any stage of the LIP, the Parties shall encourage water intake owners located on the USACE Reservoirs (i.e., Hartwell, Russell and Thurmond) downstream of the Project and their customers to implement water conservation measures similar to the LIP.

3.4.7 Responsibilities of Parties – The Parties to this Agreement without specific responsibilities under the LIP shall support implementation of the LIP by the Licensee and other Large Water Intake owners by undertaking reasonable efforts to communicate: (1) the severity of drought and the restrictions associated with each LIP stage to their respective constituents; and (2) the efforts of the Licensee and other Large Water Intake owners to reduce water consumption.

3.4.8 Revising the LIP – The LIP revision process, including notification, consultation, and filing of any necessary New License amendments or 401 WQC modifications, is identified in the LIP. The filing of a revised LIP by the Licensee shall not constitute or require modification of this Agreement, and any Party to this Agreement may choose to be involved in the FERC's or SCDHEC's public processes for assessing the revised LIP, but may not oppose any part of a revised LIP that is consistent with the LIP included in this Agreement.

3.4.9 Lake Keowee Critical Reservoir Elevation – Provided Friends of Lake Keowee Society, Inc. ("FOLKS"), Advocates for Quality Development ("AQD"), The Reserve at Lake Keowee, and The Cliffs at Keowee Vineyards Community Association, Inc. are all Parties to this Agreement, the Licensee shall maintain Lake Keowee's Critical Reservoir Elevation no lower than 90.0 ft local datum / 790.0 ft AMSL for the term of the New License.

3.5 Negotiation of NOA – The Licensee shall negotiate with the USACE and the SEPA to develop a NOA that incorporates: (1) the applicable operating parameters to ensure the NOA is not inconsistent with this Agreement; (2) the usable water storage in all six hydro reservoirs owned by the Licensee and the United States of America in the Upper Savannah River Basin (i.e., Bad Creek, Jocassee, Keowee, Hartwell, Russell and Thurmond); and (3) an allowance in case lake levels at the USACE Reservoirs are intentionally maintained at lower levels (e.g., to support maintenance situations), so that the Licensee shall not have to provide a higher weekly flow release from the Keowee Development than would have otherwise been required. During the negotiation of the NOA, the Licensee shall also pursue any feasible opportunities to include requirements in the NOA promoting consistent drought response among water users throughout the Upper Savannah River Basin in a manner similar to the LIP.

3.6 Savannah River Water Resource Planning – Within two years following both i) the issuance of a New License that is not inconsistent with this Agreement, the end of all appeals, and the closure of all rehearing and administrative challenge periods and

ii) the signing by the Licensee, USACE, and SEPA of a NOA that is not inconsistent with this Agreement, the Licensee after consultation with the Parties shall make available $438,000 in funding for initiatives approved by the Licensee to improve water quantity planning and management in the Savannah River Basin.

3.7 Existing Water Withdrawals and Effluent Discharges – The Parties acknowledge the Licensee will include in its Application for New License a table(s) that identifies existing conditions with regard to Large Water Intakes and effluent discharges located within the Project Boundaries.

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4.0 Maintenance and Emergency Protocol ("MEP") Agreements

4.1 MEP License Article – The Parties recommend the proposed Maintenance and Emergency Protocol for the Keowee-Toxaway Hydroelectric Project License Article, the full text of which is provided in Appendix A of this Agreement, be incorporated verbatim into any New License the FERC may issue for the Project.

4.2 MEP – The Licensee shall file the MEP provided in Appendix E of this Agreement with its Application for New License and request the FERC incorporate it verbatim into the New License.

4.3 Importance of Human Health and Safety and the Integrity of the Public Water Supply and Electric Systems – Nothing in the MEP will limit the Licensee's ability to take any and all lawful actions necessary at its hydro projects to protect human health and safety, to protect its equipment from damage, to ensure the stability of the regional electric grid, to protect the equipment of the Large Water Intake owners from damage, and to ensure the stability of public water supply systems; provided that nothing in this Agreement or MEP will obligate the Licensee to take any actions to protect the equipment of Large Water Intake owners from damage or to ensure the stability of public water supply systems. It is recognized the Licensee may take such actions to provide this protection without prior consultation or notification.

4.4 Revising the MEP – The MEP revision process, including notification, consultation and filing of any necessary New License amendments or 401 WQC modifications, is identified in the MEP. The filing of a revised MEP by the Licensee will not constitute or require modification of this Agreement, and any Party to this Agreement may be involved in the FERC or SCDHEC public processes for assessing the revised MEP, but may not oppose any part of a revised MEP that is consistent with the MEP included in this Agreement.

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5.0 Historic Properties Agreements

5.1 Historic Properties License Article – The Parties recommend the proposed Historic Properties License Article, the full text of which is provided in Appendix A of this Agreement, be incorporated verbatim into any New License the FERC may issue for the Project.

5.2 Historic Properties Management Plan ("HPMP") – The Licensee shall include the following actions in the proposed HPMP it files with the Application for New License:

5.2.1 Archaeological Site Monitoring – The Licensee will annually monitor sites 38OC460, 38OC461, 38OC462, 38OC466, 38OC467, and 38PN175 to document their status.

5.2.2 Access Area Cemetery Management – The Licensee in consultation with the SC State Historic Preservation Office ("SCSHPO") and any lessees will develop specific management plans for the cemeteries at Stamp Creek Access Area and South Cove County Park.

5.2.3 Lake Use Permitting – The Licensee will incorporate the lake use permitting requirements regarding Historic Properties and Cultural Resources from the existing Programmatic Agreement into the HPMP.

5.2.4 Public Outreach – The Licensee in consultation with the SCSHPO, the Eastern Band of Cherokee Indians ("EBCI") Tribal Historic Preservation Office ("THPO"), and the SC Department of Parks, Recreation and Tourism ("SCDPRT") will develop interpretative signage or other materials for display at the Jocassee Gorges Visitor Center located at Keowee-Toxaway State Park and selected Project Access Areas regarding the history of the Project area. Topics will include, but will not be limited to, Cherokee history and hydropower development. The Licensee will provide drafts of the signage or other materials within two years and will install signage and complete other materials within three years following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods.

5.2.5 Traveling History Exhibit – The Licensee in consultation with the SCSHPO, the EBCI THPO, and the SCDPRT will develop a traveling exhibit on the history of the Project area to be used at various visitor centers, exhibits, schools, etc. Topics will include, but will not be limited to, Cherokee history and hydropower development. The Licensee will provide drafts of the materials associated with the exhibit within two years and complete exhibit development within three years following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods.

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6.0 Public Recreation Agreements

6.1 Public Recreation License Articles – The Parties recommend the proposed Recreation Management Plan License Article and the Recreation Planning License Article, the full text of which are provided in Appendix A of this Agreement, be incorporated verbatim into any New License the FERC may issue for the Project.

6.2 Recreation Management Plan ("RMP") – The Licensee shall include the following activities in the RMP submitted with the Application for New License.

6.2.1 Specific Facility Enhancements and Construction Schedules – The Licensee shall include the following facility enhancements in the RMP and schedule their construction to occur during the first ten years of the New License.

6.2.1.1 Devils Fork State Park – The Licensee shall develop a designated location for diver access; install a new courtesy dock at the main ramps usable over a larger range of reservoir elevations than the existing courtesy dock; construct a new boat and trailer parking area to serve the existing campground; and enhance the Roundhouse Point ramps to facilitate non-motorized boating.

6.2.1.2 Expansion of Double Springs Campground – The Licensee shall add into the Project Boundary approximately 25 acres ("ac") adjoining the existing campground currently leased and operated by the SCDPRT and shall designate it as reserved for public recreation. The Licensee shall also offer to lease this additional land to the SCDPRT, construct a composting-type toilet, and construct 12 additional campsites if the SCDPRT is a Party to this Agreement and accepts the offer of additional leased land within one year following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods.

6.2.1.3 Keowee Town Access Area – The Licensee shall construct trails and, where feasible, add single vehicle parking; and install appropriate signage to support wildlife viewing and bank fishing.

6.2.1.4 Fall Creek Access Area – The Licensee shall construct trails and, where feasible, add single vehicle parking; and install appropriate signage to support wildlife viewing and bank fishing at the Fall Creek Island/peninsula.

6.2.1.5 Mile Creek County Park

6.2.1.5.1 The Licensee shall construct up to ten primitive campsites and up to five bank fishing stations with open air fishing shelters if Pickens County is a Party to this Agreement and the County agrees to operate and maintain the new facilities.

6.2.1.5.2 If Pickens County is a Party to this Agreement, the Licensee shall support the development of ten pre-manufactured camping cabins by conducting any required archaeological investigations; working with Pickens County to develop a mutually agreeable schedule and design specification for the cabins and obtain firm quotes from cabin and septic tank manufacturers; and paying the materials costs for the cabins and septic tanks with the Licensee's total cost not to exceed $350,000. The Licensee's funding shall be available within one year following FERC approval of the RMP. Pickens County shall be responsible for all other costs and all activities associated with the permitting, installation, operation, and maintenance of said cabins and shall ensure the camping cabins are available for public use consistent with the County's current Campsite Reservation Policies for Mile Creek County Park. The Licensee shall expedite its internal review of design plans provided by Pickens County.

6.2.1.6 Cane Creek Access Area – The Licensee shall designate shoreline areas by installing appropriate signage and, where feasible, add single vehicle parking to support bank fishing.

6.2.1.7 New Project Access Areas – The Licensee shall designate High Falls II (approximately 36.19 ac) and Mosquito Point (approximately 10.25 ac) as reserved for future public recreation needs as specified in Section 7.5.4.

6.2.1.8 Keowee-Toxaway State Park – The Licensee shall construct a canoe/kayak launch, fishing pier, and canoe portage as specified in Section 6.3.2.

6.2.1.9 Stamp Creek Access Area – The Licensee shall construct trails and, where feasible, add single vehicle parking; and install appropriate signage to support wildlife viewing and bank fishing.

6.2.2 Access Area Improvement Initiative ("AAII") Program

6.2.2.1 Existing AAII Lease Terms – The Licensee shall offer to extend the leases for High Falls County Park, Mile Creek County Park, Warpath Marina, Devils Fork State Park, and South Cove County Park through the term of the New License if the current lessees are Parties to this Agreement and accept the offer of lease extension within one year following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods. The Licensee will offer an extension of the Warpath Marina lease only if the facilities have been constructed consistent with the requirements of and schedule in the Existing License RMP.

6.2.2.2 New AAII Leases – The Licensee shall offer new, low-cost AAII leases as follows to support development of additional facilities to enhance public recreation at the Project if the identified organization is a Party to this Agreement and accepts the offer of lease within two years following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods:

- Bootleg Access Area to be leased to the SCDNR;
- Crow Creek Access Area to be leased to Pickens County;
- 15-ac lake at Keowee-Toxaway State Park to be leased to the SCDPRT including upland Project lands and the existing water-retaining structure associated with the impoundment; and
- Fall Creek Access Area, Keowee Town Access Area, Stamp Creek Access Area, and Cane Creek Access Area to be leased to Oconee County.

6.2.3 Bank Fishing at Project Access Areas – The Licensee shall ensure the shoreline of all Project Access Areas remains open for bank fishing for the term of the New License, except for those minimal shoreline areas where bank fishing is restricted for safety reasons, management problems, or to avoid conflicts with other access area users. The Licensee, in consultation with AAII lessees for those Project Access Areas subject to an AAII lease, shall designate with appropriate signage those portions of the shoreline within the Project Access Areas where bank fishing is prohibited.

6.2.4 Future RMP Revisions – The Licensee shall convene the Parties to assess the need for conducting a new Recreation Use and Needs ("RUN") Study in conjunction with the development of the second FERC Form 80 Licensed Hydropower Development Recreation Report ("Form 80") filing after the issuance of the New License and every second Form 80 filing thereafter. If it is determined that a new RUN Study is needed, the new study shall be conducted the following year. Based upon the findings of each RUN Study during the term of the New License, the Licensee shall revise the RMP as necessary for the Project and request FERC approval. The Licensee shall solicit input from the Parties in developing and implementing the RUN Study and in the revision of the RMP. The filing of a revised RMP by the Licensee will not constitute or require modification of this Agreement, and any Party may be involved in the FERC's public process for assessing the revised RMP, but shall not oppose any part of a revised RMP that is consistent with the RMP filed with the Application for New License. If at any time during the term of the New License the FERC changes its schedule for or no longer requires filing Form 80, the Licensee shall convene the Parties for the purposes described in this Section 6.2.4 every twelfth year of the New License beginning from last convening of the Parties to determine the need for a RUN Study under the New License or the effective date of the New License, whichever is later. While scheduled RUN studies are the primary means of regularly updating needs and plans for public recreation facilities, nothing in this paragraph precludes the Licensee's receiving and acting, in the Licensee's sole discretion, upon unscheduled recommendations for new or improved public recreational facilities based on observations of the Licensee and others. The Licensee shall also not be obligated to formally respond to or act upon such recommendations.

6.2.5 Previous Recreation-related Agreement Superseded – The agreement between Duke Power Company (predecessor to the Licensee) and the South Carolina Wildlife Resources Department (predecessor to both the SCDNR and the SCDPRT), identified as Exhibit R-5 to the Existing License and dated July 29, 1965, regarding recreational access at the Project, is superseded by this Agreement.

6.2.6 Americans with Disabilities Act ("ADA") Requirements – The Licensee shall ensure all facilities constructed at Project Access Areas comply with ADA requirements when so constructed.

6.2.7 Form 80s – The Licensee shall notify the Parties when the Form 80(s) has been filed.

6.3 Non-Project Public Recreational Enhancements

6.3.1 The Parties to this Agreement acknowledge the measures in this Section 6.3 shall not be included in the RMP because they will be located outside the Project Boundaries.

6.3.2 Keowee-Toxaway State Park – The Licensee shall connect the park to municipal water, pave an access road to a new primitive camping area, and construct ten primitive campsites, three camping cabins, a canoe/kayak launch, a new parking area, an event cabin, an outdoor gathering space with firepit, a fishing pier using the existing bridge abutment, a picnic pavilion, a portage around the existing water-retaining structure impounding 15-ac lake, and two bathhouses all within ten years following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods provided the SCDPRT is a Party to this Agreement and enters into a lease agreement for the term of the New License for the Project lands as specified in Section 6.2.2.2 above.

6.3.3 Jocassee Gorges Wildlife Management Area – If the SCDNR is a Party to this Agreement, then for one year following the issuance of the New License, the end of all appeals, and closure of all rehearing and administrative challenge periods, the Licensee shall offer to the SCDNR a low-cost lease for the term of the New License of the Licklog (46 ac) and Dismal Creek (21 ac) properties (see Appendix F, Figure F-1) for inclusion in the Jocassee Gorges Wildlife Management Area. If the SCDNR declines the offer of lease or does not enter into the lease within the one-year offer period, the Licensee may offer a similar lease to another entity to manage the property for public recreation and conservation purposes.

6.3.4 Granny Gear Access Area – The Licensee shall maintain the existing Granny Gear Access Area (see Appendix F, Figure F-1) for the term of the New License if the SCDNR is a Party to this Agreement and for so long as the SCDNR continues to maintain the Dug Mountain Access Area.

6.3.5 Jocassee Spillway Tract – The Licensee shall retain the Jocassee Spillway Tract (approximately 124 ac; see Appendix F, Figure F-1) for the term of the New License and restrict its use during the New License term to the support of power production, power transmission, and public recreation.

6.3.6 Bad Creek South Tract – The Licensee shall retain the Bad Creek South Tract (approximately 300 ac; see Appendix F, Figure F-1) until the end of the Bad Creek Project license term in 2027 and restrict its use until then to the support of power production, power transmission, and public recreation.

6.3.7 Fishers Knob Tract – If the SCDNR is a Party to this Agreement, then for one year following the issuance of the New License, the end of all appeals, and closure of all rehearing and administrative challenge periods, the Licensee shall offer a low-cost lease of approximately 45 ac on Fishers Knob (see Appendix F, Figure F-1) to the SCDNR for the term of the New License. If the SCDNR accepts the offer of lease, the SCDNR shall be responsible for all administrative activities and costs associated with the management of the property. The SCDNR acknowledges there shall be no public access via Fishers Knob road to the property and that the Licensee may remove portions of the leased land to support power production, power transmission, and public recreation. If the

SCDNR declines the offer of lease or does not enter into the lease within the one-year offer period, the Licensee is under no obligation under the terms of this Agreement to retain ownership of the tract or manage it in any particular way.

6.3.8 Jocassee East Tract – The Licensee shall retain approximately 158 ac east of the Jocassee Pumped Storage Station (see Appendix F, Figure F-1) for the term of the New License and restrict its use during the New License term to the support of power production, power transmission and public recreation.

6.3.9 Laurel Preserve Tract – If the SCDNR and Pickens County are both Parties to this Agreement, then for two years following the issuance of the New License, the end of all appeals, and closure of all rehearing and administrative challenge periods, the Licensee shall offer a low-cost lease of the Laurel Preserve Tract (approximately 504 ac; see Appendix F, Figure F-1) to the SCDNR for the term of the New License. If the SCDNR accepts the offer of lease, the SCDNR shall be responsible for all administrative activities and costs associated with the management of the property. If the SCDNR declines the offer of lease or does not enter into the lease within the two-year offer period, the Licensee may offer a similar lease to another entity to manage the property for public recreation and conservation purposes.

6.3.10 Eastatoe Creek Tract – If the SCDNR and Pickens County are both Parties to this Agreement, then for two years following the issuance of the New License, the end of all appeals, and closure of all rehearing and administrative challenge periods, the Licensee shall offer a low-cost lease of the Eastatoe Creek Tract (approximately 23 ac; see Appendix F, Figure F-1) to the SCDNR for the term of the New License. If the SCDNR accepts the offer of lease, the SCDNR shall be responsible for all administrative activities and costs associated with the management of the property. If the SCDNR declines the offer of lease or does not enter into the lease within the two-year offer period, the Licensee may offer a similar lease to another entity to manage the property for public recreation and conservation purposes.

6.3.11 Nine Times Tract – If the SCDNR, Upstate Forever, South Carolina Wildlife Federation, and Pickens County are all Parties to this Agreement, the Licensee shall provide $1,044,000 to Naturaland Trust to be applied to the purchase price of the Nine Times Tract (approximately 1,648 ac) so long as Naturaland Trust enters into a Memorandum of Agreement ("MOA") with the Licensee no later than December 3, 2013, to comply with the use, management, and ownership requirements of the U.S. Forest Service Community Forest and Open Space Conservation Program and the following stipulations:

6.3.11.1 The Licensee's funding shall be used only to help purchase the Nine Times Tract consistent with the Naturaland Trust's existing purchase option. The Licensee shall provide its funding after the MOA is signed by the Licensee and Naturaland Trust and not later than December 26, 2013.

6.3.11.2 MOA Stipulations – The Licensee shall include the following stipulations in its MOA with Naturaland Trust.

6.3.11.2.1 Management Plan – Naturaland Trust shall collaboratively develop a management plan (the U.S. Forest Service Community Forest Management Plan) for the property. The management plan shall, among other things, provide significant opportunities for public access to the vast majority of the property and shall allow for traditional recreational uses of the property, including but not necessarily limited to significant opportunities for public hunting for the term of the New License.

6.3.11.2.2 Parties' Involvement in Management Plan Development – Naturaland Trust shall invite the Parties to this Agreement to consult and have a meaningful role in the development of the management plan for the property. The initial management plan shall be completed within 120 days after the acquisition of the Nine Times Tract. If the management plan is modified at any point during the term of the New License, Naturaland Trust shall invite the Parties to this Agreement to review and comment on the proposed changes and Naturaland Trust will endeavor in good faith to accommodate reasonable input from Parties to this Agreement.

6.3.11.2.3 Ownership of Tract – Naturaland Trust shall maintain ownership of the property for the term of the New License or ensure it is transferred to an eligible governmental entity (as defined by then-current laws and regulations) that will maintain it for the term of the New License consistent with the collaboratively developed management plan. If permitted under the U.S. Forest Service Community Forest and Open Space Conservation Program, the Nine Times Tract shall be made subject to a permanent conservation easement held by Upstate Forever.

6.3.12 Oconee County Conservation Bank – If Oconee County, Upstate Forever, and the South Carolina Wildlife Federation are all Parties to this Agreement, the Licensee shall provide $600,000 to the Oconee County Conservation Bank within two years following the issuance of the New License, the end of all appeals, and closure of all rehearing and administrative challenge periods.

6.3.13 World of Energy Picnic and Fishing Access Area – To the extent not prohibited by the Nuclear Regulatory Commission, the Licensee shall designate a trail for angler access to the Oconee Nuclear Station ("ONS") discharge canal, and the Licensee shall operate and maintain the existing picnic and fishing facilities near the World of Energy for public recreation support. The Parties acknowledge this access area will be limited to day-use only, and it may be closed at the Licensee's sole discretion without notice for security- and safety-related issues at ONS. The Parties also acknowledge this access area may be closed permanently at the Licensee's sole discretion at the end of the New License term, during the term of the New License, or if either the World of Energy or ONS are permanently closed.

6.3.14 Exclusive Right to Purchase

6.3.14.1 Pickens County Tracts – If the SCDNR, SCDPRT, Upstate Forever, South Carolina Wildlife Federation, and Pickens County are all Parties to this Agreement, the Licensee shall grant to the SCDNR an Exclusive Right to Purchase the Jocassee East, Eastatoe Creek, and Laurel Preserve tracts at a price agreeable to both the Licensee and the SCDNR to be negotiated between the Licensee and the SCDNR prior to purchase. The Exclusive Right to Purchase shall be granted by the Licensee within three months following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods. The Licensee shall ensure any Exclusive Right to Purchase it enters into in accordance with this paragraph is provided to the Pickens County Register of Deeds Office for recordation within 90 days following signing of such Exclusive Right to Purchase by the Licensee and the SCDNR. The Exclusive Right to Purchase shall extend for the term of the New License. During the term of the New License, the Licensee may not offer to sell these identified tracts to anyone other than the SCDNR, its successor, or an assign that is mutually agreeable to the Licensee and the SCDNR.

6.3.14.2 Oconee County Tracts – If the SCDNR, SCDPRT, Upstate Forever, South Carolina Wildlife Federation, and Oconee County are all Parties to this Agreement, the Licensee shall grant to the SCDNR an Exclusive Right to Purchase the Bad Creek South, Jocassee Spillway, Licklog, and Dismal Creek tracts at a price agreeable to both the Licensee and the SCDNR to be negotiated between the Licensee and the SCDNR prior to purchase. The Exclusive Right to Purchase shall be granted by the Licensee within three months following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods. The Licensee shall ensure any Exclusive Right to Purchase it enters into in accordance with this paragraph is provided to the Oconee County Register of Deeds Office for recordation within 90 days following signing of such Exclusive Right to Purchase by the Licensee and the SCDNR. The Exclusive Right to Purchase shall extend until July 31, 2027, for the Bad Creek South Tract, and for the term of the New License for the remaining tracts referenced in this Section 6.3.14.2. During the term of the New License, the Licensee may not offer to sell these identified tracts to anyone other than the SCDNR, its successor, or an assign that is mutually agreeable to the Licensee and the SCDNR.

6.3.14.3 Purchase of any tract identified in this Section 6.3.14 by the SCDNR releases the Licensee from its obligation to retain, lease, or restrict use of the specific purchased tract only and does not affect the Licensee's obligation to retain, lease, or restrict use of any other lands identified in Section 6.3.

6.3.14.4 The Exclusive Right to Purchase the properties identified in this Section 6.3.14 will specify that the Licensee may elect to retain portions of said tracts adjoining FERC project boundaries or located within transmission line rights-of-way similar to previous property sales to South Carolina.

6.3.15 Sassafras Mountain Observation Tower – If the SCDNR, Upstate Forever, Greenville Water ("GW"), and Pickens County are all Parties to this Agreement, the Licensee shall provide $350,000 to the SCDNR to support construction of an observation tower, restroom facilities, and interpretive signage at Sassafras Mountain within two years following the Effective Date of this Agreement. The SCDNR shall invite the Parties to this Agreement to consult and have a meaningful role in the development of the management plan for the property and the development of interpretive signage. If the management plan is modified at any point during the term of the New License, the SCDNR shall invite the Parties to this Agreement to review and comment on the proposed modifications. To the extent practical, the SCDNR will endeavor to accommodate reasonable input from the Parties to this Agreement.

6.4 Recreation User Education and Outreach

6.4.1 The Licensee shall support the following recreation user education and outreach efforts for term of the New License.

6.4.1.1 The Licensee shall sponsor an annual community safe boating educational effort in the Project area in partnership with the SCDNR and other interested organizations.

6.4.1.2 If Oconee County is a Party to this Agreement, the Licensee shall provide $10,000 per year to Oconee County to support school programs on environmental stewardship and litter prevention.

6.4.1.3 If Pickens County is a Party to this Agreement, the Licensee shall provide $10,000 per year to Pickens County to support school programs on environmental stewardship and litter prevention.

6.4.1.4 If FOLKS is a Party to this Agreement, the Licensee shall support semiannual litter collection efforts at the Project in partnership with FOLKS by providing bags and disposing of collected trash deposited at Licensee-designated Project Access Areas. The Licensee shall invite other interested organizations, including the Friends of Jocassee, to participate in these litter collection efforts.

6.4.2 After the first ten years of the New License, the Licensee and the other Parties participating in the initiatives identified in Section 6.4.1 may jointly elect to modify or discontinue their cooperative education and outreach efforts identified in Section 6.4.1, and such modification or discontinuance will not constitute or require a modification of this Agreement.

6.5 <u>Islands</u> – The Licensee shall retain ownership of the islands within the Project for the term of the New License.

6.6 <u>Commercial Recreation Area Amenities at Project Access Areas on Lake Keowee</u>

6.6.1 <u>Allowable Public Recreation Amenities at All Project Access Areas at Lake Keowee</u> – The Parties shall not oppose the use by the Licensee or its lessees of all Licensee-owned Project Access Areas at Lake Keowee for the following public recreation support amenities: courtesy docks; facilities where boats can be launched, retrieved, and moored; picnic sites and shelters; hiking, nature, and bank fishing trails; fishing piers; restrooms, vault toilets, or bathhouses; parking and lighting; wildlife viewing platforms; swimming areas and associated changing facilities; fire, rescue, and law enforcement facilities; and playgrounds and playground equipment.

6.6.2 <u>Restriction on Commercial Recreation Area Amenities at Project Access Areas on Lake Keowee</u> – The Licensee shall neither use nor allow lessees to use Crow Creek, Cane Creek, and Stamp Creek Project Access Areas for any of the following Commercial Recreation Area amenities: multi-slip marinas; convenience retailing; food services; pump-out facilities; gas-dispensing and sales; dry stack and boat yard storage facilities; or lodging.

6.6.3 <u>Allowable Commercial Recreation Area Amenities at Specified Project Access Areas on Lake Keowee</u> – The Parties shall not oppose the use of Keowee Town, Fall Creek, High Falls County Park, High Falls II, Mile Creek County Park, Mosquito Point, and South Cove County Park Project Access Areas for the following commercial recreation amenities: multi-slip marinas; convenience retailing; food services; pump-out facilities; gas dispensing and sales; dry stack and boat yard storage facilities; lodging except hotels and motels; and the amenities identified in Section 6.6.1. The Parties to this Agreement reserve the right to comment on the details of future commercial lake use permit applications through various public comment opportunities.

6.7 Construction, Approvals and Permits – The Parties acknowledge that construction of the public recreation facilities described in this Section 6.0 and in the proposed RMP License Article is contingent upon the ability of the Licensee and/or other recreation facility providers to obtain any necessary federal, tribal, state, or local government approvals or permits required. If any of the facilities are not constructed because of the inability to obtain such permits or approvals, then the Licensee and/or other recreation facility providers shall endeavor in good faith to construct comparable facilities as a replacement within a reasonable time schedule. The Licensee and/or other recreation facility providers shall endeavor in good faith to find a suitable location and obtain the necessary approvals and permits for such replacement facilities that are acceptable to and approved by the FERC, if FERC approval is required.

6.8 Construction Feasibility – The Parties acknowledge that construction of the public recreation facilities described in this Section 6.0 is contingent upon the ability of the Licensee and/or other recreation facility providers to design and construct the facilities consistent with accepted recreation facility standards, user safety, and public infrastructure security requirements. If any of the facilities are not constructed because of feasibility problems, then the Licensee and/or other recreation facility providers shall endeavor in good faith to provide appropriate replacement alternatives for which they can obtain the necessary permits and approvals, including FERC approval, if FERC approval is required to be constructed within a reasonable time schedule.

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7.0 Shoreline Management Agreements

7.1 Shoreline Management License Articles – The Parties recommend that the proposed Shoreline Management Plan License Article and the Shoreline Management Plan Review and Update Procedures License Article, the full text of which are provided in Appendix A of this Agreement, be incorporated verbatim into any New License the FERC may issue for the Project.

7.2 Combined Project Shoreline Management Plan ("SMP") – The Parties understand the Licensee will combine the Lake Keowee SMP approved by the FERC in 2007 and Lake Jocassee SMP approved by the FERC in 2013 into a single Project SMP it will submit with the Application for New License. The Parties understand it will be necessary for the Licensee to make a large number of formatting and other changes to combine the components of the Lake Jocassee and Lake Keowee SMPs into the Project SMP.

7.3 Shoreline Management Plan Effective Date – The SMP, including the revised Shoreline Classification Maps and associated Lake Use Restrictions and the revised Shoreline Management Guidelines ("SMG"), submitted with the Licensee's Application for New License shall be effective on September 1, 2014.

7.4 Shoreline Classification Maps – The Licensee shall include the Shoreline Classification Maps made available to the Parties as drafts on September 13, 2013, with any corrections resulting from a quality assurance review conducted prior to filing the Application for New License.

7.5 SMG Revisions – The Licensee shall include the following changes in the revised SMG it will file with the Application for New License.

7.5.1 Unencapsulated Foam – Existing residential dock owners must remove and properly dispose of unencapsulated foam from their docks by September 1, 2018. No lake use permit application or Habitat Enhancement Program ("HEP") fees will be charged for lake use permit applications that are only removing unencapsulated foam and replacing it with approved floatation.

7.5.2 Modification of Existing Docks to Reach Deeper Water – Property owners with a previously constructed or permitted dock may wish to modify their boat dock to reach deeper water and improve the dock's usability during future extended droughts. Such modifications for the purpose of reaching deeper water must follow the then-current SMP, including but not limited to getting written approval from the Licensee before making such modifications. However, to facilitate boat dock modifications to reach deeper water, the Licensee will implement the following accommodations for the fixed period of time and applicability stated below.

7.5.2.1 Exception for Larger Dock Surface Area – The normal maximum size limit of 1,000 square ft for a boat dock approved under the Private Facilities Program is increased to 1,200 square ft if the larger size is needed to reach deeper water. The SMG restrict boat docks adjacent to certain properties to less than 1,000 square ft based on certain criteria. Boat docks with a maximum size limit of less than 1,000 square ft will be allowed a size limit that is 200 square ft larger if the larger size is needed to reach deeper water.

7.5.2.2 Exception for Longer Build-out Period – To better handle the expected construction volume, the normal build-out period as stated in the applicable SMG program is increased by one year for boat dock modifications needed to reach deeper water.

7.5.2.3 Waiver of Certain Fees – For the fixed period identified in Section 7.5.2.4, the Licensee will not charge a lake use permit application fee or a HEP fee for permitting dock modifications needed to reach deeper water.

7.5.2.4 Window of Opportunity for Surface Area and Build-out Period Exceptions and Waiver of Certain Fees – The Licensee will accept lake use permit applications from property owners eligible for the surface area and build-out period exceptions and fee waivers stated herein following the completion of all of the events stated below, but no sooner than December 1, 2014.

7.5.2.4.1 This Agreement has been signed by the Licensee, FOLKS and AQD;

7.5.2.4.2 Any additional required regulatory actions are taken (e.g., issuance of a revised Permit for Construction in Navigable Waters by the SCDHEC, and General Permit to perform work in or affecting waters of the United States by the USACE for the Keowee-Toxaway Hydroelectric Project); and

7.5.2.4.3 A NOA that is not inconsistent with this Agreement has been signed by the Licensee, the USACE, and the SEPA.

The Licensee will provide broad public notification at least 30 days prior to the opening of this window of opportunity. Once the window of opportunity opens, then for a period of 365 days the Licensee will accept eligible lake use permit applications for the surface area and build-out period exceptions and fee waivers.

7.5.2.5 Applicability – Docks managed under any of the Licensee's Lake Use Permitting Programs are eligible for the accommodations listed herein, provided the pre-existence or pre-approval criteria are met and the proposed modifications are for the purpose of reaching deeper water. Modifications can include complete replacement of the dock, relocation of the dock along the approved shoreline, reconfiguration, simple extensions of gangways, or combinations of these. Only property owners having one of the following by the Effective Date of this Agreement are eligible for the surface area and build-out period exceptions and fee waivers stated above: (1) an existing Licensee-approved boat dock or (2) a Licensee-approved lake use permit for a not-yet-constructed boat dock issued less than 12 months prior to the Effective Date of this Agreement.

7.5.2.6 Modification of Docks to Reach Deeper Water Prior to or after the Window of Opportunity – Property owners who wish to modify their docks to reach deeper water either before or after the window of opportunity stated above may do so with the proper approvals including written approval from the Licensee. In such situations, the applicant is not eligible for the surface area and build-out period exceptions or fee waivers listed in this Section 7.5.2.

7.5.3 Follow the Water – Dock owners, including owners of commercial and residential marinas and public recreation facilities, may "follow the water" in an effort to maintain usability of their boat or dock during LIP Stages 2, 3, or 4. The procedure and requirements that apply to following the water are included in Appendix G.

7.5.3.1 After experience is gained with this following-the-water process, the Licensee reserves the right to modify the procedures to follow the water in the future to protect human health and safety, to meet the tenets of the SMP, to meet the requirements in the USACE and SCDHEC General Permits, or if directed by the FERC. The Licensee shall consult with the Parties to this Agreement prior to making any such modifications and will file the modifications with the FERC and other regulatory agencies as required. Any such modification shall not require revision of this Agreement, and any Party to this Agreement may participate in the regulatory agencies' review processes but shall not oppose any part of the revised following-the-water process that is consistent with the following-the-water process in this Agreement.

7.5.4 Commercial Marina Classification at Lake Keowee – The Licensee shall modify the Commercial Marina shoreline classification on Lake Keowee as follows.

7.5.4.1 The Parties acknowledge the Licensee has converted shoreline classified as Future Commercial Marina to Future Residential Marina on the draft SMP maps made available to the Parties on September 13, 2013, and this conversion to Future Residential Marina was applied to areas upstream of the Restriction Areas lines in Appendix F, Figures F-2 and F-3.

7.5.4.2 The Licensee shall eliminate the "Proximity to Existing Facilities" guideline (SMG: Section 1, B-2).

7.5.4.3 The Licensee shall classify the shoreline and the land area of the Licensee-owned property labeled High Falls II (approximately 36.19 ac) on Appendix F, Figure F-3 as "Future Public Recreation" and incorporate the land area into the Project Boundary in the Application for New License.

7.5.4.4 The Licensee shall classify the land area of the Licensee-owned property labeled Mosquito Point (approximately 10.25 ac) on Appendix F, Figure F-3 as "Future Public Recreation" and incorporate the land area into the Project Boundary in the Application for New License.

7.5.4.5 Available for Future Commercial Marinas – The Parties agree all Lake Keowee shoreline classified as Available for Future Commercial Marinas on Appendix F, Figures F-2 and F-3 shall remain classified as such until such time as the shoreline is developed. No Party will oppose the use of locations classified as Available for Future Commercial Marinas on Appendix F, Figures F-2 and F-3 for the following recreational amenities: multi-slip marinas; convenience retailing; food services; pump-out facilities; gas dispensing and sales; dry stack storage; boat yard storage; lodging except hotels and motels; courtesy docks; facilities where boats can be launched, retrieved, and moored; picnic sites and shelters; hiking, nature, and bank fishing trails; fishing piers; restrooms, vault toilets, or bathhouses; parking and lighting; wildlife viewing platforms; swimming areas and associated changing facilities; fire, rescue, and law enforcement facilities; and playgrounds and playground equipment. The Parties reserve the right to comment on the details of future commercial lake use permit applications through various public comment opportunities.

7.5.5 Commercial Marina Classification at Lake Jocassee – The Licensee shall not designate any shoreline as available for Future Commercial Marinas or Future Residential Marinas at Lake Jocassee.

7.5.6 Permitting of Water Intakes

7.5.6.1 Water Intakes on Lake Jocassee – The Licensee shall not authorize new water intakes for public or industrial water supplies on Lake Jocassee.

7.5.6.2 Permanent Large Water Intakes – Criterion 7 from the Conveyance Program in the SMG shall be changed to comply with the requirements of Section 3.3 of this Agreement to protect and enhance usable water storage.

7.5.7 Lake Use Policy Statements – The Licensee shall no longer apply the Lake Use Policy Statements at the Project and shall remove references to them from the SMG.

7.5.8 Archaeological and Historic Resources – The procedures for protecting known and unknown archaeological and historic resources outlined in the SMG shall be modified to reflect the requirements set forth in Section 5.2.3.

7.6 Future SMP Updates

7.6.1 The Parties to this Agreement agree the SMP shall be reviewed and updated no more frequently than every tenth year of the New License term and then only if necessary.

7.6.2 SMP Changes – All Parties agree that changes made to the SMP, which includes the SMG, pursuant to the proposed Shoreline Management Plan License Article or the proposed Shoreline Management Plan Review and Update Procedures License Article shall not constitute or require modification of this Agreement. The Licensee shall invite the Parties to participate in revisions of the SMP for the term of the New License, and any Party may be involved in the FERC's public process for assessing the revised SMP but shall not oppose any part of the revised SMP that is consistent with this Agreement.

7.7 Shoreline Erosion – The Licensee shall install enhanced rip-rap to stabilize approximately 12,500 ft of actively eroding shoreline (generally denoted by scarps of three ft or higher) on Lake Keowee Islands currently identified as 1C, 1E, 3B', 3C, 3C'', 5, 6, 8, and 16; on the east side of the Fall Creek Peninsula; and on portions of High Falls II and Mosquito Point (see Appendix F, Figures F-2 and F-3) within three years following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods.

8.0 Species Protection Agreements

8.1 Federal Threatened and Endangered Species

8.1.1 The Licensee will implement species protection plans for all federally listed Threatened and Endangered species affected by the Project.

8.1.2 The Parties acknowledge the Existing License does not contain any specific requirements for the protection of federally listed Threatened and Endangered species and, as of the Effective Date of this Agreement, no Federal Threatened and Endangered Species Protection Plans have been filed in association with the Project because no such species has been found occurring within the Project Boundaries, nor shown to be affected by the Project. All Parties agree that any future filing by the Licensee of new or revised Species Protection Plans that may be required shall not constitute or require modification of this Agreement.

8.2 Shoreline Woody Debris at Lake Jocassee – The Parties agree shoreline woody debris at Lake Jocassee enhances shoreline habitat and should not be routinely removed as required under the Existing License.

8.3 Habitat Enhancement Program (“HEP”)

8.3.1 If the SCDNR, FOLKS and AQD are all Parties to this Agreement, the Licensee shall establish a HEP as described in Appendix H to create, enhance, and protect aquatic and wildlife habitat within the Project Boundaries, including the Project Reservoirs and islands, plus any part of the watershed draining into Project Reservoirs. The HEP will exist for the term of the New License.

8.3.2 HEP Fee – The HEP will be funded by a fee charged to those requesting lake use permits from the Licensee. The Licensee shall begin collecting the HEP fee upon the SMP Effective Date (September 1, 2014).

8.3.3 Licensee Contributions – Also beginning on the SMP Effective Date, the Licensee shall match HEP fee payments from lake use permit applicants for the first three years up to an annual cap of $100,000. The Licensee shall provide $1,000,000, less the total amounts provided in the matching payments, as the remainder of the start-up funding for the HEP. The Licensee shall provide the remainder of its contribution within two years following issuance of a New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods.

8.3.4 Revising the HEP – The Parties acknowledge that the HEP fees and fee structure may be amended over time. Any fee changes will be determined after considering the recommendations from the Proposal Review Committee (“PRC”). It is the Licensee’s expectation that it will approve all PRC-recommended HEP fees, and the Licensee will consult with the PRC before rejecting PRC recommended HEP fee changes. Such changes will not constitute or require a modification of this Agreement. If the FERC requires the Licensee to file HEP fee changes with the FERC for approval, any Party to this Agreement may be involved in the FERC’s public process for assessing the revised HEP fees but shall not oppose any part of the revised HEP fees that is consistent with this Agreement.

8.4 Botanical Species

8.4.1 The Licensee shall protect Special Status Species and botanical Priority Species at known sites within the Project Boundaries by:

8.4.1.1 Classifying shoreline with these species as Environmental or Natural;

8.4.1.2 Ensuring recreation facility development at Project Access Areas avoids these species; and

8.4.1.3 Providing appropriate signage for these species located within the Project Boundaries in proximity to Project structures (powerhouses, dams, and dikes).

8.5 Fish Species

8.5.1 SCDNR Tributary Stream Restoration – If the SCDNR is a Party to this Agreement, the Licensee shall provide a one-time contribution of $100,000 to the SCDNR within two years following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods. The funds shall be used by the SCDNR as matching funds for obtaining grants associated with Project headwater streams.

8.5.2 Trout Habitat – If the SCDNR is a Party to this Agreement, the Licensee shall annually monitor (beginning in 2016 for the term of the New License) the depth of winter mixing in Lake Jocassee (February or March at Licensee Monitoring Station 558.0) and model the projected thickness of pelagic trout habitat (defined as a band of water ≤ 20 °C (68 °F) and containing ≥ 5 mg/L dissolved oxygen ("DO")) expected to be present the following September. The Licensee shall provide this projected thickness of trout habitat to the SCDNR in May and verify the accuracy of this projection with a September measurement. If trout habitat is projected to be less than 10 meters (32.8 ft) thick by September, the Licensee shall measure temperature and DO in June and August to monitor habitat thickness. The Licensee shall then consult with the SCDNR regarding the modification of hydro operations to the extent practical so trout habitat thickness is not reduced to less than 5 meters (16.4 ft).

8.5.3 Fish Entrainment

8.5.3.1 If the SCDNR is a Party to this Agreement, the Licensee shall take the following actions to reduce fish entrainment at Jocassee Pumped Storage Station:

8.5.3.1.1 Intake Lighting Modifications – Redesign and modify lighting for the FERC-required public safety devices on the intake towers to eliminate or reduce the amount of light shining on the lake surface. Such modifications may include replacing white lights with red lights and illuminating signage from below rather than above the safety devices.

8.5.3.1.2 Tailwater Lighting Modifications – Redesign and modify lighting illuminating the tailwater area to eliminate or reduce the amount of light shining on the lake surface immediately downstream of the hydro units.

8.5.3.1.3 Hydro Unit Starting Sequence Modifications – When operating the hydro units in pumping mode, use a start-up sequence of Unit 3, Unit 4, Unit 1, and Unit 2, to the extent practicable.

8.5.3.2 The following conditions and schedule apply to the fish entrainment reduction actions identified in Section 8.5.3.1 above:

8.5.3.2.1 The Licensee shall consult with the SCDNR and the US Fish and Wildlife Service ("USFWS") on its plan for lighting modifications prior to implementation.

8.5.3.2.2 The design of the lighting modifications shall conform with FERC public safety requirements and shall provide for the continued safety of hydro station personnel and the continued security of hydro station personnel and facilities.

8.5.3.2.3 The Licensee shall implement the pumping start-up sequence within 60 days following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods.

8.5.3.2.4 The Licensee shall implement the lighting modifications within one year following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods. The Licensee shall incorporate the lighting modifications to the extent necessary into its FERC Public Safety Plan and file the plan with the FERC's Atlanta Regional Office.

8.5.3.2.5 The Parties to this Agreement agree the operational test performed by the Licensee in July 2013 at the Jocassee Pumped Storage Station is adequate for testing the efficacy of the fish entrainment reduction actions identified in Section 8.5.3.1.

8.5.4 Reservoir Level Stability for Black Bass Spawning – If the SCDNR is a Party to this Agreement, the Licensee shall endeavor to maintain to the extent practical relatively stable water levels in Lake Keowee and Lake Jocassee during the April 1 to May 15 (stabilization) period beginning in 2016 for the term of the New License. To do this, the Licensee shall maintain reservoir levels consistent with the general reservoir elevation trends observed during the stabilization periods in 1996-1999, 2003-2007, and 2010. The Parties agree this informal stabilization program should not be included as an article in the New License. The Licensee shall not be obligated to implement this stabilization during an MEP event or during any stage of the LIP. If water levels drop greater than the reservoir level trends observed during the years listed above, the Licensee shall consult with the SCDNR on options for reservoir stability, to the extent practical, for the remainder of the then-current stabilization period.

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9.0 Water Quality Agreements

9.1 Water Quality License Article – The Parties recommend the proposed Water Quality Monitoring License Article, the full text of which is provided in Appendix A of this Agreement, be incorporated verbatim into any New License the FERC may issue for the Project.

9.2 Request for 401 WQC – The Licensee shall request that the SCDHEC issue a 401 WQC as required by the Clean Water Act. The Licensee's request for a 401 WQC shall be consistent with this Agreement and propose the monitoring of DO levels as described in Section 9.3.

9.3 Project Tailwater DO Monitoring – During the first complete month of August occurring at least 60 days following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods, and during each subsequent August for the term of the New License, the Licensee shall continuously monitor DO concentrations in both the Keowee Hydro Station and Jocassee Pumped Storage Station tailwaters. The Licensee shall submit the results obtained from this annual monitoring to the SCDHEC each year by November 30.

9.4 Source Water Protection Program – If FOLKS, GW, and City of Seneca ("Seneca") are Parties to this Agreement, the Licensee shall provide, within two years following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods, $1,000,000 to a local, to-be-established Clean Water Group ("CWG") to fund a Source Water Protection Program ("SWPP"), as described in Appendix I. Funding by the Licensee is contingent upon the establishment of this yet-to-be-formed CWG as a 501(c)(3) federally tax-exempt corporation prior to the receipt of funds. FOLKS shall take the lead in establishing the CWG and drafting its charter. FOLKS shall invite the Licensee to consult and have a meaningful role in the development of the charter. FOLKS will endeavor in good faith to accommodate reasonable input from the Licensee.

9.5 Water Quality Model and Data Provided to FOLKS – If FOLKS is a Party to this Agreement, the Licensee shall provide within 60 days following the Effective Date of this Agreement the existing calibrated CE-QUAL-W2 reservoir water quality model developed for Lake Keowee during the relicensing process. Data sets required to run the 2011 WQ4 calibrated model, including reservoir and stream water quality, lake bathymetry, meteorology, hydrology, and operational data will be included in the data package provided to FOLKS. The data provided to FOLKS shall be in compliance with terms of applicable data release policies of the Licensee effective at that time.

(intentionally blank)

10.0 Other Agreements

10.1 Requirement to be a Party to Receive Funding and Property Rights – The Parties agree that, unless the entity receiving the funding or property rights did not have the opportunity to sign this Agreement, all provisions of funding or granting to a specified entity of any rights associated with real property are contingent upon said recipient of funding or real property rights having signed this Agreement. In the event the intended recipient of Licensee funds or grants of real property rights was eligible to be a signatory Party to this Agreement but chose not to, the Parties acknowledge the Licensee is under no obligation to provide the funding, grants, or any provision of such benefits to any entity.

10.2 Reporting Requirements for Funding Recipients – Any entity that receives Licensee funding under this Agreement will be required to provide documentation to the Licensee within two years of receipt of such funding, including any installment funding that occurs over multiple years, specifying how the funding was used and how the funding recipient met any of the designated restrictions for the use of such funding. The funding recipient will also provide the Licensee copies of final research reports, project summaries, or other summaries of work.

(intentionally blank)

GENERAL AGREEMENTS AND PROCEDURES

11.0 Effective Date and Term of Agreement

11.1 This Agreement shall become effective for all Parties on December 1, 2013 ("Effective Date of this Agreement"). This Agreement shall remain in effect for the term of the New License and for any annual licenses issued subsequent thereto, unless terminated pursuant to Section 22.0.

11.2 If a rehearing of the FERC order issuing the New License is sought by any person or entity, including any Party, any Party may request a stay of the effective date of the order and/or any other dates or articles specified in the order until the resolution of the rehearing request and the expiration of the statutory periods for appeals. Any Party may oppose such request for stay.

11.3 The Parties agree to support a New License term that is at least 40 years.

12.0 Offer of Settlement

The Licensee shall, by December 6, 2013, provide to all Parties a draft "Explanatory Statement," which is required by FERC rules. Parties may provide comments to the Licensee within 45 days of receipt of the draft Explanatory Statement and the Licensee shall address such comments when filing this Agreement and the Explanatory Statement with the FERC.

13.0 Adoption by the FERC Without Material Modification

13.1 The Parties have entered into this Agreement with the express desire and expectation that the FERC will approve this Agreement as an Offer of Settlement and issue a New License for the Project that incorporates, without material modification, the proposed License Articles in Appendix A.

13.2 Except as provided herein, the Parties agree that, if the FERC incorporates the proposed License Articles into the New License without material modification, no Party will seek rehearing of the FERC order granting the New License for any issues covered by this Agreement or support in any way any such request for rehearing by any person or entity.

13.3 The Parties have entered into this Agreement with the express understanding that each term in this Agreement, including the proposed License Articles in Appendix A, is in consideration of each other term.

14.0 Statutory Responsibilities of Federal, Tribal, State and Local Governmental Bodies

14.1 Except as provided in this Section and elsewhere in this Agreement, by becoming Parties to this Agreement, all Parties that are governmental bodies, including Tribes, believe this Agreement is consistent with their statutory responsibilities.

14.2 Notwithstanding Section 14.1, nothing in this Agreement is intended or shall be construed to restrict any Party that is a governmental body or Tribe with responsibilities, duties, or obligations imposed by law from fulfilling its responsibilities, duties, and obligations under any applicable local, state, or federal law or regulation. Nothing in this Agreement is intended or shall be construed to restrict these governmental bodies and Tribes from fully and objectively considering any and all public comments received in any regulatory process related to the Project, from conducting an independent review of the Project under applicable statutes, or from providing comments to the FERC that are necessary to meet their responsibilities, duties, and obligations provided by law. All commitments and obligations of these governmental bodies and Tribes in, under, and pursuant to this Agreement shall be construed and interpreted as including, and meaning "to the extent allowed by local, state, and federal law and regulation, and consistent with local, state, and federal law and regulation."

14.3 Notwithstanding Section 14.1, nothing in this Agreement is intended or shall be construed to affect or limit in any way the authority of the SCDHEC pursuant to 33 U.S.C. § 1341, and related state statutes and rules, to issue a 401 WQC, or to alter its 401 WQC, with whatever conditions the SCDHEC determines should be included. Nothing in this Agreement shall limit the right of the SCDHEC from enforcing its 401 WQC and from taking any steps within its discretion to protect and defend its authority, such as seeking rehearing of any FERC action regarding issues related to the exercise of SCDHEC's authority with regard to its 401 WQC.

14.4 Nothing in this Agreement is intended or shall be construed to prevent any governmental body engaged in a public process from addressing issues included in this Agreement when raised before such governmental body in a public proceeding; provided, however, that addressing such issues in a public proceeding shall not relieve any Party that is a governmental body from its obligations to act consistently with this Agreement.

14.5 Nothing in this Agreement is intended to restrict, limit, interfere with, impede, or impair the rights, responsibilities, duties, or obligations of any governmental body in implementation of and in furtherance of its rights, responsibilities, duties, or obligations.

15.0 Parties' Rights, Obligations and Restrictions During the Period when the FERC is Developing the New License and/or the SCDHEC is Developing the Water Quality Certification

15.1 Parties' Rights, Obligations, and Restrictions Related to the FERC's Licensing Process for Developing the New License

15.1.1 The Parties reserve the right to be actively involved in the FERC licensing, including by intervention, in a manner consistent with this Agreement.

15.1.2 During the period of this relicensing prior to the FERC's issuance of the New License and the closure of all rehearing and administrative challenge periods, and except as allowed by Section 14.0, no Party may request or advocate by any means, including but not limited to intervention, filing comments with the FERC or any other agency, participating in public hearings or meetings, communicating with the media or in any public forum, encouraging, coaching or funding non-Parties to this Agreement, concurring with comments filed with the FERC or any agency, and communicating with or lobbying state or federal officials, for any New License requirements that would, if adopted by the FERC, be an Inconsistent Act.

15.1.3 Except as allowed by Section 14.0, during the period of this relicensing prior to the FERC's issuance of the New License and the closure of all rehearing and administrative challenge periods, no Party may request or advocate by any means, including but not limited to intervention, filing comments with the FERC or any other agency, participating in public hearings or meetings, communicating with the media or in any public forum, encouraging, coaching or funding non-Parties to this Agreement, concurring with comments filed with the FERC or any agency, and communicating with or lobbying state or federal officials, for New License reopeners of any kind beyond those that are included in the FERC's standard L-Form applicable to this Project.

15.2 Parties' Rights, Obligations and Restrictions during SCDHEC's Process for Developing the 401 WQC

15.2.1 The Parties reserve the right to be actively involved in any 401 WQC process in a manner consistent with this Agreement.

15.2.2 During the period of this relicensing prior to the FERC's issuance of the New License and the closure of all rehearing and administrative challenge periods, and except as allowed by Section 14.0, no Party may request or advocate by any means, including but not limited to intervention, filing comments with the FERC or any other agency, participating in public hearings or meetings, communicating with the media or in any public forum, encouraging, coaching or funding non-Parties to this Agreement, concurring with comments filed with the FERC or any agency, and communicating with or lobbying state or federal officials for, (i) any 401 WQC requirements or conditions that would result in an Inconsistent Act or (ii) 401 WQC reopeners of any kind other than a reopener for failure to comply with requirements of any 401 WQC.

16.0 Agreements on Action Steps when a Jurisdictional Body Imposes a Requirement that is an Inconsistent Act

16.1 If any Party believes the actions of a Jurisdictional Body, through the imposition of a requirement or the failure to impose any requirement on the Licensee, have resulted in an Inconsistent Act, the Party shall notify the other Parties pursuant to Section 23.0.

16.2 If notice is given pursuant to Section 16.1 the Licensee shall convene a meeting of all Parties to determine by consensus a course of action to: (i) work with the FERC and any appropriate Jurisdictional Body to pursue an alternative to the Inconsistent Act that is acceptable to all Parties and to the FERC and the Jurisdictional Body(ies); (ii) acceptably rebalance and modify this Agreement; or (iii) take such other actions as the Parties may agree upon to address the Inconsistent Act. If requested by any Party, mediation as described in Section 25.2 may be used to help reach consensus. The Parties shall use their best efforts to cooperatively implement this Section 16.2 to address the Inconsistent Act in a manner agreeable to all the Parties.

16.3 If the Parties modify this Agreement, pursuant to Section 19.0, to address the Inconsistent Act, the Licensee shall promptly file the Modified Agreement with the FERC, and any Party may take actions, such as submitting comments, consistent with the Modified Agreement. However, if all Parties do not agree to modify this Agreement to address the Inconsistent Act, then no Party may support the Inconsistent Act, and the Parties shall not modify this Agreement.

16.4 Any Party may pursue any available legal remedies (i.e., administrative or judicial review) to alter a proposed or final Inconsistent Act to conform to this Agreement whether or not that Party is simultaneously following the procedures in this Section 16.0. No Party shall oppose such legal remedies that seek only to conform the Inconsistent Act to this Agreement.

17.0 Review of Inconsistent Act Imposed by Jurisdictional Body that Substantially Negatively Affects a Party

17.1 A Party may initiate or maintain an action (e.g., administrative or judicial review), to contest an Inconsistent Act imposed by a Jurisdictional Body. Because this Agreement itself is legally enforceable, the omission of any proposed License Article from any authorization (including the New License and any 401 WQC), notwithstanding Section 16.0, shall not, by itself, be deemed an Inconsistent Act that conflicts with this Agreement. However, any Party may petition the issuing agency to include such Article in such authorization and may exhaust such administrative and related judicial processes. Conversely, the inclusion of any requirement of this Agreement in any authorization (including the New License and any 401 WQC) shall not, by itself, be deemed an Inconsistent Act that conflicts with this Agreement. However, any Party may petition the issuing agency to exclude such Article in such authorization and may exhaust such administrative and related judicial processes. No Party except the relevant Jurisdictional Body may oppose another Party's action pursuant to this Section 17.1.

17.2 No Party will seek to use its status as a Party to this Agreement to establish standing or aggrieved-party status to challenge any action of any governmental agency that is also a Party to this Agreement when that governmental agency's actions are pursuant to fulfilling its statutory duties.

17.3 If, after exhausting any legal reviews initiated pursuant to Section 17.1, any Party still believes the Jurisdictional Body's action or omission is an Inconsistent Act and that it is substantially negatively affected by the Inconsistent Act, then that Party may initiate withdrawal pursuant to Section 21.0 by giving notice of its intent to withdraw from this Agreement pursuant to Section 23.0. No Party may give Notice of Intent to Withdraw until all administrative and judicial challenges regarding the issue over which the Party intends to withdraw have been finally resolved and until all time periods for further administrative or judicial review have expired when that governmental agency's actions are complete pursuant to fulfilling its statutory duties.

18.0 Agreements on Action Steps upon Breach by Any Party

18.1 If any Party is alleged by any other Party to be in breach of this Agreement, the Party alleging the breach shall immediately notify, pursuant to Section 23.0, all Parties to this Agreement of the alleged breach and shall consult with the allegedly breaching Party to discuss the breach and reach a resolution satisfactory to all Parties. To allow for consultation, no Party may seek relief from a court or any other forum, including the FERC, concerning the alleged breach until sixty days have elapsed following the notice required in the preceding sentence, except that a Party may seek relief prior to the passing of the sixty days if the Party's rights would be prejudiced by such delay.

18.2 If any Party has a credible reason to believe it or another Party may be unable to comply with any future obligation under this Agreement, including any schedule, the Party may inform the other Parties. The Licensee shall convene the Parties to attempt to ensure clear communications concerning the potential breach and to identify actions that may be acceptable to all the Parties that would eliminate the concern relative to the potential breach.

18.3 The Parties agree to use their best efforts to cure any alleged breach of this Agreement in a reasonable and timely manner. If such best efforts and consultation fail to resolve the alleged breach or alleged anticipatory breach, any Party may pursue its legal remedies for any alleged breach or alleged anticipatory breach once the sixty-day period set forth in Section 18.1 has elapsed.

18.4 When any Party withdraws from this Agreement or is found to have breached this Agreement, the withdrawing or breaching Party is obligated to return any benefits previously obtained under this Agreement, if such benefits consist of monetary funds or interests in real property. The Parties acknowledge that no withdrawing or breaching Party ought to be able to withdraw from or breach this Agreement and retain benefits bargained for, and the Parties agree that this remedy is to be specifically enforceable.

19.0 Modification of this Agreement

19.1 Except as provided in Sections 3.4.8, 4.4, 6.2.4, 6.3.14.3, 6.4.2, 7.5.3.1, 7.6.2, 8.1.2, 8.3.4, 19.2, 19.3, and 23.0, any modification of any provision of this Agreement to become effective must be made in writing and, after notice of the modification is provided pursuant to Section 23.0, signed by an authorized representative of each Party except that a Party who fails to respond to such notice within 60 days shall be deemed to have consented to the proposed modification. Except as provided herein, nothing in this Agreement is intended to limit the Parties' ability to modify this Agreement.

19.2 The Parties acknowledge that, for long-term clarity of this Agreement, it may be beneficial to remove from this Agreement those benefits and obligations that were conditioned on certain entities becoming Parties to this Agreement but are no longer benefits or obligations of this Agreement because these entities did not become Parties. The Parties agree that when considering modification of this Agreement, the Licensee shall also confer with the Parties to reform this Agreement for the limited purpose of reflecting accurately only the Parties' benefits and obligations hereunder by deleting specific benefits and obligations of entities that were signatories to the AIP but declined to become Parties to this Agreement. If any signatories to the AIP decline to become Parties to this Agreement, the Licensee will circulate a reformed Agreement to all Parties, pursuant to the notice provision of Section 23.0, and such reformed Agreement shall automatically supersede this Agreement unless any Party objects by giving notice to the Licensee within 60 days of notice of the reformed Agreement.

19.3 Prior to December 2, 2013, a Party to this Agreement may seek to initiate a process for rebalancing this Agreement if there is a loss of Agreement provisions conditioned upon the Party and at least one other AIP Signatory signing this Agreement, when at least one of said AIP Signatories does not sign this Agreement. If the attempt to rebalance this Agreement is unsatisfactory, the Party may seek to withdraw without following the procedures in Section 16.0.

20.0 Parties' Ability to Petition the FERC or SCDHEC

A Party may petition the FERC to amend the New License, pursuant to any reopener condition contained in the New License, or to take any other action with regard to the

License or the Project or may petition the SCDHEC to amend its respective 401 WQC, pursuant to any reopener condition included in any 401 WQC, or to take any other action with regard to the Licensee or the Project, so long as the amendment or other action would not substantially conflict with this Agreement and would not directly result in an Inconsistent Act for any other Party; provided, however, that before filing any such petition, the petitioning Party shall notify all other Parties pursuant to Section 23.0 and consult with any Party that indicates that it may be substantially negatively affected, but under no circumstance shall such consultation prevent a Party from pursuing such relief before the FERC or the SCDHEC within the time required by law or regulation.

21.0 Withdrawal from this Agreement

21.1 A Party may initiate withdrawal from this Agreement if it is substantially negatively affected by an Inconsistent Act and has followed the procedures in Section 16.0, as applicable, to attempt to remedy the cause for the withdrawal.

21.2 A Party may initiate withdrawal from this Agreement without following the procedures in Section 16.0 if it is substantially negatively affected by: (i) withdrawal of another Party, as set forth in Section 21.11; (ii) a new law or regulation that requires a Party to act in a manner that breaches this Agreement, as set forth in Section 32.0; (iii) the invalidation of a portion of this Agreement, as set forth in Section 33.6; or (iv) transfer of the Existing or New License to a transferee that is not bound by all the terms of this Agreement, as set forth in Section 33.15.

21.3 A Party shall initiate the withdrawal process by providing Notice of Intent to Withdraw to all Parties in accordance with Section 23.0. This Notice must include a brief, non-binding statement setting forth:

> 21.3.1 The date and nature of the Inconsistent Act, or other event giving rise to the right to withdraw, including a reference to the specific section of this Agreement under which withdrawal is permitted; and
>
> 21.3.2 (i) If withdrawal is based on an alleged Inconsistent Act, how the alleged Inconsistent Act meets the definition of “Inconsistent Act” and how it conflicts with this Agreement; and (ii) how the alleged Inconsistent Act or event listed in Section 21.2 substantially negatively affects the withdrawing Party.

21.4 If any Party opposes the withdrawal, that Party shall submit a notice, pursuant to Section 23.0, to the withdrawing Party indicating that it opposes withdrawal and seeks arbitration of the Party’s right to withdraw.

21.5 If, after 60 days from the Notice of Intent to Withdraw, no Party opposes the withdrawal, the withdrawal is final.

21.6 Within 30 days of the notice opposing withdrawal, the withdrawing Party shall post an Arbitration Escrow Fee of $2,000. The Arbitration Escrow Fee shall be made payable to an acceptable escrow agent, which may be the Licensee, and shall bear a notation that it is to be held in escrow. Once the arbitrator is selected, the withdrawing Party shall ensure that the escrow agent may release the funds to the arbitrator upon proof of the withdrawing Party’s failure to pay its share of the arbitration costs. If the withdrawing Party fails to post the Arbitration Escrow Fee in a timely manner, it shall thereby waive its right to withdraw based on the Inconsistent Act or other event cited in the withdrawal notice.

21.7 The arbitrator shall be selected and the arbitration conducted pursuant to the procedures of the American Arbitration Association under its Commercial Arbitration Rules. The arbitrator's decision shall be binding only as to the Parties before it.

21.8 Withdrawal shall be allowed only if the arbitrator determines that the withdrawing Party substantially complied with all material procedural prerequisites to withdraw specified in this Agreement and:

21.8.1 A requirement imposed by a Jurisdictional Body (i) conflicts with this Agreement and (ii) is an Inconsistent Act that substantially negatively affects the withdrawing Party; or

21.8.2 The withdrawing Party was substantially negatively affected by the withdrawal of another Party, as set forth in Section 21.11; or

21.8.3 A new law or regulation requires a Party to act in a manner that breaches this Agreement, as set forth in Section 32.0, and that breach substantially negatively affects the withdrawing Party; or

21.8.4 A portion of this Agreement is invalidated which results in the withdrawing Party's being substantially negatively affected, as set forth in Section 33.6; or

21.8.5 The Existing or New License is transferred to a transferee that is not bound by all the terms of this Agreement which results in the withdrawing Party's being substantially negatively affected, as set forth in Section 33.15.

21.9 An effective withdrawal relieves the withdrawing Party of its performance obligations under this Agreement.

21.10 The costs of the arbitration shall be shared equally between the Party seeking withdrawal (50 percent) and the combination of Parties requesting arbitration (50 percent). The Parties shall request that the arbitrator invoice each Party separately. Any unused amounts of the Arbitration Escrow Fee will be returned to the withdrawing Party.

21.11 Upon withdrawal of any Party, any other Party (hereinafter "Second Party") may exercise its right to withdraw pursuant to the procedures set forth in this Section 21.0, except that, if the issue goes to arbitration, withdrawal shall be allowed only if the arbitrator determines that (i) the Second Party substantially complied with all procedural prerequisites to withdrawal specified in this Agreement; and (ii) the previous withdrawal of another Party will substantially negatively affect the Second Party.

21.12 No Party is required to pursue administrative or judicial remedies prior to withdrawing; however, no Party may give Notice of Intent to Withdraw until all administrative and judicial challenges, if any, regarding the issue over which the Party intends to withdraw have been finally resolved and until all time periods for further administrative or judicial review have expired. Any right to withdraw is waived if the Party does not give Notice of Intent to Withdraw within 180 days of the expiration of the last time period for administrative or judicial review of a matter related to the reason for withdrawal.

21.13 If a Party is prohibited by law from submitting to binding arbitration, then, after that Party has provided Notice of Intent to Withdraw and after another Party has given notice of its opposition to withdrawal, as set forth in Section 21.4, the Party seeking to withdraw shall give notice to all Parties pursuant to Section 23.0 that it is prohibited by law from submitting to binding arbitration and shall provide with such notice evidence of the legal prohibition and shall within 30 days following provision of its notice of prohibition to submit to arbitration, file an action for declaratory judgment: (i) seeking the court's determination of its legal right to withdraw pursuant to the terms of this Agreement; and (ii) naming the Party opposing withdrawal as the defendant. The withdrawing Party shall serve notice of its filing of the declaratory judgment action on all Parties to allow any Party the opportunity to intervene. The court shall use the criteria set forth in Section 21.0 and sections cross-referenced therein to determine whether a Party seeking to withdraw is entitled to withdraw under this Agreement. If the Party seeking to withdraw fails to file an action for declaratory judgment within 30 days following its notice to the Parties of its prohibition to submit to arbitration, then it shall thereby waive its right to withdraw based on the Inconsistent Act or other event cited in the withdrawal notice.

21.14 Any opposition to any withdrawal shall be ineffective if the arbitrator determines that the Party opposing withdrawal failed to give notice to the withdrawing Party as required in Section 21.4.

22.0 Termination of this Agreement

This Agreement, and all obligations arising hereunder, shall terminate and be of no further force or effect upon withdrawal of the Licensee, upon the expiration or other termination of the term of the New License and any annual licenses issued thereafter, or upon transfer of the license to a subsequent licensee that is not bound by any part of this Agreement.

23.0 Notice

Each Party shall designate a representative for the receipt of notices. All notices required to be given under this Agreement shall be in writing and be given by personal delivery, overnight express service, or U.S. mail to each Party using the contact information set forth in this Agreement and included as Appendix B. The sender shall retain proof of posting or delivery, and notices shall be effective upon the date and time identified on the proof of posting or delivery. The Licensee will be responsible for maintaining the contact information included as Appendix B. A Party may change the contact information or the designated representative by notifying the Licensee of such change, and such change will not be considered a modification of this Agreement. Each Party shall be responsible for providing the Licensee with their updated contact information in a timely and accurate manner. If a Party no longer exists at the time that notice is required to be given by this Agreement, notice to such Party is not required. If a Party required to give notice knows that another Party's designated representative is deceased or is no longer employed by and/or affiliated with such other Party, the Party required to give notice must make a reasonably diligent effort to provide notice to an appropriate person affiliated with such other Party. A "reasonably diligent effort" shall include notice to any person upon whom process could be served under the Federal Rules of Civil Procedure in effect at the time that notice is required to be given.

24.0 Licensed Project Cessation

24.1 In the event the Licensee decides to surrender the New License prior to its expiration or the United States takes over the Project, the Licensee agrees to take the following actions.

24.1.1 Notify all Parties pursuant to Section 23.0 and convene a meeting for all Parties no later than 30 days after its decision to surrender the Project in whole or in part, or becoming aware that the United States may take over the Project in whole or in part.

24.1.2 Notify all Parties at least 60 days prior to the Licensee's filing at the Commission an application to surrender its License in whole or in part.

24.1.3 Negotiate in good faith with the SCDNR, the SCDPRT, and any other interested Party with the objective of ensuring continued public access to Project Reservoirs through the remaining period of the New License term for those properties designated for public access in the New License and that will continue to be owned by the Licensee.

24.1.4 Negotiate in good faith with the SCDNR, SCDPRT, and any other interested Party to develop a plan for managing lands and waters within the Project Boundaries.

24.1.5 Negotiate in good faith with each public water supplier authorized to withdraw water from any Project Reservoir to assure continued access by public water suppliers to such reservoir and other necessary facilities, including land through the remaining period of the New License term.

24.1.6 Within 180 days after becoming aware that any of the Project's developments will no longer be licensed by the FERC or after filing an application with the FERC to surrender the license for any of the Project's developments, and provided the Licensee desires to close and/or sell any affected Licensee-owned recreation land or facilities at the Project, then provide notice to all Parties that are tribal or governmental bodies, pursuant to Section 23.0, to offer to sell the affected Licensee-owned recreation land and facilities at the appraised market value, as determined by the average of two appraisals completed in accordance with Appraisal Institute standards, one appraisal to be paid for by Licensee and the other to be paid for by the first tribal or governmental entity that notifies the Licensee, pursuant to Section 23.0, of its desire to acquire Licensee-owned recreation land and facilities. Any said recreation land or facilities that are leased to a Party to this Agreement will first be offered for sale to the lessee under the same arrangements above in this Section 24.1.6 for a period of 60 days. An offer to acquire such facilities by a tribal or governmental entity may be for all or any portion of such Licensee-owned recreation land and facilities.

180 days after providing such notice of an offer to sell, the Licensee shall be free to sell to any entity any affected Licensee-owned recreation land or facilities for which the Licensee does not receive an acceptable purchase option from a Party that is a tribal or government entity.

25.0 Dispute Resolution

25.1 Dispute Resolution – Except as otherwise specifically provided in this Agreement, disputes among Parties arising under or related to this Agreement or the New License shall be resolved as follows.

25.1.1 Consultation

25.1.1.1 Any Party alleging a dispute shall notify the Licensee. The Licensee shall notify all Parties pursuant to Section 23.0 and shall give at least 15 days notice of a meeting scheduled to resolve the dispute. The Party alleging a dispute and each Party that attends such meeting or notifies all other Parties pursuant to Section 23.0 of the Party's interest in the resolution of the alleged dispute shall be considered to be an "Interested Party." The meeting notice shall describe the dispute and shall provide the time and location of the meeting. All Parties who are Interested Parties agree to engage in good-faith negotiations to resolve the dispute for a period of at least 45 days ("Consultation Period") from the date of notice provided by the Party alleging a dispute in an effort to resolve the dispute; except that, in emergency situations, or if required to preclude the running of any applicable limitations period, an Interested Party may, for good cause, seek relief prior to the expiration of the 45-day period.

25.1.1.2 The Interested Parties may agree to extend the Consultation Period up to an additional 75 days and may employ a mediator. To the extent allowed by law, the Parties shall consider any applicable limitations period, whether arising by statute, regulation, contract, or otherwise to be tolled during the Consultation Period. No Party shall raise as a defense to any action, whether judicial or administrative, the running of any period of limitation, so long as the action was filed within the limitations period plus the Consultation Period.

25.1.1.3 The Consultation Period ends when the times described above expire or when all Interested Parties except one indicate that consultation is no longer useful, whichever is sooner.

25.1.2 Consensus – Upon resolution of a dispute, by agreement or otherwise, the Interested Parties shall notify all Parties of the resolution. A resolution based on consensus shall have the unanimous support of all Interested Parties and no opposition from any other Party. Any resolution that requires modification of this Agreement requires written approval signed by all Parties, pursuant to Section 19.0.

25.1.3 Remedies – If, after the Consultation Period, the Interested Parties have not reached consensus, or in the event a schedule to cure an alleged noncompliance has been established through Consultation and a Party has not cured the failure within the time established, any Interested Party may seek resolution as follows.

25.1.3.1 Provisions of this Agreement that are Also Included in the New License – For disputes related to License Articles, a Party shall petition the FERC to enforce the License Article with which the Licensee is alleged to have failed to comply. If FERC enforces any alleged failure to comply with a License Article, such enforcement action shall be the sole remedy under this Agreement. If the FERC finds that a violation occurred but affirmatively declines to enforce a License Article or fails to act within a reasonable time after a petition to enforce has been filed, which period of time shall not be less than 180 days from the date on which the petition was filed, then such Party may file with the FERC a petition for rehearing regarding the alleged failure and pursue any further remedies, including judicial review. Once the

180-day period has expired or FERC has affirmatively indicated that it will not take enforcement action (whichever occurs sooner), any Party may seek to enforce, by any available means, any provision of this Agreement that was also incorporated into the New License, except that any Party may file such action sooner in order to preclude the running of any applicable limitations period. If any Party has sought direct review of any FERC action related to enforcement, the Party may not seek to enforce by other means until that action is resolved and any applicable review periods have expired.

25.1.3.2 Provisions of this Agreement that are Not Also Included in the New License – For disputes not related to License Articles, a Party shall seek resolution in a court or agency of competent jurisdiction.

25.2 Mediation Services

25.2.1 Any Party may propose the use of a professional mediator to facilitate dispute resolution. To initiate professional mediation, a Party shall notify all Parties pursuant to Section 23.0 and shall convene a meeting not sooner than 15 days nor more than 30 days following notice. Such notice shall state the date, time, and location of the initial meeting to consider mediation. At that initial meeting all Parties in attendance shall determine their interest in mediation. Mediation is purely voluntary, and no Party shall be compelled against its will to participate in mediation.

25.2.2 Those Parties agreeing to mediation shall execute a contractually binding agreement with a professional mediator, and such agreement shall determine both how the mediating parties will share the cost of mediation and the schedule to undertake and complete mediation. No Party that chooses not to participate in mediation shall be responsible for any costs related to mediation. No mediated resolution shall modify this Agreement unless all the Parties so modify this Agreement pursuant to Section 19.0.

26.0 Adjustment for Inflation / Deflation

26.1 Unless otherwise indicated in this Agreement, all costs or payment amounts in this Agreement that are specified in dollars and are to be paid by the Licensee shall be adjusted on an annual basis starting on January 1, 2015 and January 1 of each following year according to the following formula:

AD = (D x (NGDP)) / IGDP

Where:

AD = Adjusted dollar amount as of January 1 of the year in which the adjustment is made (or, in the case of the first adjustment, 2015).

D = Dollar amount prior to adjustment.

NGDP = GDP-IPD for the third quarter of the year before the adjustment date (or, in the case of the first adjustment, 2014).

IGDP = GDP-IPD for the third quarter of the year before the previous adjustment date (or, in the case of the first adjustment, 2013).

26.2 "GDP-IPD" is the value published for the Gross Domestic Product Implicit Price Deflator by the U.S. Department of Commerce, Bureau of Economic Analysis in the publication "Survey of Current Business" (being on the basis of 2005 = 100), in the third month following the end of the applicable quarter. If that index ceases to be published, any reasonably equivalent index published by the Bureau of Economic Analysis may be substituted. If the base year for GDP-IPD is changed or if publication of the index is discontinued, the Licensee shall promptly make adjustments or, if necessary, select an appropriate alternative index to achieve the same economic effect. Adjusted amounts will be rounded to the nearest whole dollar.

27.0 Ability of Parties to Request FERC Approvals or New License Amendments Related to Non-Project Use Requests

27.1 Nothing in this Agreement shall impair or supersede the right of any Party to apply for and/or support, including by intervention, an amendment to the New License or other order from the FERC authorizing any entity to expand or modify an existing water intake or to add a new water intake, unless such amendment is specifically prohibited in this Agreement.

27.2 Unless such action is specifically prohibited in this Agreement, nothing in this Agreement shall impair or supersede: (i) any Party's right to file with the Licensee a Non-Project Use request that is in compliance with the SMG or to support (e.g., provide comments on individual lake use permit applications, such as marinas, multi-slip facilities, etc.), including by intervention, that request with the FERC; (ii) any Party's right to support, oppose, or request modification to such a request with the FERC; or (iii) any Party's legal obligations related to such requests.

27.3 Nothing in this Agreement is intended to or may be construed to alter, modify, amend, or in any way impact or affect state law applicable to the Non-Project Use requests.

28.0 Parties' Participation in Future Relicensings and 401 WQC

28.1 Nothing in this Agreement shall be construed to restrict any Party's participation or comments in future relicensings or 401 WQC related to licenses for this Project beyond the New License.

28.2 Nothing in this Agreement shall be construed to restrict any Party's participation in any other FERC licensing proceeding including any other project for which Duke Energy Carolinas, LLC is the licensee.

29.0 Early Implementation

Unless otherwise prohibited in the New License, the Existing License, or this Agreement, the Licensee at its own discretion may choose to voluntarily implement, partially or in full, any of the operational changes or its other obligations called for in this Agreement earlier than the dates indicated in this Agreement.

30.0 Coordination with the Licensee's Budgeting Cycle

Unless otherwise specified in this Agreement, the timing for financial contributions from the Licensee described in this Agreement will be coordinated with the Licensee's budgeting cycle. The Licensee's contributions will become available the latter of any of the following: (i) January 1 of the first calendar year after the issuance of the New License and the closure of all rehearing and administrative challenge periods if the date for financial contribution is on or before June 30; or (ii) January 1 of the second calendar year following the issuance of the New License and the closure of all rehearing and administrative challenge periods if the date for financial contribution is after June 30.

31.0 Assessments and Procedures for New Information or Material Mistakes

A Party that becomes aware of significant new information or a material mutual mistake may bring that information to the Licensee and/or may convene a meeting of all Parties pursuant to Section 23.0, inviting Parties to meet to discuss a modification of this Agreement pursuant to Section 19.0. No Party may use new information as a defense to an alleged breach of this Agreement, as a basis for taking an action inconsistent with this Agreement, or as a basis to withdraw from this Agreement.

32.0 Procedures for New Law or Regulation

Should any new law, regulation, or other regulatory action, such as a permit or License requirement, require a Party to breach this Agreement (including, without limitation, for a governmental Party, denying that Party's funds with which to fulfill its obligations under this Agreement), such Party shall not be liable for such breach. Should a new law or regulation require a Party to act in a manner that breaches this Agreement, then any other Party that believes it is substantially negatively affected thereby may withdraw from this Agreement by following the procedures in Section 21.0. If arbitration is initiated, withdrawal shall be allowed only if the arbitrator determines that: (i) the withdrawing Party substantially complied with all procedural prerequisites to withdrawal specified in this Agreement; (ii) there is no adequate remedy at law or in equity for the breach and the breach substantially negatively affects the withdrawing Party; and (iii) the breach was required by or the unavoidable result of the new law or regulation.

33.0 Miscellaneous Agreements

33.1 No Admission of Liability – This Agreement is a compromise of many interests. The actions taken pursuant to this Agreement are not intended nor shall they be construed as an admission on the part of any Party, or its agents, representatives, attorneys or employees that such Party was so obligated in any manner independent of this Agreement. Except as provided herein, no Party shall be prejudiced, prevented, or estopped from advocating in any manner or before any entity, including the FERC or any state agency, any position inconsistent with those contained in this Agreement regarding the licensing, permitting, and license compliance of this or any other hydropower project.

33.2 Agreement Terms Contractual – The terms of this Agreement are contractual and not mere recitals. This Agreement, including Appendices A through I, constitutes the entire Agreement between the Licensee and the other Parties with respect to the subject matter hereof, and all prior contemporaneous or other oral or written statements, representations or agreements by, between or among any of the Parties, including the AIP, are superseded hereby. However, nothing herein alters any valid easement, lease, user's agreement, or permit previously granted or issued by the Licensee to any entity that is a Party to this Agreement for use of Project land or Project waters including, without limitation: (i) the water removal easement granted to the City of Seneca in the

Water Contract dated March 31, 1969, which is incorporated by reference, and (ii) the Indenture and Agreement, effective January 31, 1973, by and between the Licensee and Greenville Water, which is incorporated by reference.

33.3 Enforceability – As noted in Section 25.1.3, all terms of this Agreement not incorporated as License Articles shall be enforced through remedies available under applicable state or federal law.

33.4 Force Majeure – The Parties agree neither the Licensee, nor any other Party, shall be in breach of this Agreement to the extent any delay or default in performance is due to causes beyond the reasonable control of the delayed or defaulting Party; provided the delayed or defaulting Party notifies the other Parties as soon as possible of: (i) the event; (ii) the expected duration of the event; and (iii) the delayed or defaulting Party's plan to mitigate the effects of the delay or default. Such causes may include, but are not limited to, natural disasters, labor or civil disruption, acts of terrorism, the inability to secure any legal authorization from another entity (e.g., a permit or license) where such legal authorization is a prerequisite or requirement for complying with this Agreement, or breakdown or failure of the Project works, provided such causes are beyond the reasonable control of the delayed or defaulting Party.

33.5 Applicable Law and Venue – The Parties agree that all actions arising wholly within North Carolina must be litigated in courts located in the State of North Carolina and shall be governed by North Carolina law; those actions arising wholly within South Carolina must be litigated in courts located in the State of South Carolina and shall be governed by South Carolina law; where an action arises in both states, or in the case in which an act or omission giving rise to an action to enforce this Agreement occurred in neither state or its state of origin cannot be determined, the action must be litigated in courts located in either the State of North Carolina or the State of South Carolina, and laws of the state where the action is brought shall govern. The Parties agree that such courts are convenient forums and irrevocably submit to the personal jurisdiction of such courts, except that the governmental bodies who are Parties do not by entering into this Agreement waive sovereign immunity, and such Parties waive such defense only to the extent required by law, if at all.

33.6 Severability – Should any provision of this Agreement or part hereof be held under any circumstances in any jurisdiction to be invalid or unenforceable, such invalidity or unenforceability shall not affect the validity or enforceability of any other provision of this Agreement or other part of such provision. If such invalidity or unenforceability substantially negatively affects any Party, that Party may withdraw from this Agreement pursuant to the procedures established in Section 21.0. If arbitration is initiated, withdrawal shall be allowed only if the arbitrator determines that: (i) the withdrawing Party substantially complied with all procedural prerequisites to withdrawal specified in this Agreement; and (ii) the unenforceability or invalidity of the relevant part of this Agreement substantially negatively affects the withdrawing Party.

33.7 Waiver Independence – No consent to or waiver of any provision of this Agreement shall be deemed either a consent to or waiver of any other provision hereof, whether or not they are similar, or a continuing consent or waiver, unless otherwise specifically provided.

33.8 Definitions – The terms, phrases, and abbreviations defined in this Agreement and Appendix C, Appendix D, Appendix E, and Appendix I hereto, when used in this Agreement, shall have the meanings as defined in this Agreement and Appendix C, Appendix D, Appendix E, and Appendix I.

33.9 Water Rights Unaffected – This Agreement does not release, deny, grant or affirm any property right, license, or privilege in any waters or any right of use in any waters nor impact or affect any requirements or obligations under state law. This Agreement does not authorize any person or entity to interfere with the riparian rights, littoral rights, or water use rights of any other kind of any other person or entity. No person or entity shall interpose this Agreement as a defense in an action respecting the determination of riparian or littoral rights or other water use rights.

33.10 Parties' Own Costs – Except as expressly provided for in this Agreement, all Parties are to bear their own costs of participating in this Agreement.

33.11 Existing Laws – Unless otherwise noted, any reference to any statute, regulation, or other document refers to the statute, regulation, or document as it exists on the date of the first signature on this Agreement. No changes to any document to which this Agreement refers are incorporated into this Agreement, unless explicitly provided for in this Agreement or unless such change is made in accordance with Section 19.0.

33.12 No Third-Party Beneficiary – This Agreement shall not create any right in any individual or entity that is not a Party hereto or in the public as a third-party beneficiary. This Agreement shall not be construed to authorize any such third party to initiate or to maintain a suit in law or equity or other administrative proceeding.

33.13 No Commitment of Funds – Nothing in this Agreement shall be construed as obligating any federal, tribal, state, or local agency to expend in any fiscal year any sum in excess of appropriations made by Congress, tribal councils, or state or local legislatures; administratively allocated for the purpose of this Agreement for the fiscal year or to involve any federal, tribal, state, or local agency in any contract or obligations for the future expenditure of money in excess of such appropriations or allocations.

33.14 No Government Agency Delegation – Nothing in this Agreement shall be construed as requiring or involving the delegation by any governmental agency to any other body of any authority entrusted to it by Congress, tribal council, or by the legislature of any state.

33.15 Successors and Assigns – This Agreement shall apply to, and be binding on, the Parties and their successors and assigns. No change in ownership of or transfer of the New License for the Project, or any of its developments shall in any way modify or otherwise affect any Party's interests, rights, responsibilities, or obligations under this Agreement. Unless prohibited by applicable law, the Licensee of the Project shall provide that, in any transfer of the Existing or New License for the Project, such subsequent licensee shall be bound by, and shall assume the rights and obligations of, this Agreement upon completion of the change of ownership and, as applicable, approval by the FERC of the license transfer. The Licensee shall provide notice to the other Parties at least 90 days prior to completing such transfer of the Existing or New License. Notwithstanding the foregoing provisions of this Section, if any subsequent licensee is only partially bound by the terms of this Agreement, any Party that believes that it is substantially negatively affected by the fact that the subsequent licensee is only partially bound by this Agreement may initiate withdrawal from this Agreement pursuant to the procedures established in Section 21.0. If arbitration is initiated, withdrawal shall be allowed only if the arbitrator determines that: (i) the withdrawing Party substantially complied with all procedural prerequisites to withdrawal specified in this Agreement; and (ii) the fact that the subsequent licensee is only partially bound by this Agreement substantially negatively affects the withdrawing Party.

33.16 Damages – Damages at law are an inadequate remedy to redress any prospective or continuing breach of this Agreement and any Party shall be entitled to specific performance only regarding such breach, and no Party may bring an action seeking monetary damages but shall be limited to seeking specific performance, injunctive, or declaratory relief. This Section shall not be construed to prohibit any Party from receiving money in settling any claim arising from a prospective or continuing breach.

33.17 Limitation of Applicability – This Agreement is made on the express understanding that it constitutes a negotiated settlement of issues specific to the Project. No Party shall be deemed, by virtue of execution of this Agreement, to have established precedent, or admitted or consented to any fact, opinion, approach, methodology, or principle except as expressly provided herein. In the event this Agreement is approved by the FERC, such approval shall not be deemed precedential or controlling regarding any particular issue or contention in any other proceeding.

33.18 Execution in Counterparts – This Agreement may be executed in separate counterparts, with each counterpart deemed to be an original having the full force and effect thereof, but with all such counterparts, taken together, constituting but one and the same document.

33.19 Full Legal Authority – Each Party to this Agreement represents that it has the full legal authority to execute this Agreement and that its signatory is authorized to bind the Party (principal) that it represents, and that by such representative's signature, such principal shall be bound upon full execution of this Agreement.

33.20 Timing – In various places throughout this Agreement, the following phrase related to timing of actions appears: "*within ___ year(s) following the issuance of the New License, the end of all appeals, and the closure of all rehearing and administrative challenge periods*." The Parties acknowledge and agree that this phrase is intended to define the end of all periods during which someone may contest the validity of the New License or the 401 WQC, and it is further intended to make clear that certain required actions, described by this phrase, do not become requirements obligating Parties to act until all opportunities to contest or appeal the New License or the 401 WQC have come to a complete and final end.

SIGNATURES OF THE PARTIES

DUKE ENERGY CAROLINAS, LLC

By: ______________________________ 11/20/13

Steven D. Jester (Date)
Vice President
Water Strategy, Hydro Licensing & Lake Services

ADVOCATES FOR QUALITY DEVELOPMENT, INC.

By: Joseph M. Smith 11/20/13

Joseph M. Smith
President

(Date)

ANDERSON AREA CHAMBER OF COMMERCE

By: ______________________________ 11-20-13

Howard D. Spencer (Date)

CITY OF SENECA

By: ______________________ 11-20-13

Gregory P. Dietterick (Date)
City Administrator

By: ______________________ 11/20/13

Robert W. Faires, III (Date)
Director of Utilities

COMMISSIONERS OF PUBLIC WORKS OF THE CITY OF GREENVILLE

By: ______________________________ 11-20-13

David Bereskin (Date)
Chief Executive Officer

FRIENDS OF LAKE KEOWEE SOCIETY, INC.

By: ________________________ 11/20/2013

Ben Turetzky (Date)
Executive Director

OCONEE COUNTY, SOUTH CAROLINA

By: ______________________________ ______________________
Joel Thrift, Chairman (Date)
Oconee County Council

PICKENS COUNTY, SOUTH CAROLINA

By: ______________________________ ______________________

G. Neil Smith, Chairman (Date)
Pickens County Council

PICKENS COUNTY WATER AUTHORITY

By: William H. Smith, Jr.   20 Nov 2013

William H. Smith, Jr.
Chairman

(Date)

SOUTH CAROLINA DEPARTMENT OF ARCHIVES AND HISTORY

By: W. Eric Emerson 11-21-13

Dr. W. Eric Emerson
Director

(Date)

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

By: ______________________________ 11-18-13

Alvin A. Taylor
Director

(Date)

SOUTH CAROLINA DEPARTMENT OF PARKS, RECREATION AND TOURISM

By: Duane Parrish 11/20/13

Duane Parrish (Date)
Director

SOUTH CAROLINA WILDLIFE FEDERATION

By: ______________________ 20 Nov 2013

Wes Cooler (Date)

By: ______________________ 20 Nov 2013

Dave Hargett (Date)

THE CLIFFS AT KEOWEE VINEYARDS COMMUNITY ASSOCIATION, INC.

By: ______________________ ______________
Jim Burgner (Date)

By: ______________________ ______________
R. A. McGimpsey (Date)
President

THE RESERVE AT LAKE KEOWEE

By: C. A. Niemeyer [signature] 11-20-13

C. A. Niemeyer
Keowee River Club, LLC, Owner and Developer
(Date)

By: A. J. Thompson [signature] 11/20/13

A. J. Thompson
Keowee River Club, LLC, Owner and Developer
(Date)

UPSTATE FOREVER

By: [signature] 11-20-2013

Brad Wyche (Date)
Executive Director

By: [signature] 11-20-2013

Van Whitehead (Date)
Deputy Director

WARPATH DEVELOPMENT, INC.

By: ______________________ 11-20-13

Tim Roberson (Date)

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APPENDIX A

PROPOSED LICENSE ARTICLES

This Agreement represents a balance of many interests and is the culmination of years of negotiation by the Parties. While the Parties recognize the FERC is not constrained by this Agreement, the Parties wish to emphasize that, if the FERC acts inconsistently with this Agreement, it may result in the withdrawal from this Agreement of one or more Parties and could result in the termination of this Agreement. To avoid that result, the Parties respectfully request the following proposed License Articles in this Appendix A be incorporated without material modification into any New License the FERC may issue for the project and that the New License term be at least 40 years.

A-1.0 Reservoir Elevation Article

ARTICLE – Reservoir Elevations

(A) Reservoir Elevations – Within 60 days following the issuance of this license, to protect and enhance the project's values that may be affected by reservoir level fluctuations, the Licensee shall maintain the elevations of the project reservoirs between the Normal Minimum and Normal Maximum Elevations indicated in the table below.

Reservoir	Normal Maximum Elevation (ft local datum / ft AMSL)	Normal Minimum Elevation (ft local datum / ft AMSL)
Lake Jocassee	**100.0 / 1110.0**	**86.0 / 1096.0**
Lake Keowee	**100.0 / 800.0**	**96.0 / 796.0**

(B) Temporary Variances – The reservoir elevation requirements outlined in Paragraph (A) above may be temporarily modified if required by conditions beyond the control of the Licensee, for short periods during annual inspection and repairs, or by operating emergencies or maintenance needs as defined in the Commission-approved Low Inflow Protocol (LIP) or Maintenance and Emergency Protocol (MEP). When implementing the LIP or MEP, the Licensee shall notify the Commission of modifications to the reservoir elevation requirements in accordance with the requirements of the LIP or MEP. For all other modifications in reservoir elevation requirements, the Licensee shall notify the Commission as soon as possible, but no later than 10 days after each event and shall provide the reason for the change in reservoir levels.

END OF PROPOSED LICENSE ARTICLE

A-2.0 Low Inflow Protocol Article

ARTICLE – Low Inflow Protocol for the Keowee-Toxaway Hydroelectric Project

(A) The Low Inflow Protocol (LIP) for the Keowee-Toxaway Hydroelectric Project filed with the license application as Appendix D of the Relicensing Agreement is approved and incorporated into this license and the Licensee shall implement the LIP.

(B) The Licensee may modify the LIP in accordance with the procedures in the LIP. The Licensee may also make temporary modifications to the LIP to account for any changed physical conditions at the Keowee and Jocassee developments. The Licensee shall notify the Commission of any such modifications in accordance with the LIP. Any modifications may be subject to Commission approval.

END OF PROPOSED LICENSE ARTICLE

A-3.0 Maintenance and Emergency Protocol Article

ARTICLE – Maintenance and Emergency Protocol for the Keowee-Toxaway Hydroelectric Project

Hydroelectric Project

(A) The Maintenance and Emergency Protocol (MEP) for the Keowee-Toxaway Hydroelectric Project filed with the license application as Appendix E of the Relicensing Agreement is approved and incorporated into this license and the Licensee shall implement the MEP.

(B) The Licensee may make minor changes as necessary to the MEP for the Keowee-Toxaway Hydroelectric Project. The Licensee may also make temporary modifications to the MEP to account for any changed physical conditions at the Jocassee and Keowee developments. The Licensee shall notify the Commission of any such temporary modifications in accordance with the MEP. Any modifications may be subject to Commission approval.

END OF PROPOSED LICENSE ARTICLE

A-4.0 Historic Properties Article

ARTICLE – Historic Properties

The Licensee shall implement any existing Programmatic Agreement for the project regarding Historic Properties management and protection including, but not limited to, the Historic Properties Management Plan (HPMP) for the project. In the event that the Programmatic Agreement is terminated, the Licensee shall continue to implement the provisions of its approved HPMP. The Commission reserves the authority to require changes to the HPMP at any time during the term of the license.

END OF PROPOSED LICENSE ARTICLE

A-5.0 Public Recreation Articles

ARTICLE – Recreation Management Plan

(A) The Recreation Management Plan (RMP) filed with the license application is approved and incorporated into this license and the Licensee shall implement the RMP.

(B) For the first 10 years following the issuance of this license, the Licensee shall file with the Commission by March 1 of each year a report of the progress made by the Licensee on completing the measures in the RMP during the previous calendar year.

(C) The Commission reserves the right to require changes to the RMP and the Licensee shall implement the changes.

END OF PROPOSED LICENSE ARTICLE

ARTICLE – Recreation Planning

(A) No later than September 1, 2031, the Licensee shall consult with the South Carolina Department of Parks, Recreation and Tourism (SCDPRT) and the South Carolina Department of Natural Resources (SCDNR) to develop a plan to conduct a Recreation Use and Needs Study. The Recreation Use and Needs Study shall include at least the following: (1) a review of existing recreation resources, (2) an analysis of recreational use at the Project Access Areas and the need for additional recreation amenities, (3) a review of agency current recreation and/or land use management plans relevant to the project, and (4) a discussion of the need for any changes to the Recreation Management Plan.

(B) The Licensee shall complete the Recreation Use and Needs Study no later than December 31, 2032, and provide a draft of the study report to the agencies in Paragraph (A) for review and comment. The Licensee shall allow at least 30 days for the agencies to review and comment. The Licensee shall file the report with the Commission for approval and include documentation of consultation including copies of comments and recommendations on the draft report.

(C) Based upon the results of any Recreation Use and Needs Study conducted in accordance with Paragraph (B), the Licensee shall file a revised and updated Recreation Management Plan (RMP) no later than December 31, 2033. The Licensee shall include with its RMP documentation of consultation with the above agencies, local governments and other interested parties; copies of comments and recommendations on the draft RMP; and specific descriptions of how the agencies', local governments', and other interested parties' comments and recommendations are accommodated by the draft new RMP. The Licensee shall allow a minimum of 30 days for the agencies, local governments, and other interested parties to comment on the draft revised and updated RMP prior to filing it with the Commission for approval. If the Licensee does not adopt a recommendation, the filing shall include the Licensee's reasons.

(D) The Commission reserves the right to require changes to any revised and updated RMP developed in accordance with the above. The Licensee shall implement any revised and updated RMP as approved by the Commission, including any changes required by the Commission.

END OF PROPOSED LICENSE ARTICLE

A-6.0 Shoreline Management Articles

ARTICLE – Shoreline Management Plan

(A) The Shoreline Management Plan (SMP) filed with the license application is approved and incorporated into this license and the Licensee shall implement the SMP.

(B) The Licensee may make minor changes to the Shoreline Management Guidelines (SMG) and the Shoreline Classification Maps and associated Lake Use Restrictions to protect newly discovered resources such as archaeological or historic sites, Threatened or Endangered Species, Special Concern Species, or to correct mapping errors. The Commission reserves the right to review such changes.

(C) The Commission may require changes to the SMP at any time during the term of this license.

END OF PROPOSED LICENSE ARTICLE

ARTICLE – Shoreline Management Plan Review and Update Procedures

(A) At ten years following the issuance of this license, and every ten years thereafter for the term of this license, the Licensee shall file with the Commission, for approval, a revised Shoreline Management Plan (SMP). In developing the revised SMP, the Licensee shall, at least one year prior to the due date for each revised SMP submittal, convene and consult with a workgroup consisting of the South Carolina Department of Parks, Recreation and Tourism, the South Carolina Department of Natural Resources, and the U.S. Fish and Wildlife Service to review the implementation of the SMP and to recommend potential modifications. The Licensee shall include with the revised SMP filing documentation of consultation with the above agencies; copies of comments and recommendations on the revised SMP, after it has been prepared and provided to the agencies; and specific descriptions of how comments and recommendations received are accommodated by the revised SMP. The Licensee shall allow a minimum of 30 days for the agencies participating in the workgroup to comment prior to filing the revised SMP with the Commission for approval. If the Licensee does not adopt a recommendation, the revised-SMP filing shall include the Licensee's reasons.

(B) The Commission reserves the right to require changes to any revised and updated SMP developed in accordance with the above. The Licensee shall implement any revised and updated SMP as approved by the Commission, including any changes required by the Commission.

END OF PROPOSED LICENSE ARTICLE

A-7.0 Water Quality Article

ARTICLE – Water Quality Monitoring

(A) During the first full month of August occurring at least 60 days following issuance of this license and during every subsequent August for the term of this license, the Licensee shall continuously monitor dissolved oxygen concentrations in both the Keowee Hydro Station and Jocassee Pumped Storage Station tailwaters to demonstrate compliance with South Carolina's water quality certification.

(B) The Licensee shall submit the results obtained from this annual monitoring to the Commission and the South Carolina Department of Health and Environmental Control each year by November 30.

END OF PROPOSED LICENSE ARTICLE

(intentionally blank)

APPENDIX B: PARTIES AND DESIGNATED REPRESENTATIVES

Party[1]	Designated Representative	Mailing Address	Overnight Express Address
Duke Energy Carolinas, LLC and Duke Energy Corporation	Jennifer R. Huff Keowee-Toxaway Hydro Project Licensing Manager	Duke Energy PO Box 1006 Mail Code EC12Y Charlotte, NC 28201	Duke Energy 526 S. Church St Mail Code EC12Y Charlotte, NC 28202
Advocates for Quality Development, Inc.	Chuck Smith	PO Box 802 Seneca, SC 29679	211 N Harbour Drive Seneca, SC 29672-6822
Anderson Area Chamber of Commerce	Howard D. Spencer	1719 Circle Road Powdersville, SC 29642	1719 Circle Road Powdersville, SC 29642
City of Seneca	Bob Faires	PO Box 4773 Seneca, SC 29679	225 E North 1st Street Seneca, SC 29679
Friends of Lake Keowee Society, Inc.	Ben Turetzky Executive Director	4065 Keowee School Road Seneca, SC 29672	4065 Keowee School Road Seneca, SC 29672
Greenville Water	David Bereskin	PO Box 687 Greenville, SC 29602	406 W. Broad Street Greenville, SC 29601
Oconee County, SC	Art Holbrooks	415 S. Pine Street Walhalla, SC 29691	415 S. Pine Street Walhalla, SC 29691
Pickens County, SC	Chris Brink	222 McDaniel Avenue, B-10 Pickens, SC 29671	222 McDaniel Avenue, B-10 Pickens, SC 29671

[1] These entities are Parties to this Agreement provided their duly authorized representatives sign this Agreement. All Parties shall notify the Licensee of changes to the contact information for the Party's Designated Representative.

Party[1]	**Designated Representative**	**Mailing Address**	**Overnight Express Address**
Pickens County Water Authority	Steve Jewsbury	222 McDaniel Avenue, B-1 Pickens, SC 29671	222 McDaniel Avenue, B-1 Pickens, SC 29671
South Carolina Dept. of Archives and History	Elizabeth M. Johnson Director, Historical Services, D-SHPO	8301 Parklane Rd. Columbia, SC 29223	8301 Parklane Rd. Columbia, SC 29223
South Carolina Dept. of Natural Resources	Bill Marshall	P.O. Box 167 Columbia, SC 29202	1000 Assembly Street Columbia, SC 29202
South Carolina Dept. of Parks, Recreation and Tourism	Phil Gaines	1205 Pendleton Street Columbia, SC 29201	1205 Pendleton Street Columbia, SC 29201
South Carolina Wildlife Federation	Ben Gregg Executive Director	2711 Middleburg Dr, Ste 101 Columbia, SC 29204	2711 Middleburg Dr, Ste 101 Columbia, SC 29204
The Cliffs at Keowee Vineyards Community Association, Inc.	Jim Burgner	309 Wake Robin Drive Sunset, SC 29685-2247	309 Wake Robin Drive Sunset, SC 29685-2247
The Reserve at Lake Keowee	Tony Niemeyer	100A Village Green Loop Sunset, SC 29685	100A Village Green Loop Sunset, SC 29685
Upstate Forever	Van Whitehead	507 Pettigru Street Greenville, SC 29601	507 Pettigru Street Greenville, SC 29601
Warpath Development, Inc.	Tim Roberson	335 Blue Water Way West Union, SC 29696	335 Blue Water Way West Union, SC 29696

APPENDIX C: ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

1968 Agreement	An agreement between the Licensee, the US Army Corps of Engineers, and Southeastern Power Administration that attempts to balance usable water storage between the Project and the USACE's Hartwell and J. Strom Thurmond hydroelectric projects
401 WQC	401 Water Quality Certification
AAII	Access Area Improvement Initiative
ac	acre(s)
ac-ft	acre-feet
ADA	Americans with Disabilities Act
AIP	Agreement-in-Principle
AMSL	above mean sea level
AQD	Advocates for Quality Development, Inc.
°C	degrees Celsius
cfs	cubic feet per second
Commercial Recreation Area	Recreation areas provided and maintained by the private sector not including the Licensee, which are available to the general public
Critical Reservoir Elevation	Unless otherwise defined herein, the level of water in a reservoir (measured in ft AMSL or ft relative to the full pond contour with 100.0 ft corresponding to full pond) below which any Large Water Intake used for public water supply, industrial water supply or regional power plant water supply located on the reservoir will not operate at its Licensee-approved capacity
CWG	Clean Water Group
DCP	Drought Contingency Plan: the plan used by the USACE to manage water quantity in the USACE Reservoirs in the Savannah River Basin during drought
DMAG, KT-DMAG	Keowee-Toxaway Drought Management Advisory Group
DO	dissolved oxygen
EAP	Emergency Action Plan
EBCI	Eastern Band of Cherokee Indians

Existing License	License document issued to the Licensee for the Keowee-Toxaway Hydroelectric Project (FERC Project No. 2503) with an effective date of September 1, 1966, and including all license amendments since that time, with requirements relative to the Licensee's operation of the Project through the license expiration date of August 31, 2016, and as extended by an annual license(s)
°F	degrees Fahrenheit
FERC or Commission	Federal Energy Regulatory Commission (Note: The FERC refers to itself in license articles, other documents, and conversation as the "Commission.")
FOLKS	Friends of Lake Keowee Society, Inc.
Form 80	Licensed Hydropower Development Recreation Report: a form submitted by licensees to the FERC providing data on recreation amenities at FERC-licensed hydropower projects; Form 80 submittals required every six years beginning in 2015
ft	foot / feet
Full Pond Elevation	The level of a reservoir corresponding to the point at which water would first begin to spill from the reservoir's dam(s) or exceed the safety margin for a reservoir's dam(s) if the Licensee took no action; the level corresponds to the lowest point along the top of the floodgates for both Lake Jocassee and Lake Keowee
GA	Georgia
GW or Greenville Water	Legally known as the Commissioners of Public Works of the City of Greenville
HEP	Habitat Enhancement Program
Historic Properties	Sites, buildings, and structures included in or eligible for inclusion in the National Register of Historic Places
HPMP	Historic Properties Management Plan
Inconsistent Act	Any action by a Jurisdictional Body that increases the burden upon or cost or risk to a Party substantially beyond the burden, cost, or risk assumed by the Party in this Agreement, or deprives a Party of a substantial benefit promised by another Party in this Agreement, such as by relieving another Party of a substantial bargained-for obligation
Jurisdictional Body	A governmental body that has the authority to place requirements on the Licensee in accordance with statutory mandates (e.g., FERC, USFWS, NMFS, SCDHEC)
KT	Keowee-Toxaway
KT Basin	Keowee-Toxaway River Basin

Large Water Intake	Any water intake (e.g., public water supply, industrial, agricultural, power plant, irrigation, etc.) having a maximum instantaneous capacity greater than or equal to one million gallons per day (MGD)
Large Water Intake owner	The owner of a Large Water Intake (e.g., Greenville Water, City of Seneca, Licensee, etc.)
Licensee	Duke Energy Carolinas, LLC
Licensee's Reservoirs	Bad Creek Reservoir, Lake Jocassee, and Lake Keowee
LIP	Low Inflow Protocol; the plan used by the Licensee and others to manage water quantity in the Licensee's Reservoirs in the Savannah River Basin during drought
MEP	Maintenance and Emergency Protocol
MGD	million gallons per day
mg/L	milligrams per liter
MLCA	Mountain Lakes Community Association
MOA	memorandum of agreement
NC	North Carolina
NCSHPO	NC State Historic Preservation Office
New License	The license anticipated to be issued by the FERC to replace the Existing License
NMFS	National Marine Fisheries Service
NOA	New Operating Agreement; an agreement anticipated to replace the 1968 Agreement between the Licensee, USACE, and SEPA regarding required flow releases from the Keowee Development into the USACE's Hartwell Project
Normal Maximum Elevation	The level of a reservoir (measured in ft AMSL or feet relative to the full pond contour with 100.0 ft corresponding to full pond) that defines the top of the reservoir's Normal Operating Range for a given day of the year
Normal Minimum Elevation	The level of a reservoir (measured in ft AMSL or feet relative to the full pond contour with 100.0 ft corresponding to full pond) that defines the bottom of the reservoir's Normal Operating Range for a given day of the year
Normal Operating Range	The band of reservoir levels, between the Normal Maximum and Normal Minimum Elevations, within which the Licensee normally attempts to maintain a given reservoir on a given day
NRHP	National Register of Historic Places

ONS	Oconee Nuclear Station
Park	Recreation areas provided and maintained by a county or state government which are available to the general public
PRC	Proposal Review Committee
Priority Species	Species given a priority status by the SCDNR's Comprehensive Wildlife Conservation Plan
Project	Keowee-Toxaway Hydroelectric Project
Project Access Area	Recreation land owned by the Licensee within the Project Boundaries which is available to the general public
Project Boundary (ies)	The line(s) demarking lands designated by the FERC as necessary for operation of the Project and therefore subject to FERC jurisdiction
Project Reservoirs	Lake Keowee and Lake Jocassee
RA or Agreement	Relicensing Agreement
RMP	Recreation Management Plan
RTE	Rare, Threatened or Endangered
RUN	Recreation Use and Needs
SC	South Carolina
SCDHEC	SC Department of Health and Environmental Control
SCDNR	SC Department of Natural Resources
SCDPRT	SC Department of Parks, Recreation and Tourism
SCSHPO	SC State Historic Preservation Office
SCWF	South Carolina Wildlife Federation
Seneca or Seneca Light & Water	City of Seneca
SEPA	Southeastern Power Administration
SHPO	State Historic Preservation Office
SMG	Shoreline Management Guidelines

SMP	Shoreline Management Plan: the Licensee's process for evaluating requests for lake use permits which includes the following components: digital orthographic aerial photography; GPS-based geo-videography; consultation materials; process for challenges to shoreline classification; Structure Renovation / Removal Process; riparian zone management information; Shoreline Stabilization Technique Selection Process ("SSTSP"); consultation process with the EBCI; True Public Marina requirements; SMG; and Shoreline Classification Maps and Lake Use Restrictions
Special Status Species	State- and federally listed RTE species and others listed as Species of Concern and Special Concern Species
SWPP	Source Water Protection Program
TBD	to be determined
THPO	Tribal Historic Preservation Office
True Public Marina	A commercial recreation area that provides for the public's use of Project lands and waters with facilities where boats can be launched, retrieved, or moored and where activities customarily associated with marinas are provided to the general public with no predetermination of user groups for the use of any of the land or water-based facilities, no membership requirements, and transient services (e.g., use of gas dock, restrooms, or pump-out facilities) do not require wet slip or dry storage rental
Upper Savannah River Basin	The portion of the Savannah River Basin draining into J. Strom Thurmond Lake
U.S. or US	United States
USACE	U.S. Army Corps of Engineers
USACE Reservoirs	Hartwell Lake, Richard B. Russell Lake, and J. Strom Thurmond Lake
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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APPENDIX D

LOW INFLOW PROTOCOL (LIP) FOR THE KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

Purpose

To establish a joint management plan that Duke Energy Carolinas, LLC (Licensee); Seneca Light & Water (Seneca), Greenville Water (GW), any public water suppliers that add Large Water Intakes withdrawing water from Project Reservoirs (Jocassee and Keowee); and any public water suppliers with Large Water Intakes on the U.S. Army Corps of Engineers' (USACE) Reservoirs (Hartwell, Russell and Thurmond) that choose to participate, will follow in response to drought conditions.

Key Facts and Assumptions

1. Importance of Human Health and Safety and the Integrity of the Public Water Supply and Electric Systems – Nothing in this LIP will limit the Licensee's ability to take any and all lawful actions necessary at the Keowee-Toxaway Hydroelectric Project ("Project") to protect human health and safety, to protect its equipment from damage, to ensure the stability of the regional electric grid, to protect the equipment of the Large Water Intake owners from damage, and to ensure the stability of public water supply systems; provided that nothing in the Relicensing Agreement (RA) or LIP obligates the Licensee to take any actions to protect the equipment of Large Water Intake owners from damage or to ensure the stability of public water supply systems. It is recognized that the Licensee may provide this protection without prior consultation or notification.

2. This LIP is intended to support management of the Licensee's Reservoirs (Bad Creek, Jocassee and Keowee) in the Upper Savannah River Basin for the Licensee's operations, while meeting the water resource needs of the public.

3. As of the date of this LIP, only five entities have Large Water Intakes withdrawing water from the Project. GW and Seneca are public water suppliers. The Licensee's Large Water Intake at Oconee Nuclear Station (ONS) is used for thermal power plant cooling. The Reserve at Lake Keowee and The Cliffs Club at Keowee Vineyards, LLC each use Large Water Intakes for irrigation. The Reserve at Lake Keowee and The Cliffs Club at Keowee Vineyards, LLC have easements with clauses permitting the Licensee to require water conservation measures during droughts.

4. Any public water supplier owning a Large Water Intake that intends to locate a new intake, expand an existing intake, or rebuild an existing intake on Lake Keowee will be required to abide by the applicable portions of this LIP, except as provided for in existing agreements (e.g., easements, leases, lake use permits or other written agreements) between the Large Water Intake owner and the Licensee.

5. Nothing in this LIP amends or replaces any other contract or agreement to which the Licensee and/or any other Large Water Intake owner is a party.

6. Revising the LIP – During the term of the New License, the Keowee-Toxaway Drought Management Advisory Group (KT-DMAG) will periodically review and recommend updates to the LIP to ensure continuous improvement of the LIP and its implementation. These evaluations and modifications will be considered at least

once every ten (10) years during the New License term. Any modifications must be approved by the Licensee and all of the applicable public water suppliers with Large Water Intakes on Project Reservoirs. If such unanimous approval cannot be reached, then the dispute resolution procedures set forth in the RA will apply. Approved modifications will be incorporated through revision of the LIP, and the Licensee will file the revised LIP with the Federal Energy Regulatory Commission (FERC). If any modifications of the LIP require amendment of the New License, the Licensee will: (i) provide notice to all Parties to the RA, pursuant to Section 23.0 of the RA, advising them of the New License amendment and the Licensee's intent to file it with the FERC; (ii) submit a modification request to the South Carolina Department of Health and Environmental Control (SCDHEC) for formal review and approval if required; and (iii) file a license amendment request for FERC approval if required. The filing of a revised LIP by the Licensee will not constitute or require modification of the RA, and any Party to the RA may be involved in the FERC's or SCDHEC's public processes for assessing the revised LIP, but may not oppose any part of a revised LIP that is consistent with the LIP included in the RA.

7. <u>Transitioning to a Lower Critical Reservoir Elevation on Lake Keowee</u> – The Licensee will operate in accordance with the provisions of the LIP, except Lake Keowee's Critical Reservoir Elevation will remain at or above 94.6 ft local datum / 794.6 ft above Mean Sea Level (AMSL) until December 1, 2019, to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. The Licensee may also, in its sole discretion, decide to maintain Lake Keowee's Critical Reservoir Elevation at or above 94.6 ft local datum / 794.6 ft AMSL until both of the following are complete:

   a. A New License that is consistent with the RA has been issued, the end of all appeals, and all rehearing and administrative challenge periods have closed; and

   b. The Licensee, the USACE, and the Southeastern Power Administration (SEPA) have signed a New Operating Agreement (NOA) that is not inconsistent with the RA.

8. The following table provides storage volumes at various lake elevations in the Licensee's Reservoirs. Data for the Bad Creek Reservoir are from original licensing data. Data for Lakes Jocassee and Keowee are from a 2010 bathymetric study performed by the Licensee. These data are for planning purposes and not of physical survey quality.

Reservoir	Elevations (ft local datum / ft AMSL)		Storage Increment (ac-ft)	Storage Increment (%)
	Elevation From	Elevation To		
Bad Creek	100.0 / 2310	-60.0 / 2150	30,229	
		Total Bad Creek	30,229	7
Jocassee	100.0 / 1110	86.0 / 1096	108,738	
	86.0 / 1096	82.0 / 1092	30,000	
	82.0 / 1092	77.0 / 1087	36,687	
	77.0 / 1087	73.0 / 1083	28,730	
	73.0 / 1083	70.0 / 1080	21,233	
		Total Jocassee	225,387	54
Keowee	100.0 / 800.0	96.0 / 796.0	67,636	
	96.0 / 796.0	95.0 / 795.0	16,249	
	95.0 / 795.0	94.6 / 794.6	6,434	
	94.6 / 794.6	93.0 /793.0	25,368	
	93.0 / 793.0	92.0 / 792.0	15,565	
	92.0 / 792.0	91.5 / 791.5	7,700	
	91.5 / 791.5	90.0 / 790.0	22,775	
		Total Keowee	161,727	39
Total for Licensee's Reservoirs			417,343	100

Definitions

1. Critical Reservoir Elevation – Unless otherwise defined herein, the Critical Reservoir Elevation is the level of water in a reservoir (measured by reference to local datum or in ft AMSL) below which any Large Water Intake used for public water supply, industrial water supply, or any regional power plant water supply located on the reservoir will not operate at its Licensee-approved capacity. The Critical Reservoir Elevations are:

Reservoir	Critical Reservoir Elevation (ft local datum / ft AMSL)	Type of Limit
Lake Keowee	90.0[1] / 790.0[1]	Power Production
Lake Jocassee	70.0 / 1080.0	Power Production
Bad Creek	-60.0 / 2150.0	Power Production

Note 1 – This new Critical Reservoir Elevation will become effective December 1, 2019, to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. See Item 7 under Key Facts and Assumptions for guidance prior to converting to this new Critical Reservoir Elevation.

2. Total Usable Storage – For the Licensee's Reservoirs (Keowee, Jocassee, and Bad Creek), Total Usable Storage is the sum of the volume of water contained between

each reservoir's Critical Reservoir Elevation and its Full Pond Elevation, expressed in acre-feet (ac-ft). For the USACE Reservoirs in the Upper Savannah River Basin (Hartwell, Richard B. Russell, and J. Strom Thurmond), Total Usable Storage is the sum of the volume of water contained between each reservoir's bottom-of-power-pool elevation (top of inactive pool) and the guide curve elevation denoting the top of conservation storage for any particular time of year, expressed in ac-ft.

3. Remaining Usable Storage – The sum of the volume of water contained between each reservoir's Critical Reservoir Elevation and the actual reservoir elevation at any given point in time, expressed in ac-ft, for the Licensee's Reservoirs. The Remaining Usable Storage calculation for the Licensee's Reservoirs is based on a maximum drawdown elevation of 90 ft local datum / 790 ft AMSL for Lake Keowee, a maximum drawdown elevation of 70 ft local datum / 1080 ft AMSL for Lake Jocassee, and a maximum drawdown elevation of -60 ft local datum / 2150 ft AMSL for the Bad Creek Reservoir. For the USACE Reservoirs in the Upper Savannah River Basin (Hartwell, Richard B. Russell, and J. Strom Thurmond), Remaining Usable Storage is the sum of the volume of water contained between each reservoir's bottom-of-power-pool elevation (top of inactive pool) and the actual elevation, expressed in ac-ft.

4. Storage Index – The ratio, expressed in percent, of Remaining Usable Storage to Total Usable Storage at any given point in time.

5. Large Water Intake – Any water intake (e.g., public water supply, industrial, agricultural, power plant, irrigation, etc.) having a maximum instantaneous capacity greater than or equal to one million gallons per day (MGD).

6. Keowee-Toxaway Drought Management Advisory Group (KT-DMAG) – The KT-DMAG is a voluntary advisory group to be formed and tasked with working with the Licensee when the LIP is initiated. This KT-DMAG will also meet as necessary to foster a basin-wide response to a Low Inflow Condition (see Specific Actions at Each LIP Stage). The KT-DMAG will consist of a representative from each of the following organizations that decides to form or join the KT-DMAG. By agreeing to form or join the KT-DMAG, each Member agrees to comply with all applicable requirements of this LIP. Each KT-DMAG Member may have a primary representative and an alternate representative, who may act in the absence of the primary representative.

   a. SC Department of Natural Resources (SCDNR);
   b. SCDHEC;
   c. US Geological Survey (USGS);
   d. USACE;
   e. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on the Project Reservoirs;
   f. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on any tributary stream within the Keowee-Toxaway River Basin that ultimately drains to Lake Keowee and that agrees to coordinate its drought planning and management under the KT-DMAG;
   g. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on the USACE Reservoirs that agrees to coordinate its drought planning and management under the KT-DMAG; and
   h. Licensee (KT-DMAG Coordinator).

Members of the KT-DMAG will adopt a Charter to guide the operation of the KT-DMAG, as set forth in part below, and said Charter will require KT-DMAG Members to comply with the applicable requirements of this LIP. The KT-DMAG will meet at least annually (typically during the month of June), beginning in 2014 and continuing throughout the term of the New License, regardless of the Low Inflow Condition status, to review prior year activities, discuss data input from public water suppliers that are Large Water Intake owners, and discuss other issues relevant to the LIP. The Licensee will lead the formation of the KT-DMAG, will call meetings and set agendas, and will maintain an active roster of the KT-DMAG and update the roster as needed. The Licensee will prepare meeting summaries of all KT-DMAG meetings, make these meeting summaries available to the public by posting on its website, and notify Parties to the RA without specific responsibilities under the LIP of the availability of information on the current LIP status and possible actions.

Basic Responsibilities

Licensee's Responsibilities

The Licensee accepts the following basic responsibilities in furtherance of this LIP.

1. Monitor the following drought triggers and relevant data at least monthly or as specified for each LIP Stage.
    - Remaining Usable Storage in the Licensee's Reservoirs
    - Composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC (USGS Gage # 02186000); Chattooga River near Clayton, GA (USGS Gage # 02177000); French Broad River near Rosman, NC (USGS Gage # 03439000))
    - U.S. Drought Monitor for the Upper Savannah River Basin (i.e., from Thurmond Dam upstream)
    - Composite average of the Licensee's rainfall gauge readings at the Jocassee Pumped Storage Station, Keowee Hydro Station, and the Bad Creek Project
    - Oconee County USGS groundwater gage (USGS Gage # 345051083041800 OC-233) (Note: Data from other groundwater gages can be added in the future if beneficial.)
    - Remaining Usable Storage in the USACE Reservoirs downstream
    - USACE Savannah River Basin drought status
2. Coordinate KT-DMAG meetings including those noted for the particular drought stage. Provide to the KT-DMAG trigger updates, composite rainfall gauge readings, and operational and meteorological projections. Meetings can be in person, telephonic or by use of other appropriate communications. In consultation with KT-DMAG members, select and publicly communicate the LIP Stage based on the triggers established in this LIP.
3. Provide to the KT-DMAG the estimated water consumption rate by ONS (average for the current month and projections for the next month) and the estimated natural evaporation rate by reservoir from the Licensee's Reservoirs for the current month and projections for the next month.

4. Quantify total weekly flow releases (hydro generation, flood gate releases, hydro unit leakage, and dam seepage) made from the Keowee Development for the previous four weeks and provide to the KT-DMAG.
5. Coordinate with the USACE to make flow releases from Lake Keowee in accordance with the NOA between the Licensee, USACE, and SEPA regarding flow releases from the Keowee Development into the USACE's Hartwell Project and this LIP.
6. Depending on the LIP Stage, request voluntary or require mandatory water use restrictions for withdrawing water from the Licensee's Reservoirs to irrigate lakeside properties.
7. When operating in the LIP near Stage Minimum Elevations, except for flow releases required for ONS operations or situations covered by the Maintenance and Emergency Protocol (MEP), the Licensee will not make an intentional flow release from Keowee Dam if that flow release would reduce the level of Lake Jocassee or Lake Keowee below its Stage Minimum Elevation as specified for the applicable LIP stage.
8. When operating in the LIP, the Licensee will limit weekly flow releases from the Keowee Dam to no more than the maximum weekly flow release for the applicable LIP Stage except for flow releases required for ONS operations or situations covered in the MEP. The weekly flow release amount includes the sum of all water released downstream from the Keowee Dam (i.e., hydro unit generation plus hydro unit leakage plus dam seepage plus any flood gate releases).
9. Stage Minimum Elevations are defined for each Stage of the LIP. When a subsequent Stage of the LIP is reached, the Licensee agrees both Project Reservoirs must be within 0.25 ft of the Stage Minimum Elevation of the previous Stage of the LIP before each reservoir can be lowered to the next Stage Minimum Elevation.

Responsibilities of Large Water Intake Owners that are Public Water Suppliers

Large Water Intake owners that are public water suppliers withdrawing water from the Licensee's Reservoirs agree to the following basic responsibilities in furtherance of this LIP.

1. Provide to the Licensee current month and projections for next month's water use from the Licensee's Reservoirs and from any alternative water supply sources.
2. Provide to the Licensee an overview of system conditions related to water use from the Licensee's Reservoirs (i.e., leaks, status of alternative water sources, new or potential large water users, etc.).
3. Request or require water use restrictions from water customers and/or make greater use of alternative water sources for the purpose of reducing water withdrawals from the Licensee's Reservoirs below what those withdrawals would have been otherwise, consistent with best practices and operating principles for those Large Water Intake owners' systems in accordance with the specific actions listed in this document at each LIP stage.

LIP Stage Triggers

For the purposes of this LIP, the following triggers will define the LIP Stage.

Stage 0 (Low Inflow Watch) Drought Trigger Levels

1. Storage Index in USACE Reservoirs and Storage Index in the Licensee's Reservoirs are both less than 90% (using the Critical Reservoir Elevations defined above); and
2. One of the following triggers:
   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 0; or
   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 85% of long-term average for the previous four months.

Stage 1 Drought Trigger Levels

1. USACE implements Level 1 of its existing Drought Contingency Plan (DCP); and
2. One of the following triggers:
   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 1; or
   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 75% of long-term average for the previous four months.

Stage 2 Drought Trigger Levels

1. USACE implements Level 2 of its existing DCP; and
2. One of the following triggers:
   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 2; or
   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 65% of long-term average for the previous four months.

Stage 3 Drought Trigger Levels

1. USACE implements Level 3 of its existing DCP; and
2. One of the following triggers:
   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 3; or

b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 55% of long-term average for the previous four months.

Stage 4 Drought Trigger Levels

1. Storage Index in the Licensee's Reservoirs is less than 25%; and
2. One of the following triggers:
   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is equal to 4; or
   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 40% of long-term average for the previous four months.

Specific Actions at Each LIP Stage

Stage 0

The Licensee will:

1. Notify the KT-DMAG members and the South Carolina Department of Parks, Recreation and Tourism (SCDPRT) that LIP Stage 0 has been reached;
2. Initiate drought meetings (typically monthly) among the KT-DMAG members and any other interested water system managers;
3. Provide detailed updates to the KT-DMAG on drought triggers and other relevant data, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous four weeks;
5. Provide flow releases from Keowee Dam in accordance with the following limitations:
   a. When the Storage Index for the Licensee's Reservoirs is below 90% but greater than or equal to 85%, limit the total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 25,000 ac-ft (1800 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Normal Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP;
   b. When the Storage Index for the Licensee's Reservoirs is below 85% but greater than or equal to 80%, limit the total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 20,000 ac-ft (1440 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Normal Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
6. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will provide detailed updates to the Licensee on relevant data as noted in the Basic Responsibilities section.

Stage 1

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 1 has been reached;
2. Coordinate drought meetings (typically monthly) among the KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous four weeks;
5. Request those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties voluntarily limit their withdrawals to no more than two days per week, with the days to be specified by the Licensee;
6. Reduce the Minimum Elevation for Lake Keowee to 95.0 ft local datum / 795.0 ft AMSL (Stage 1 Minimum Elevation);
7. Reduce the Minimum Elevation for Lake Jocassee to 82.0 ft local datum / 1092.0 ft AMSL (Stage 1 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 18,750 ac-ft (1350 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 1 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 3-5% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Stage 2

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 2 has been reached;
2. Coordinate drought meetings (typically bi-weekly) among the KT-DMAG members and any other interested water system managers;

3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to limit their withdrawals to no more than two days per week, with the days to be specified by the Licensee;
6. Reduce the Minimum Elevation for Lake Keowee to 93 ft local datum / 793.0 ft AMSL (Stage 2 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 77.0 ft local datum / 1087.0 ft AMSL (Stage 2 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 15,000 ac-ft (1080 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 2 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 5-10% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

<u>Stage 3</u>

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 3 has been reached;
2. Coordinate drought meetings (typically bi-weekly) among the KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to limit their withdrawals to no more than one day per week, with the day to be specified by the Licensee;

6. Reduce the Minimum Elevation for Lake Keowee to 92.0 ft local datum / 792.0 ft AMSL (Stage 3 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 73.0 ft local datum / 1083.0 ft AMSL (Stage 3 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 10,000 ac-ft (720 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 3 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with increased emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 10-20% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

<u>Stage 4</u>

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 4 has been reached;
2. Coordinate bi-weekly (or more frequently if needed) drought meetings among KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to cease all such withdrawals;
6. Reduce the Minimum Elevation for Lake Keowee to 90.0 ft local datum / 790.0 ft AMSL (Stage 4 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 70.0 ft local datum / 1080.0 ft AMSL (Stage 4 Minimum Elevation);
8. Limit flow releases from Keowee Dam to the following:
   a. When the Storage Index for the Licensee's Reservoirs is below 25% but greater than 12%, except for flow releases required by the FERC, for ONS operations, or situations covered by the MEP, limit the total maximum weekly flow release (i.e.,

hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 7,500 ac-ft (540 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee below its Stage 4 Minimum Elevation and to maintain the level of Lake Keowee at or above 91.5 ft local datum / 791.5 ft AMSL or its Critical Reservoir Elevation, whichever is higher;

b. When the Storage Index for the Licensee's Reservoirs is at or below 12%, cease making hydro unit and floodgate flow releases, except for flow releases required by the FERC, for ONS operations, or situations covered by the MEP.

9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with increased emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee by 20-30% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Recovery from LIP Stages

Recovery under this LIP as conditions improve will be accomplished by reversing the staged approach outlined above, except the only trigger to recover from a stage is for either the storage index for the Licensee's Reservoirs or the USACE drought trigger to be exceeded for the current stage as described below. The following table provides the storage levels required for recovery from a higher numbered "Stage Y" to a lower numbered "Stage X":

Recovery from Stage Y to Stage X	**Required Storage**
From Stage 4 to Stage 3	Storage Index for the Licensee's Reservoirs is greater than or equal to 25%
From Stage 3 to Stage 2	Storage for the USACE Reservoirs recovers to amount for initial implementation[1] of Level 2 of its DCP
From Stage 2 to Stage 1	Storage for the USACE Reservoirs recovers to amount for initial implementation[1] of Level 1 of its DCP
From Stage 1 to Stage 0	Storage for the USACE Reservoirs returns to amount required for Normal operations[1]
From Stage 0 to Normal	Storage Index for the Licensee's Reservoirs is greater than or equal to 90%

Note 1 – These are USACE storage amounts that indicate when the USACE increases its drought level (Normal to 1, 1 to 2 or 2 to 3) which is not the same storage amount that indicates when USACE decreases its drought level (3 to 2, 2 to 1 or 1 to Normal). The USACE requires greater storage amounts when recovering from drought (decreasing drought levels).

APPENDIX E

MAINTENANCE AND EMERGENCY PROTOCOL (MEP) FOR THE KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

Introduction

Under some emergency, equipment failure, power plant maintenance, and other situations, certain license conditions may be impractical or even impossible to meet and may need to be suspended or modified temporarily to avoid taking unnecessary risks. The objectives of this protocol are to define the most likely situations of this type, identify the potentially impacted license conditions, and outline the general approach the Licensee will take to mitigate the impacts to license conditions and to communicate with the resource agencies and affected parties.

Note: Due to the potential variability of these situations, this protocol is not intended to give an exact step-by-step solution for all situations. It does, however, provide basic expectations for the Licensee's approach to dealing with such situations. Specific details will vary and will be determined on a case-by-case basis as the protocol is implemented.

The Licensee will review the requirements of this protocol each time it is used and may revise the MEP from time to time as noted below.

Key Facts and Definitions

1. Human Health and Safety and the Integrity of the Public Water Supply and Electric Systems – Nothing in this protocol will limit the Licensee's ability to take any and all lawful actions necessary at the Keowee-Toxaway Hydroelectric Project (Project) to protect human health and safety, to protect its equipment from damage, to ensure the stability of the regional electric grid, to protect the equipment of the Large Water Intake owners from damage, and to ensure the stability of public water supply systems; provided that nothing in the Relicensing Agreement ("RA") or MEP obligates the Licensee to take any actions to protect the equipment of Large Water Intake owners from damage or to ensure the stability of public water supply systems. It is recognized the Licensee may provide this protection without prior consultation or notification.

2. Normal Full Pond Elevation – Also referred to simply as "full pond," this is the level of a reservoir corresponding to the point at which water would first begin to spill from the reservoir's dam(s) if the Licensee took no action. This level corresponds to the lowest point along the top of the floodgates for Project Reservoirs (i.e., Lake Jocassee and Lake Keowee). To avoid confusion among the many reservoirs the Licensee operates, it has adopted the practice of referring to the Full Pond Elevation for all of its reservoirs as equal to 100.0 ft relative to local datum. The Full Pond Elevations for the Project Reservoirs are:

	Full Pond Elevation	
Reservoir	**Local Datum (ft)**	**Above Mean Sea Level (ft AMSL)**
Lake Jocassee	100.0	1110.0
Lake Keowee	100.0	800.0

3. Normal Minimum Elevation – The level of a reservoir (measured in ft AMSL, or feet relative to the full pond contour with 100.0 ft corresponding to full pond) that defines the bottom of the reservoir's Normal Operating Range for a given day of the year. If inflows and outflows to the reservoir are kept within some reasonable range of the average or expected amounts, hydroelectric project equipment is operating properly, and neither the Low Inflow Protocol (LIP) nor MEP has been implemented, reservoir level excursions below the Normal Minimum Elevation should not occur.

4. Normal Maximum Elevation – The level of a reservoir (measured in ft AMSL, or feet relative to the full pond contour with 100.0 ft corresponding to full pond) that defines the top of the reservoir's Normal Operating Range for a given day of the year. If inflows and outflows to the reservoir are kept within some reasonable range of the average or expected amounts, hydroelectric project equipment is operating properly, and neither the LIP nor MEP has been implemented, reservoir level excursions above the Normal Maximum Elevation should not occur.

5. Normal Operating Range – The band of reservoir levels within which the Licensee normally attempts to maintain a given reservoir on a given day. Each Project Reservoir has its own specific Normal Operating Range bounded by a Normal Maximum Elevation and a Normal Minimum Elevation. If inflows and outflows to the reservoir are kept within some reasonable range of the average or expected amounts, hydroelectric project equipment is operating properly and neither the LIP nor MEP has been implemented, reservoir level excursions outside of the Normal Operating Range should not occur. The New License for the Project includes the Normal Operating Ranges for the Project Reservoirs (i.e., Normal Minimum, Normal Maximum) as listed in the proposed Reservoir Elevations License Article and as follows.

Reservoir	**Normal Maximum Elevation** (ft local datum / ft AMSL)	**Normal Minimum Elevation** (ft local datum / ft AMSL)
Lake Jocassee	100.0 / 1110.0	86.0 / 1096.0
Lake Keowee	100.0 / 800.0	96.0 / 796.0

6. Returning to Normal – Some of the situations noted in this MEP can impact the Licensee's ability to operate the Project in the most efficient and safest manner for power production. The Licensee will therefore endeavor in good faith to repair existing Project equipment and facilities and return them to service within a reasonable period of time, commensurate with the severity of the equipment / facility repair requirements. If the Licensee decides that repair is not cost-effective or that hydro station or dam retirement is necessary, the Licensee will notify the Parties to the RA, pursuant to Section 23.0 of the RA and consult with them as well as with the Federal Energy Regulatory Commission (FERC) to determine any necessary modifications of the New License and / or the RA.

7. Incidental Maintenance – This is a maintenance activity at the Project works that is very brief in nature or that requires minimal if any deviation from normal license conditions and that does not require deviation from any license conditions related to prescribed flow releases from Project structures, or the Normal Operating Ranges for reservoir levels, or that is less than 72 hours in duration and will not require any excursions below any applicable Critical Reservoir Elevations. Except for the notification steps identified in the tables below for communication with resource agencies and affected parties for conditions

that impact prescribed flow releases, Incidental Maintenance is exempt from the requirements of this protocol.

8. Notification Guidance

   a. Scheduled Maintenance that Affects License Conditions – Typically, scheduled maintenance is planned in advance. Once a likely maintenance schedule has been established, the Licensee will endeavor in good faith to provide as much advance notice as possible to the affected parties identified in this protocol.

   b. Unscheduled Maintenance and Emergencies that Affect License Conditions – It is not possible for the Licensee to assure any level of advance notice. For these situations, the Licensee will endeavor in good faith to inform the affected parties identified in this protocol within some reasonable amount of time after the situation has been identified.

9. Relationship Between this MEP and the LIP – The LIP provides for reductions in Project water use and modification of the Normal Operating Ranges for reservoir levels when water demands on Project Reservoirs substantially exceed net inflow. Lowered reservoir levels caused by situations addressed under this MEP will not invoke implementation of the LIP. Also, if the LIP has already been implemented at the time this MEP is initiated, the Licensee will typically suspend its implementation of the LIP requirements until the MEP situation has been eliminated. The Licensee may however choose to continue with the LIP.

10. Peak Recreation Period – The period when recreation use on Project Reservoirs is generally at the highest levels (i.e., April 1 through September 30).

11. Critical Reservoir Elevation – Unless otherwise defined herein, the Critical Reservoir Elevation is the level of water in a reservoir (measured by reference to local datum or in ft AMSL) below which any Large Water Intake used for public water supply, industrial water supply, or any regional power plant water supply located on the reservoir will not operate at its Licensee-approved capacity. The Critical Reservoir Elevations are as follows.

Reservoir	**Critical Reservoir Elevation** (ft local datum / ft AMSL)	**Type of Limit**
Lake Jocassee	70.0 / 1080.0	Power Production
Lake Keowee	90.0[1] / 790.0[1]	Power Production

Note 1 - This new Critical Reservoir Elevation of 90.0 / 790.0 will become effective December 1, 2019 to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. See Item 12 below for guidance prior to converting to this new Critical Reservoir Elevation.

12. Transitioning to a Lower Critical Reservoir Elevation on Lake Keowee – The Licensee will operate in accordance with the provisions of the MEP, except Lake Keowee's Critical Reservoir Elevation will remain at or above 94.6 ft local datum / 794.6 ft AMSL until December 1, 2019, to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. The Licensee may also, in its sole discretion, decide to maintain Lake Keowee's Critical Reservoir Elevation at or above 94.6 ft local datum / 794.6 ft AMSL until both of the following are complete:

   a. A New License that is consistent with the RA has been issued, the end of all appeals, and all rehearing and administrative challenge periods have closed; and

b. The Licensee, the United States Army Corps of Engineers, and the Southeastern Power Administration have signed a New Operating Agreement (NOA) that is not inconsistent with the RA.

13. Abbreviations for Organizational Contacts – Greenville Water (GW); North Carolina State Historic Preservation Office (NCSHPO); Seneca Light and Water (Seneca); South Carolina Department of Natural Resources (SCDNR); South Carolina Department of Health and Environmental Control (SCDHEC); South Carolina State Historic Preservation Office (SCSHPO); United States Fish and Wildlife Service (USFWS); the Eastern Band of Cherokee Indians (EBCI); US Army Corps of Engineers - Savannah District (USACE); South Carolina Department of Parks, Recreation and Tourism (SCDPRT); Friends of Lake Keowee Society (FOLKS), Advocates for Quality Development (AQD), and Mountain Lakes Community Association (MLCA).

14. Voltage and Capacity Emergencies – The electric transmission system serving the Project area is part of the Licensee's main transmission system. The Licensee's system is connected to other large transmission systems located in the southeast. If the Licensee's system reliability is at risk due to Voltage and Capacity Emergencies, the ability to provide secure and continuous electric service to the Licensee's electric customers becomes compromised. The Licensee continuously monitors the electric transmission system. Therefore, for the purposes of this protocol, a Voltage or Capacity Emergency shall exist when declared by the Licensee.

15. Large Water Intake – Any water intake (e.g., public water supply, industrial, agricultural, power plant, irrigation, etc.) having a maximum instantaneous capacity greater than or equal to one million gallons per day (MGD).

16. Preparation for High Inflow Events – With modern forecasting, it is possible to forecast many high inflow events days in advance and to increase hydro generation hours to lower reservoir levels to reduce the potential for spilling and high water. This type of advance action is typically taken from one to five days or more before the expected arrival of the storm. The Normal Operating Ranges of reservoir levels may not allow for this type of reservoir level reduction under anticipated heavy inflow circumstances, and therefore, allowances are made in this MEP to lower reservoir levels below the Normal Minimum Elevations if needed in preparation for such events.

17. Revising the MEP – The Licensee will review the requirements of this MEP each time it is used and will consult with the organizations listed in Item 13 above if the Licensee determines modifications are warranted. If the MEP is modified, the Licensee will inform the Parties to the RA. If any modifications of the MEP require amendment of the New License, the Licensee will: (i) provide notice to all Parties to the RA, pursuant to Section 23.0 of the RA, advising them of the proposed New License amendment and the Licensee's intent to file it with the FERC; (ii) request the SCDHEC formally review and approve modification of the 401 WQC if required; and (iii) file a license amendment request for FERC approval if required. The filing of a revised MEP by the Licensee will not by itself constitute or require modification of the RA, and any Party to the RA may be involved in the FERC's or SCDHEC's public processes for assessing the revised MEP, but may not oppose any part of a revised MEP that is consistent with the MEP included in the RA.

Guidance for Responding to MEP Conditions

This section provides guidance for responding to the most likely MEP conditions (see Table 1 below) when this protocol will be enacted. Required flow releases and normal reservoir operating ranges are the license requirements most likely to be affected by MEP conditions.

Table 1: Conditions and Potential Impacts to License Requirements

Condition	Condition Name	Indications
MEP1	Hydro Unit Maintenance	Maintenance will require hydro unit shutdown
MEP2	Dam Safety Emergency	Condition A or B per the Emergency Action Plan (EAP) (i.e., dam failure has occurred, is imminent or a potentially hazardous situation exists) or some other dam safety concern is identified
MEP3	Voltage or Capacity Emergency	Voltage or capacity conditions on the electric grid in the Licensee's system or the larger regional electric grid cause the Licensee's system reliability and safety to be at risk and a voltage or capacity emergency is declared by the Licensee
MEP4	Reservoir Drawdown Below Normal Minimum Elevation due to maintenance, emergency or other reasons (not due to low or high inflow)	The reservoir level is below Normal Minimum Elevation
MEP5	Expected or existing high inflow event	The water level at a reservoir is or is projected to be significantly above or below the Normal Operating Range

Communication with Resource Agencies and Affected Parties

The Licensee will implement the appropriate communications based on the potential license requirements affected by the MEP condition. Communications include the following:

- Notification – The Licensee notifies the organization of the MEP event and the Licensee's planned actions; and
- Consultation – The Licensee notifies the organization of the MEP event and the Licensee's planned actions. The Licensee also requests input from the consulting organizations about options and alternatives to lessen the environmental, cultural, and human impacts of the MEP condition.

Generally, for unplanned and unscheduled MEP conditions, notifications occur as conditions unfold and will be followed by consultation.

Condition MEP1.1 – Scheduled Hydro Unit Maintenance

Mitigating Actions

1. Scheduling – To the extent practical, the Licensee will avoid scheduling hydro unit maintenance requiring drawdowns of the Project Reservoirs below the Normal Minimum Elevation during the period April 1 to May 15 to protect black bass spawning and to avoid hindering the Licensee's ability to provide recreation access during the Peak Recreation Period as defined above.
2. Drawing Down the Affected Reservoir –To minimize the impacts to its electric customers, the Licensee may choose to draw down a reservoir using its hydro units to minimize spillage from the dam during maintenance operations. The Licensee may draw down reservoir levels below the Normal Minimum Elevations, but not to levels below the applicable Critical Reservoir Elevations, unless such deeper drawdown is essential for access or safety.

Communication with Resource Agencies and Affected Parties

Condition MEP1.1 – Scheduled Hydro Unit Maintenance		
Notification	**Consultation**	**Comments**
FERC	AQD FOLKS Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	If the maintenance will affect any Normal Operating Range for Project Reservoir levels, provide notification and initiate consultation when maintenance schedules are determined, but at least 30 days prior to beginning any reservoir drawdown or the hydro unit maintenance.
	NCSHPO[1] SCSHPO EBCI	Consult no less than 30 days prior to the planned activity if required by the Historic Properties Management Plan.
AQD FOLKS MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free phone system plus implement other appropriate measures to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance

Condition MEP1.2 – Unscheduled Hydro Unit Maintenance

Mitigating Actions

1. Drawing Down the Affected Reservoir –To minimize the impacts to its electric customers, the Licensee may choose to draw down a reservoir using its hydro units to minimize spillage from the dam during maintenance operations. The Licensee may draw down reservoir levels below the Normal Minimum Elevations, but not to levels below the applicable Critical Reservoir Elevations, unless such deeper drawdown is essential for access or safety.

Communication with Resource Agencies and Affected Parties

Condition MEP1.2 – Unscheduled Hydro Unit Maintenance		
Notification	**Consultation**	**Comments**
FERC AQD FOLKS Large Water Intake owners MLCA SCDHEC SCDNR SCDPRT USACE USFWS	AQD FOLKS Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	If the maintenance will affect any Normal Operating Range for Project Reservoir levels, perform notification promptly after the unscheduled maintenance begins, but no longer than 10 days afterwards. Initiate consultation within 10 days.
NCSHPO[1] SCSHPO EBCI	NCSHPO[1] SCSHPO EBCI	Consult if required by the Historic Properties Management Plan.
AQD FOLKS MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free phone system and implement other appropriate measures to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance

Condition MEP2 – Dam Safety Emergency

Mitigating Actions

1. Safety Must Come First – If a Condition A or B is declared per the Licensee's EAP, or if other dam safety concerns arise, the Licensee may modify or suspend any license conditions immediately and for as long as necessary to restore the dam to a safe condition.

Communication with Resource Agencies and Affected Parties

Condition MEP2 – Dam Safety Emergency	
Timing of Communication	**Comments**
During EAP Condition A or B	Conducted strictly in accordance with the Licensee's EAP. In cases where dam safety concerns arise that are not a Condition A or B per the Licensee's EAP, consultation with resource agencies and affected parties will occur as soon as practical after the dam safety concern arises.
Once Dam Safety Conditions Have Stabilized	When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free telephone system to inform the general public.
Access Area Closure Notification	The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.

Condition MEP3 – Voltage and Capacity Emergencies

Mitigating Actions

1. Suspension of the Normal Operating Ranges for Reservoir Levels – If a voltage or capacity emergency (as defined above) occurs, the Licensee may modify or suspend reservoir level operating limitations immediately and for as long as necessary, if doing so would allow additional hydro station operation needed to restore the electric grid to a stable condition. Reservoir levels will not be reduced below the applicable Critical Reservoir Elevations.

Communication with Resource Agencies and Affected Parties

Condition MEP3 – Voltage and Capacity Emergencies		
Notification	**Consultation**	**Comments**
FERC SCDNR SCDHEC SCDPRT USFWS USACE Large Water Intake owners	Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Perform notification as soon as practical, but no longer than 10 days following the deviation from a license condition for Voltage or Capacity Emergency reasons. Initiate consultation as soon as practical.
NCSHPO[1] SCSHPO EBCI	NCSHPO[1] SCSHPO EBCI	Consult if required by the Historic Properties Management Plan.
AQD FOLKS MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free telephone system plus implement other appropriate measure to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance

Condition MEP4.1 – Reservoir Drawdown (Planned)

Mitigating Actions

1. Scheduling – To the extent practical, the Licensee will avoid scheduling drawdowns of the Project Reservoirs below the Normal Minimum Elevations during the period from April 1 to May 15 to protect black bass spawning and to avoid hindering the Licensee's ability to provide recreation access during the Peak Recreation Period as defined above.
2. Avoid Falling Below Critical Reservoir Elevations – To the extent practical, the Licensee will avoid falling below the applicable Critical Reservoir Elevations as noted above.

Communication with Resource Agencies and Affected Parties

Condition MEP4.1 – Reservoir Drawdown (Planned)		
Notification	**Consultation**	**Comments**
FERC AQD FOLKS Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Provide notification and consult when approximate drawdown dates are determined, but at least 30 days prior to beginning drawdown.
	NCSHPO[1] SCSHPO EBCI	Consult no less than 30 days prior to the planned activity if required by the Historic Properties Management Plan.
MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free telephone system implement other appropriate measures to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance

Condition MEP4.2 – Reservoir Drawdown (Unplanned)

Mitigating Actions

1. Avoid Falling Below Critical Reservoir Elevations – To the extent practical, the Licensee will avoid falling below the applicable Critical Reservoir Elevations as noted above.

Communication with Resource Agencies and Affected Parties

Condition MEP4.2 – Reservoir Drawdown (Unplanned)		
Notification	**Consultation**	**Comments**
FERC AQD FOLKS Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Perform notification as soon as practical, but no longer than 10 days after the drawdown begins. Begin consultation within 10 days after the drawdown begins.
NCSHPO[1] SCSHPO EBCI	NCSHPO[1] SCSHPO EBCI	Consult if required by the Historic Properties Management Plan.
MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free telephone system and to implement other appropriate measures to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance drawdown

Condition MEP5 – Expected or Existing High Inflow Event

Mitigating Actions

1. As outlined in the Key Facts and Definitions section of this protocol, in preparation for high inflow events and to minimize the potential for unplanned spillage the Licensee may reduce reservoir levels below the Normal Minimum Elevation, but not below the applicable Critical Reservoir Elevations. Reservoir levels may also rise significantly above Normal Maximum Elevations as a result of high inflow events. The reservoir levels may be below Normal Minimum Elevations or above Normal Maximum Elevations for as long as necessary to minimize the effects of the high inflow event on the Project Reservoirs and downstream reservoirs and to manage reservoir elevations during high inflow events.

Communication with Resource Agencies and Affected Parties

Condition MEP5 – Expected or Existing High Inflow Event	
Notification	**Comments**
FERC SCDHEC SCDNR SCDPRT USACE USFWS	The Licensee will perform notification as soon as practical following or prior to a deviation from license requirements for an existing or expected high inflow event.
AQD FOLKS MLCA Project Access Area Lessees	The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low or high reservoir levels) in accordance with the Recreation Management Plan.
General Public	When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free phone system plus implement other appropriate measure to inform the general public.

APPENDIX F MAPS

Figure F-1 Property Map

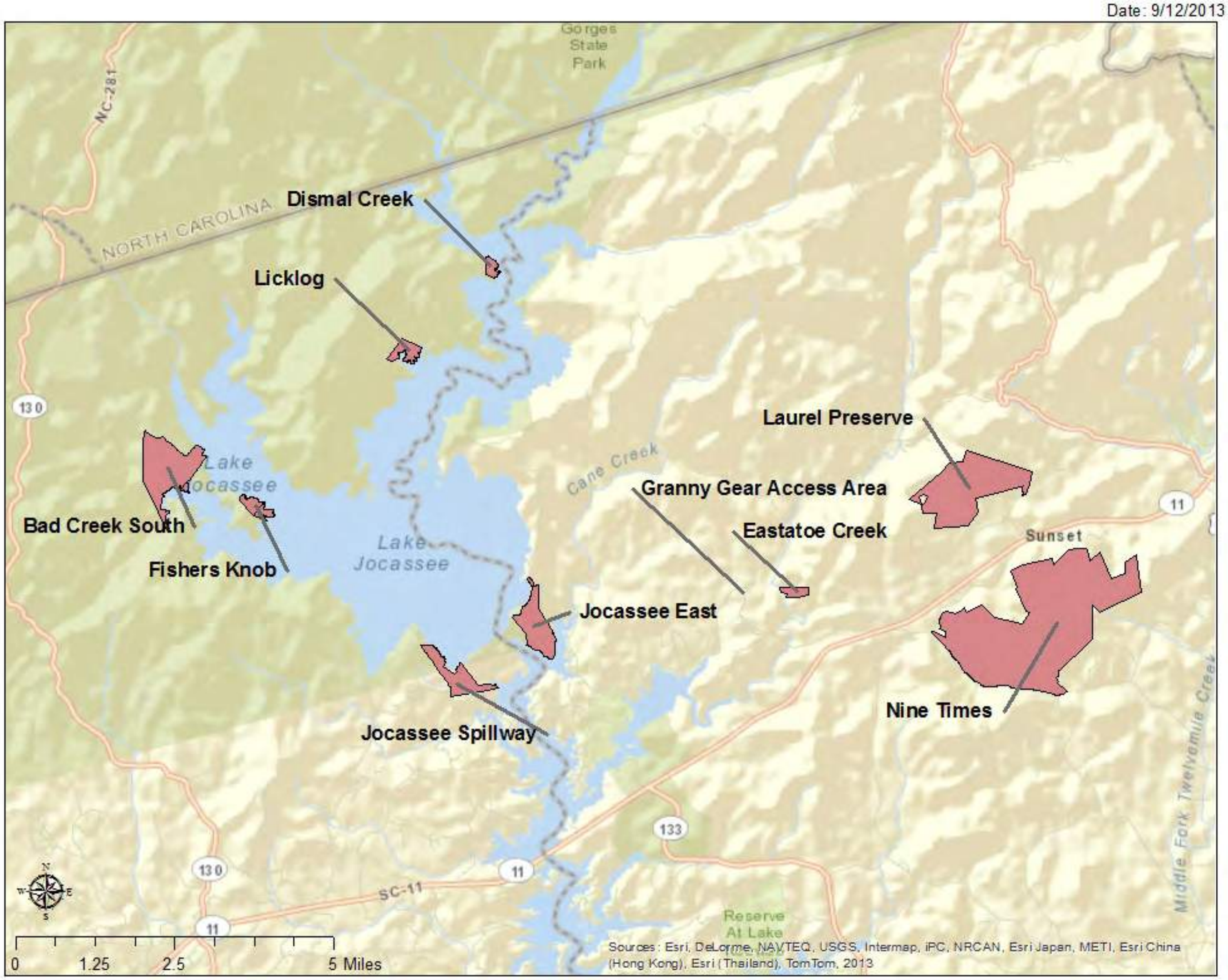


Figure F-2 Lake Keowee (north)

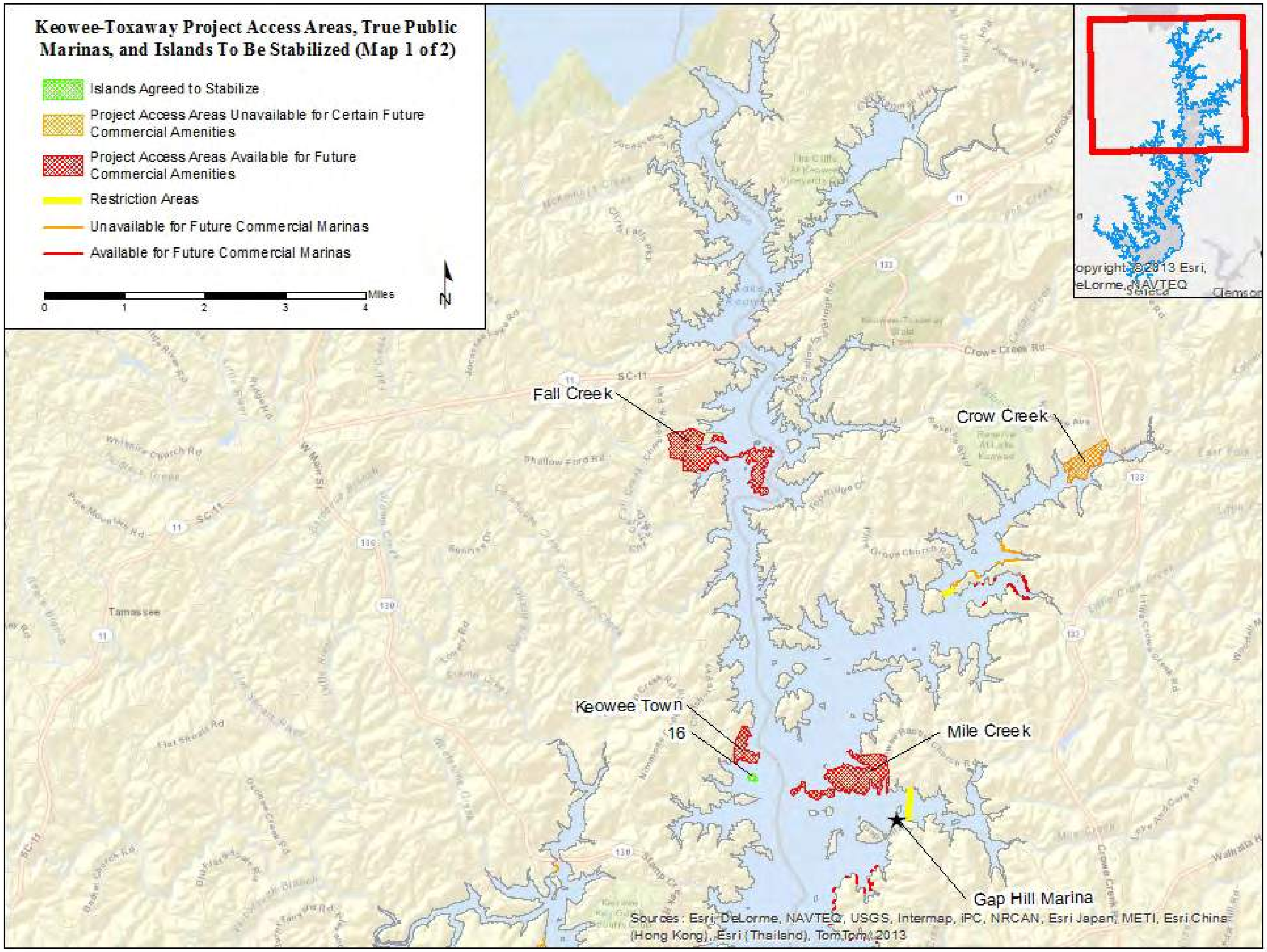
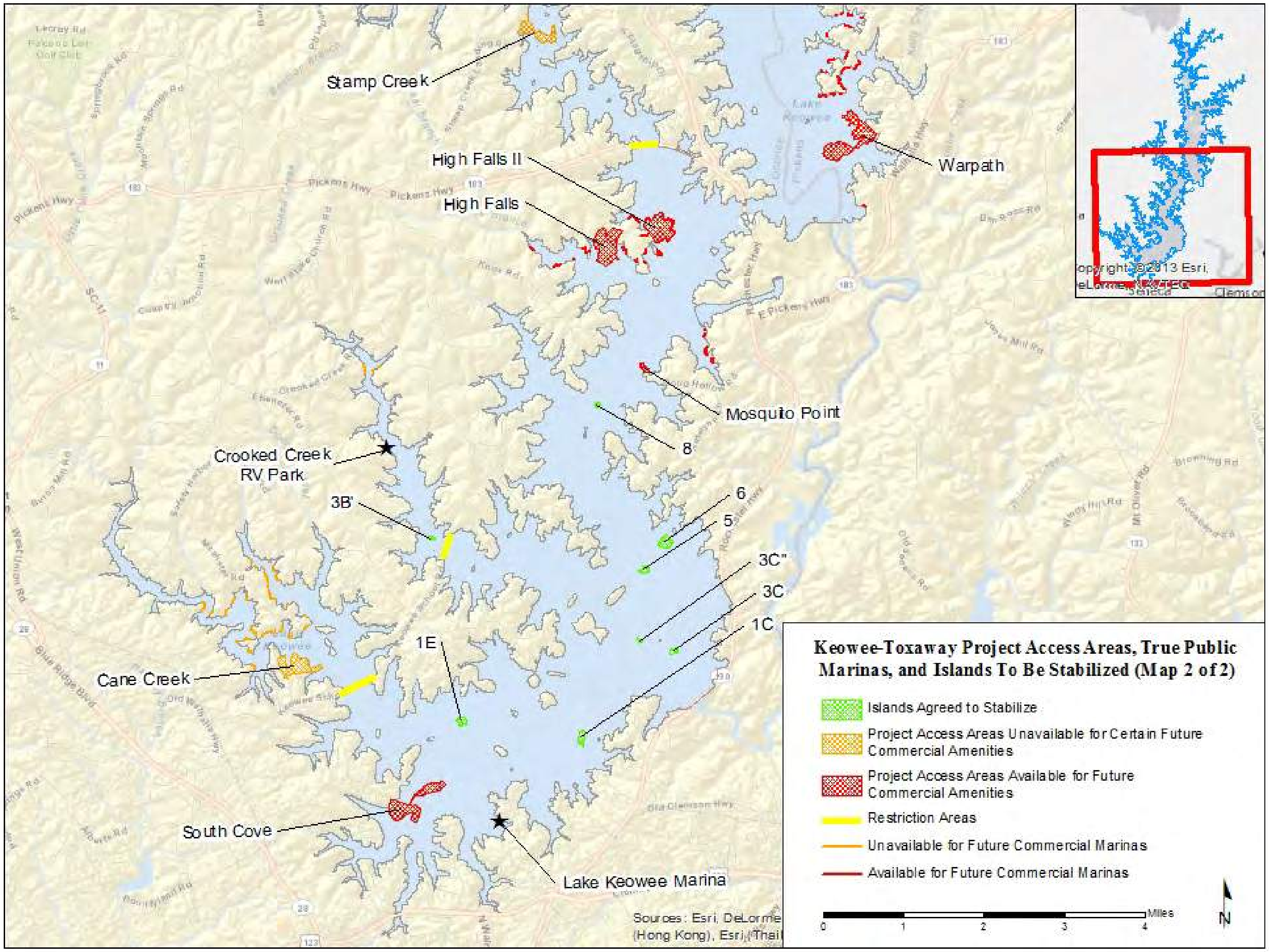


Figure F-3 Lake Keowee (south)



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APPENDIX G

PROCEDURE TO ALLOW DOCKS TO FOLLOW THE WATER

Purpose

Dock owners, including owners of commercial and residential marinas and public recreation facilities, may “follow the water” in an effort to maintain usability of their boats or docks during LIP Stages 2, 3, or 4. The requirements stated below apply to following the water.

Procedure

1. The Licensee shall work with the SCDHEC and the USACE to obtain revised General Permits for construction in navigable waters, to allow following the water on Lake Jocassee and Lake Keowee. The Parties acknowledge the Licensee may not allow following the water prior to issuance of said General Permits.
2. Following the water is authorized upon the Licensee’s public declaration of LIP Stage 2, 3 or 4. Following the water is no longer allowed once the Licensee publicly declares LIP Stage 1, 0 or Normal.
3. Dock owners shall return their boats or docks to their permitted locations and orientations and remove all temporary anchor pins within 14 calendar days following the Licensee’s public declaration of returning to LIP Stage 1, 0, or Normal.
4. During periods where following the water has been authorized, the Licensee may waive strict application of the then-current SMG requirements that would conflict with following the water (e.g., maximum distance from shoreline, one-third of the cove width, projection of property lines, maximum number of boats moored, etc.).
5. The Licensee reserves the right to require boat and dock owners to immediately restore their boats and docks to their original permitted locations if the owner is not meeting one or more of the requirements for following the water in this Appendix G or one or more of the then-current SMG requirements not waived by the Licensee.
6. Following the water shall not prevent or block access to existing docks or coves or negatively impact shoreline classified as Environmental or Natural under the Licensee’s SMP.
7. Dock owners choosing not to move their docks may moor their boats at docks belonging to other property owners during periods when following the water is allowed if prior permission is obtained from the property owner.
8. The temporary relocation of boats or docks and temporary anchoring of these facilities must not create public safety hazards, navigational hazards, or other issues.
9. No electricity-carrying lines coming from the shoreline can be connected to docks while they are following the water.
10. The Licensee shall not require a lake use permit application or charge any lake use permit-related fees to dock owners to follow the water or to make minor modifications to the docks that would facilitate moving them closer to the water

(e.g., adding wheels or sleds to gangways, or the like), provided the modification does not result in increased square footage for the dock.

11. The Licensee shall provide information and best-management suggestions for following the water on its website and direct callers to its recorded telephone message line to access the website for such suggestions.

APPENDIX H

HABITAT ENHANCEMENT PROGRAM (HEP) FOR THE KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

Purpose

The purpose of the HEP is to create, enhance, and protect aquatic and wildlife habitat within the Project Boundaries, including Keowee-Toxaway Hydroelectric Project (Project) Reservoirs and islands, plus any part of the watershed draining into Project Reservoirs by encouraging, reviewing, evaluating, and funding proposals to accomplish this purpose.

HEP Administration

The HEP will be administered in accordance with a Charter that will be developed by the Licensee in cooperation with other interested Parties to the Relicensing Agreement (RA) no later than the SMP Effective Date (defined in Section 7.3 of the RA). Charter development will begin no later than May 1, 2014. The Charter will include the following elements.

- Establishment of a Proposal Review Committee (PRC) – The PRC will consist of at least five voting members with knowledge of habitat issues representing Parties to the RA and one Licensee non-voting member to act as a facilitator. The PRC will be established and functioning prior to the distribution of any HEP funds.
- HEP Proposal Evaluation Schedules – Proposals requesting HEP funds may be submitted to the Licensee between May 1 and July 31 of each year beginning in 2015. In August of the same year, the Licensee will forward all proposals to the PRC for evaluation and funding recommendations. Funding for successful proposals will be awarded in October of the same year.
- HEP Proposal Evaluation – The PRC will establish an approach for evaluating and ranking proposals based on their potential to create, enhance, or protect aquatic and wildlife habitat. The PRC will have the flexibility to identify priority areas for funding plus specific criteria and other mechanisms for evaluating proposals. Proposals with cost sharing and/or in-kind support will be favored.
- HEP Proposal Recommendations – The PRC will review and evaluate all HEP proposals and recommend to the Licensee those worthy of funding. All PRC decisions will be by simple majority vote.
- Funding Decisions – The Licensee will determine final funding decisions for HEP proposals after considering PRC recommendations. It is the Licensee's intent to approve all PRC-recommended proposals and the Licensee will review reasons for not accepting a recommended proposal with the PRC.
- Periodic HEP Fee Evaluations – The PRC will evaluate the HEP fee schedule in conjunction with each SMP update to determine if the HEP fees should be changed. The Licensee will determine final HEP fee changes after considering the PRC's recommendations. It is the Licensee's expectation that it will approve all PRC-recommended HEP fees, and the Licensee will consult with the PRC before rejecting PRC recommended HEP fee changes. Such changes will not constitute or require a modification of the RA. Any Party to the RA may be involved in any Federal Energy Regulatory Commission (FERC) public process for assessing any HEP fee changes, but

may not oppose any part of a revised HEP fee schedule that is consistent with the HEP included in the RA.

- Licensee's HEP and PRC Responsibilities – The Licensee will be responsible for collecting fees, selecting PRC meeting dates, providing PRC meeting agendas, providing proposal copies to all PRC members in advance of the PRC meeting, producing PRC meeting summaries, requesting dispersal of HEP funds from the fund manager (see below), and collecting and distributing annual reports for funded projects.

HEP Funding

To help establish the HEP, the Licensee will provide start-up funding which will be supplemented by fees assessed to anyone applying for lake use permits within the Project as outlined below.

Table 1 – Applicable Fee Payments Into HEP

Permit Type[1]	HEP Fee[2]
Commercial marina (except True Public Marina)	$500 per slip
True Public Marina	$500 per slip – first 100 slips $250 per slip – all other slips
Private residential dock[3]	$500
Private residential marina	$500 per slip
Shoreline stabilization except for bioengineering stabilization	$500
Bioengineering shoreline stabilization[4]	no HEP fee
Conveyances	$5,000
Line crossings	$500
Private excavations	$500
All other excavations	$5,000

[1] For combined permits, the highest listed fee will be required. For example, if a lake neighbor submits a combined application to the Licensee for a private dock and shoreline stabilization with rip-rap, the HEP fee would be $500.

[2] Fee is only for the HEP and is in addition to any permit application fee, user fee, etc.

[3] Including dock expansions and other alterations requiring a permit under the SMP.

[4] HEP fees will be waived only for dock modifications needed to reach deeper water during the window of opportunity (see Section 7.5.2) and bioengineering shoreline stabilization defined in the SMG in effect at the time of proposal implementation and including techniques such as live staking, live fascines, brush mattresses, and reed clumps. HEP fees will also be waived for stabilization using coconut fiber rolls, hay bales, or spot rocks used to reduce wave energy

until vegetation is established. Enhanced rip-rap and crib walls will not qualify for a HEP fee waiver.

HEP fee collection as identified in Table 1 will begin on the SMP Effective Date. Initiating this program prior to the issuance of the New License will accelerate habitat improvements beneficial to the Project area.

All HEP fees will be collected by the Licensee at the time a final lake use permit request is submitted to the Licensee for evaluation. A separate check made payable to the KT HEP Fund must be received by the Licensee prior to processing any applicable final lake use permit request. If the permit is not approved for any reason, the HEP fee will be refunded to the permit requester.

Complete permit applications post-marked to the Licensee after the SMP Effective Date will be subjected to the applicable HEP Fee, including all marina facility and conveyance applications that have not been approved in writing or filed with the FERC, if applicable. Other than fees listed in Table 1 and the Licensee's HEP contribution, no contributions will be accepted by the HEP without the Licensee's approval at its sole discretion.

All HEP monies will be deposited and held by a local 501(c)(3) non-profit organization and dispersed for charitable purposes to implement Licensee-approved HEP proposals.

HEP Proposal Funding Eligibility

Any HEP proposal for areas within the Project Boundaries, including the Project Reservoirs and islands, or any part of the watershed flowing into Project Reservoirs will be eligible for HEP funds. Proposals located within or immediately adjoining the Project Boundaries will be given the highest priority. Proposals along or in perennial tributary streams entering the Project Boundaries will be given the next highest priority. Proposals with cost-sharing and/or in-kind support will be favored.

Only entities undertaking Licensee-approved HEP project proposals may receive HEP funding. Organizations may submit proposals to bundle small projects from other types of entities. The Licensee will maintain a list of appropriate HEP fund recipients.

The Licensee will be responsible for any habitat enhancements at Project Access Areas that are not leased to another party. No funds for these enhancements will be provided by the HEP.

Proposals for projects within the Project Boundaries must conform to the then-current SMP when the enhancement will be implemented.

PRC members will not be precluded from submitting proposals, but must be recused from voting on their own proposals.

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APPENDIX I

SOURCE WATER PROTECTION PROGRAM

Purpose

The purpose of the Source Water Protection Program (SWPP) is to protect water quality within the Keowee-Toxaway Hydroelectric Project (Project) Reservoirs, and watersheds draining into Lakes Keowee and Jocassee, through a comprehensive, multi-faceted collaborative program described as follows.

SWPP Administration

The SWPP will be administered by a Clean Water Group (CWG), a 501(c)(3) non-profit organization to be formed consistent with achieving the focus areas specified below. Until such time as all of the Licensee's funding has been disbursed, the CWG will provide an annual report to the Licensee detailing how the Licensee's funds were spent and how such activities were consistent with the stated purpose of the SWPP. The annual report to the Licensee will include statements affirming that any limitations on use of the Licensee's funding as stated in this Appendix I were met.

SWPP Focus Areas

The SWPP will focus on activities associated with protecting water quality at the Project Reservoirs. Initial activities are described below; additional activities intended to protect Project water quality may be identified throughout the New License term by the CWG consistent with the purpose of the SWPP. The CWG charter, members, and availability of matching grants, and/or collaborative funding or program participation will dictate the scope and priority of activities.

- The Licensee's contribution to the SWPP will be initially dedicated to the further development of water quality models that will allow for more detailed, state-of-the-art assessment of potential impacts of watershed-derived nutrients, reactive carbon and sediment loads on the water quality in Lake Keowee. Development of a calibrated watershed model using the United States Environmental Protection Agency (USEPA)-supported BASINS/HSPF[2] software is proposed to provide the point and non-point source loadings of water, reactive carbon, nutrients and sediments to a proposed EFDC[3]-based, three-dimensional reservoir model. The EFDC model will allow for both assessments of the impacts on water quality in shallower coves of nutrients, carbon and sediment loads draining from the watershed and the lake shoreline and assessments of flow exchange between the coves and main channel of the reservoir. The existing calibrated CE-QUAL-W2 reservoir water quality model developed for Lake Keowee during the relicensing process and the calibrated BASINS model will also be linked to the existing (Cane Creek embayment) or modified BATHTUB model for more easily estimating lakewide potential future effects of stream sediment, reactive carbon and nutrient inputs from all five major tributaries to Lake Keowee (i.e., Cane Creek, Little Cane Creek, Little River, Eastatoe River, and Little Eastatoe Creek) and the lakeshore. These linked models may be used

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[2] BASINS: Better Assessment Science Integrating point & Non-point Sources; HSPF: Hydrological Simulation Program-Fortran
[3] EFDC: Environmental Fluid Dynamics Code

to provide early warning of the eutrophication and algal bloom threats in the major drainage watershed inlet coves/lake arms which may be caused by development in the watersheds over the New License term. The models can also be used to evaluate the relative effectiveness of alternative regulatory and technological water quality protection strategies. Other models may be substituted for those specifically listed above as future modeling options may change.

The Licensee's contribution to the SWPP may also be used to support SWPP initiatives such as the following which are illustrative and not exclusive.

- Development of a "Find-and-Fix Failed Septic Systems" program to locate failed systems and cost-share repair/replacement/sewer-hookup (if feasible) with the system owners. The SWPP will prioritize its funding based on the potential impact of the failed system on the Project tributaries and Reservoirs. System owners with demonstrated limited financial resources to implement septic system repairs will be given a higher priority than those without demonstrable financial constraints. The Licensee's funding will not be used to offset repair or replacement costs for septic systems of financially capable owners.

- Educational outreach to provide information on water quality topics such as septic system maintenance; appropriate animal waste management; and methods to reduce non-point source pollution.

- Collaborative development with state and local governmental bodies of comprehensive plans for effective implementation of storm sewer upgrades and controlling non-point source pollution as development proceeds.

SWPP Funding

Following implementation of the SWPP per Section 9.4 of the RA, Licensee funds in support of the SWPP will be provided to the CWG. The Licensee's funding will not be used to pursue legislative or regulatory changes or for litigation. The CWG may seek matching grants and additional funding partners to implement the activities described above.

Appendix E

Forage Requirements of Brown Trout in Lake Jocassee

Study Completion Report

FORAGE REQUIREMENTS OF BROWN TROUT IN LAKE JOCASSEE

STUDY COMPLETION REPORT

December 9, 2010
Publication date - January 2011

Barbara Taylor, Biologist
Jim Bulak, Biologist

Division of Wildlife and Freshwater Fisheries
D. Breck Carmichael, Deputy Director

TABLE OF CONTENTS

Study Title: FORAGE REQUIREMENTS OF BROWN TROUT IN LAKE JOCASSEE

Period Covered July 2008 - June 2010

Summary

1) Population data for Lake Jocassee indicated that a small percentage of the stocked fish survived to enter the fishery (5%) and that recent annual survival of harvestable fish was low (12%). There is substantial uncertainty in these estimates.

2) Relative condition of brown trout in Lake Jocassee varied seasonally. During middle (1989-2002) and recent (2003-2008) years, condition in May was consistently high. Condition in November was consistently lower, with the decline more severe during recent years.

3) A bioenergetic model using a 10-18 ºC temperature annual range and feeding rate parameter P=0.55 provided a plausible fit to growth data from marked cohorts of brown trout in Lake Jocassee during their first year in the lake. Nine survival scenarios were run. Survival to harvestable size was set at 5, 15, or 25%, and annual survival of harvestable fish was set at 10, 30, or 50%. Scenario 1 (VERY LOW survival; 5% survival to harvestable size, 10% annual survival) represents the current population in Lake Jocassee. Forage requirements were simulated for winter (mid-November to mid-March), spring-early summer (mid-March to mid-July), and late summer-fall (mid-July to mid-November) seasons for a population with initial size and numbers of stocked fish based on data for Lake Jocassee. The prey requirement was converted from biomass to numbers of fish for comparison with forage populations in Lake Jocassee.

4) Field data from Lake Jocassee, combined with simulation results from the VERY LOW survival scenario, give a picture of a population that experiences a short season of abundant forage in spring and, possibly, early summer. During late summer-fall, forage is abundant, but thermal

stratification limits access by the trout. During the winter season, forage is initially abundant, but becomes depleted, due in part to predation by the trout. The level of depletion appears to prevent improvement in condition over the winter, although it does not severely curtail growth.

5) The simulated winter forage requirement (1.9 million fish) in the VERY LOW survival scenario was equal to about half of the median number of forage fish in Lake Jocassee during winter (hydroacoustic survey data for 1989-2005). It exceeded the winter forage population in 2 of 17 years. The simulated requirement could account for a substantial portion of the typical winter decline in forage fish (median decline of 2.6 million fish in 1989-2005).

6) The forage in Lake Jocassee appears to have limited capacity to support improvement in the brown trout fishery. At the current harvest level of brown trout, the winter forage population cannot sustain substantially higher survival to harvestable size, whether this is achieved by stocking at a higher level or by improving survival at the current stocking level. The winter forage population can sustain a reduced harvest rate of brown trout that would substantially increase the average size of a harvested fish.

7) Recent data suggest that approximately 1 of 20 stocked fish is attaining harvestable size. Future study is needed to define the immediate fate of stocked fish. Because available forage seems adequate, predation, illegal harvest, catch-and-release mortality of deep-caught trout,or failure to adapt to the wild are possible explanations.

Introduction

Lake Jocassee supports a valuable sport fishery for brown trout (*Salmo trutta*). The fishery was established in the1970s. Annual harvest was greatest (2,000-8,000 fish) during the first decade (Figure 1). The annual harvest dropped in 1989, and minimum size for harvestable fish was raised to 15 inches from 12 inches in 1991. Except for a few years of higher harvests in 2000-2002, the median harvest since 1989 has been near 1,000 fish annually.

The size of harvested fish increased sharply after the minimum limit was raised (Figure 1). More recently, the size of harvested fish has decreased: mean weights in 2000-2005 differed significantly from mean weights in 1993-1999 (two-sample t test, p=0.005). Fall condition has also declined in recent years (Figure 2). Analysis of variance showed that November means differed between the early (1977-1982) and recent (2003-2008) time periods and between the middle (1989-2002) and recent time periods (simultaneous comparisons by Tukey method). Spring condition, however, did not differ among these time periods.

The forage base for brown trout in Lake Jocassee consists mainly of blueback herring (*Alosa aestivalis*) and threadfin shad (*Dorosoma petenense*). Small (<40-50 cm) brown trout in Lake Jocassee consume more threadfin shad; large brown trout consume more blueback herring (D. Rankin, pers. comm.). Among the other major piscivores in Lake Jocassee, rainbow trout (*Onchorhynchus mykiss*) and redeye bass (*Micropterus coosae*) are believed to feed extensively on blueback herring and threadfin shad.

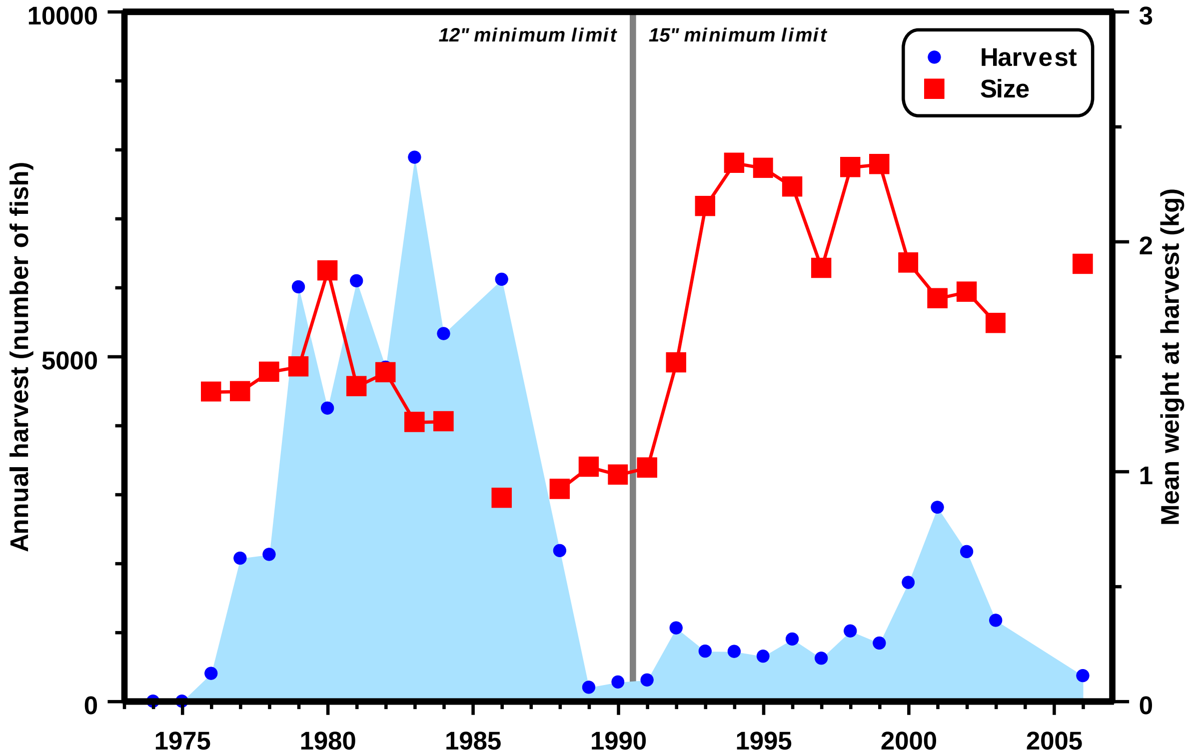

Figure 1. Harvest of brown trout at Lake Jocassee, 1974-2006. Estimates from creel surveys were provided by Dan Rankin (SC DNR). Note the change in size limit, implemented in 1991.

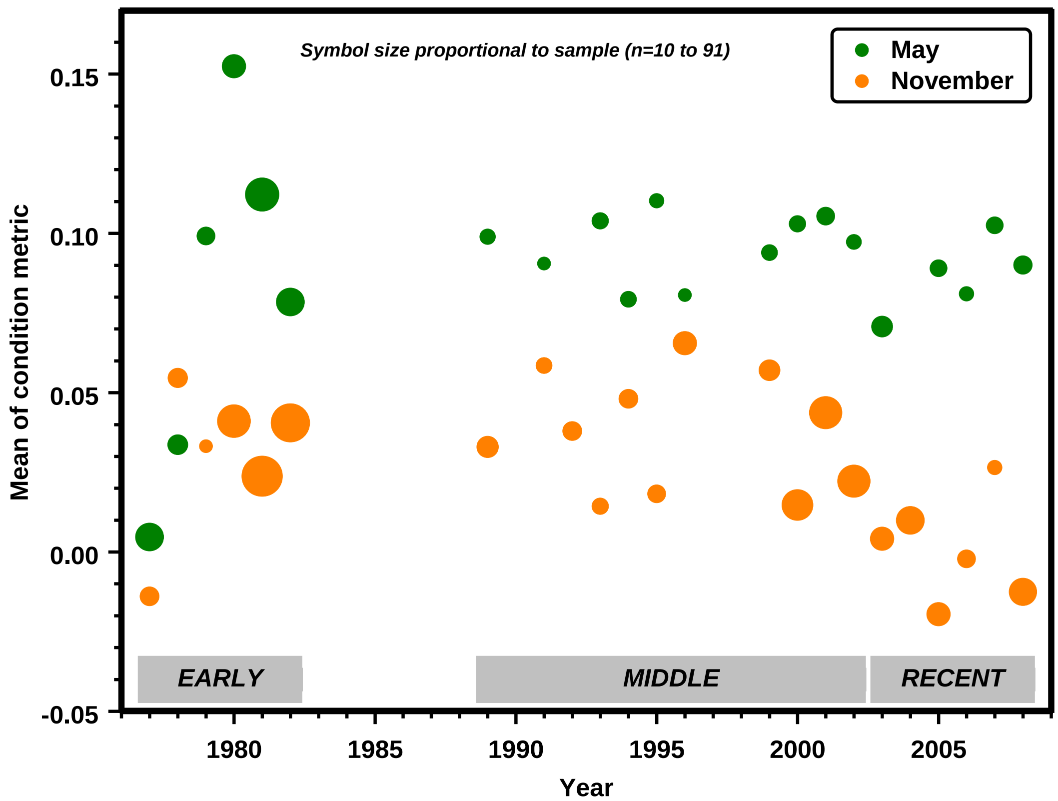

Figure 2. Condition of brown trout in Lake Jocassee, 1977-2008. Brown trout were collected by gill netting. Condition metric is defined below. Fish <300 g and condition values more extreme than ±0.4 were excluded from computation of means. Means with <10 fish were excluded from plot and analysis. The breakpoint between the middle and recent time periods maximizes the difference between the two groups of years. Data were provided by D. Rankin (SC DNR).

Wide year-to-year fluctuations in the populations of forage fish (Rodriguez, 2010), along with the variations in the harvest and conditions of brown trout, raised questions about the potential for food limitation in the brown trout population. To investigate the adequacy of the forage base, we estimate forage requirements using a cohort-structured, bioenergetics-based population model. The feeding rate parameter in the model is adjusted to fit simulated growth to data from marked cohorts stocked in Lake Jocassee. The first among nine simulated survival scenarios is based on estimates from data for the Lake Jocassee population. Additional scenarios explore the impact of higher survival on population dynamics and forage requirements. We compare simulated forage requirements of brown trout with long-term data on abundances of forage fish. We evaluate the potential for food limitation by season, considering thermal stratification of the lake and growth and condition of the brown trout, as well as the forage base.

Materials and Methods

Lake Jocassee

Lake Jocassee is a 3,063-ha impoundment in western South Carolina in the upper reaches of the Savannah River drainage. Constructed by Duke Power, it reached full pool in 1973. Lake Jocassee serves as the upper pool for the 610-MW Jocassee Pumped Storage Station and as the lower pool for the 1,065-MW Bad Creek Pumped Storage Station.

The reservoir is deep and oligomictic. Maximum depth at full pool (338.3 m above mean sea level) is 107 m; mean depth is 46 m (Barwick et al., 2004). Surface temperatures range annually from ~10 ºC in February to ~27 ºC in August (Figure 3). In the deeper parts of the reservoir, water temperature remains near 10 ºC throughout the year. The reservoir mixes completely in about 40% of years (W. Foris, Duke Power, unpublished data). Following winters without mixing, dissolved oxygen becomes depleted in the hypolimnion. By September, the zone of dissolved oxygen <5 mg/liter may extend 40-50 m up from the bottom of the lake.

The reservoir is also oligotrophic: nutrients and productivity are low. Water chemistry data for five SC DHEC monitoring stations in 1999-2006 were obtained from the EPA (STORET database). Alkalinity was low, typically 5-6 mg/liter, and pH was circumneutral, typically 5.7-7.3). Total phosphorus rarely exceeded the detection limit of 0.02 mg/liter; the maximum was 0.04 mg/liter. Total nitrogen was typically 0.03-0.25 mg/liter; the maximum was 0.7 mg/liter. Consistent with these low nutrient concentrations, summer chlorophyll values were typically 1-2 micrograms/liters (2002 and 2005 only, 4 stations); the maximum was 6.5 micrograms/liter. Nutrients and chlorophyll met the applicable water standards (SC DHEC, 20004: total phosphorus ≤ 0.2 mg/liter; total nitrogen ≤ 0.35 mg/liter; chlorophyll a ≤ 10 micrograms/liter). The waters of Lake Jocassee are listed as impaired only for excessive mercury concentrations (SC DHEC, 2006).

Brown Trout in Lake Jocassee

Distribution

For brown trout in southeastern reservoirs, water with temperature ≤ 20 ˚C and dissolved oxygen ≥ 5 mg/liter generally provides suitable habitat (Barwick, Foltz, and Rankin, 2004). During winter and most of spring (December through April), the entire water column of Lake Jocassee is thermally suitable for brown trout (Figure 3), although dissolved oxygen may be insufficient in deeper parts of the lake. As the epilimnion continues to warm during summer, trout are limited to increasingly greater depths.

During a summer study of habitat preferences in Lake Jocassee, brown trout implanted with transmitters ranged over depths from 14-15 m to 54-55 m (Barwick et al., 2004; 14 individuals, 190

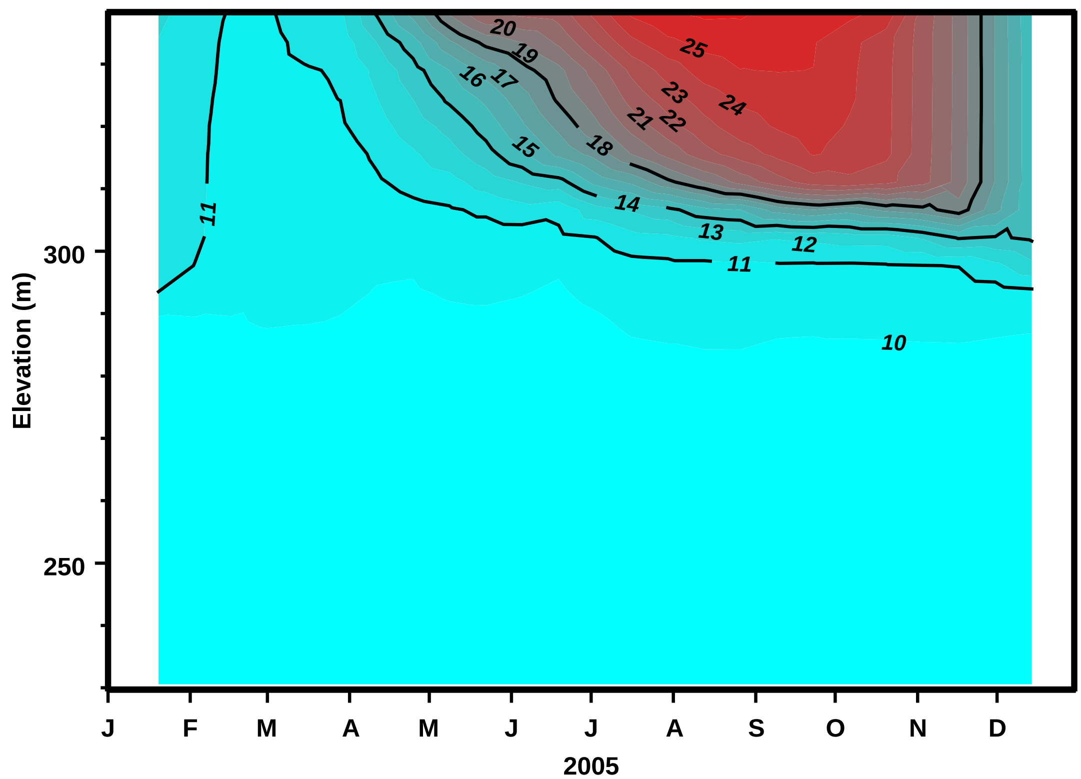

Figure 3. Depth-time plot of water temperature in Lake Jocassee, 2005. Monthly profiles of temperature at station 558.0 were provided by Duke Power. Isotherms marked with lines are used as thermal upper limits in bioenergetic models described below. The lake did not mix completely in winter of 2005.

observations). The fish were 0.8-3.6 kg in weight, but more than 95% of the observations came from fish of 1.3 kg or more. Reported temperatures were 9-21 ˚C. Distributions of the fish were bimodal in July (12 fish; modes: 14-14.9 ˚C and 18-19 m; 11-11.9 ˚C and 24-25 m) and August (13 fish; 17-17.9 ˚C and 22-23 m; 10-10.9 ˚C and 26-27 m), but unimodal in September (6 fish; 10-10.9 ˚C and 36–37 m).

Stocking and management

The brown trout fishery at Lake Jocassee is a put-grow-and take fishery. Natural reproduction is negligible.

The stocking program began in 1973, the year in which construction of the lake was completed (Figure 4). Brown trout have been stocked in fall (usually December) at age 1, in spring (usually February or March) at age 1^+, and in fall (usually November or December) at age 2. Length at stocking depends on age and culture conditions: reported ranges for fish of age 1-1^+ were typically 7-8 or 8-9 inches; for fish of age 2, 10-11 inches. Under the current stocking program, 25,000 fish of age 2 are stocked in fall.

To estimate yield, we compared the number stocked with the number harvested in the year that the stocked fish reached harvestable size. Brown trout stocked in fall at age 1 or spring at age 1^+ reach harvestable size (15 inches under the current regulations) by the following fall; brown trout stocked in fall at age 2 reach this size by the following spring or summer. The harvest is typically dominated by fish stocked in the previous year. We assumed that the contributions of earlier stocks would be equivalent to that stock's contribution to later harvests.

Since the 15-inch limit was implemented in 1991, the median yield of brown trout, based on creel survey data, has been 2% of the number stocked (Figure 4; range 1-5%, n=14 years). The most recent estimate (2005 stock; 2006 creel survey) was 1%, and the corresponding return to creel by weight was 11%. Estimates of yield since the current stocking program was implemented are not yet available.

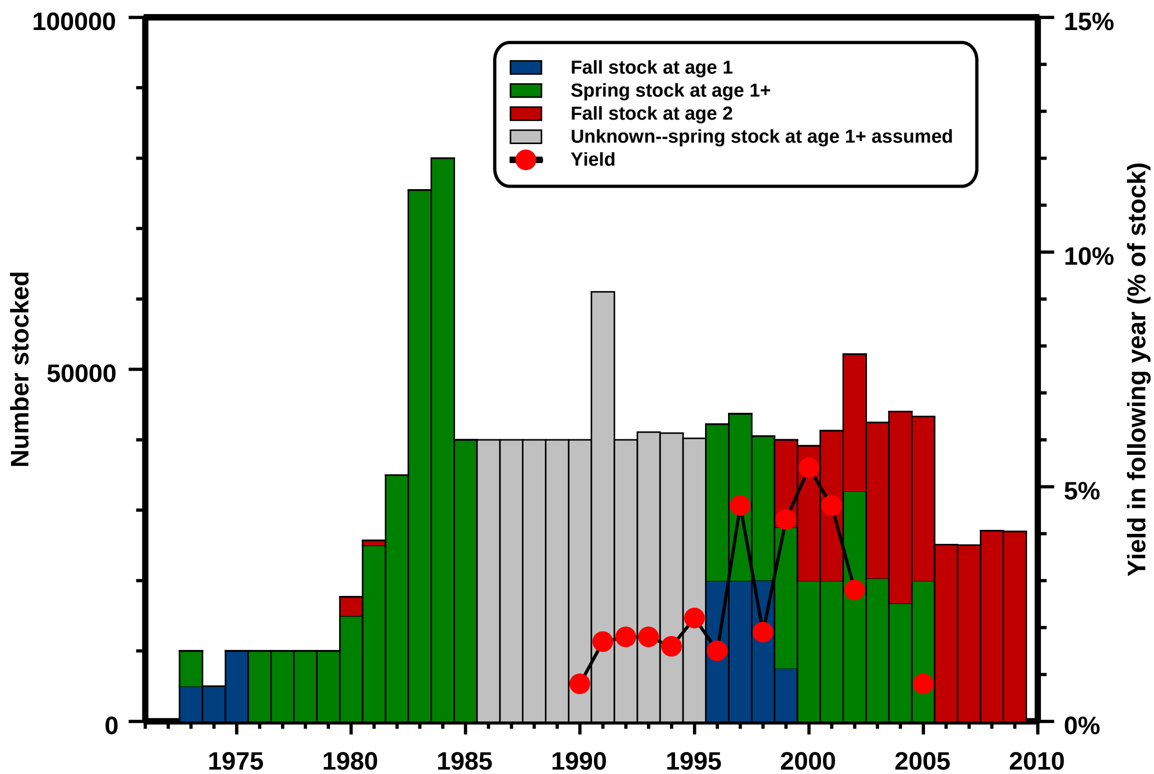

Figure 4. Stocking and yield of brown trout at Lake Jocassee, 1973-2009. Yield is shown for fish stocked in 1990 and later; these cohorts were harvested after the 15-inch minimum size limit was implemented. Note that fish stocked in fall at age 1 are assumed to reach harvestable size in the same year as fish stocked in the following spring. Data were provided by D. Rankin (SC DNR).

Recent growth and condition

Brown trout were measured at the time of stocking in 2006 and 2007 (Table 1, Figure 5). The trout stocked in 2007 were slightly larger than those stocked in 2006. Estimated mean weights of the individual stocked fish were 193 g (range 82-316 g) in 2006 and 220 g (range 88-373 g) in 2007.

All of the stocked trout were marked with a finclip (adipose fin in 2006; right pelvic fin in 2007). Subsequent sampling included gillnetting (10 or more net nights in fall, winter, and spring) and a creel survey in 2008.

The 2006 and 2007 cohorts showed similar patterns of growth during their first year in the lake (Figure 6). Growth was most rapid during the six months after stocking. Samples during this period were sparse, but suggest that growth may have accelerated after March. Growth slowed during summer. Samples were too sparse to evaluate seasonal growth rates of fish after their first year in the lake.

Growth of the recent cohorts differed substantially from growth of the well-sampled 1981 cohort (Figure 6). The 1981 cohort, stocked at age 1.5, attained a median weight of 2.5 kg by age 3, about a year sooner that the 2006 cohort. The 2006 and 2007 cohorts were about half this weight at age 3.

We measured condition as the difference between observed $\log_{10}$(weight in g) and predicted $\log_{10}$(weight). The prediction was generated using a regression of $\log_{10}$(weight) against $\log_{10}$(length in mm) for the March data (2006 and 2007 combined). We used the March data for the regression because the range of lengths was wide, all of the fish had been in the lake for at least 4 months, and the fit was excellent (r^2=0.98, n=19).

Table 1. Size of brown trout stocked into Lake Jocassee, 2006-2007. Weight was estimated using the equation log10 (mass in pounds) = 3.00809 log10 (length in inches) – 3.37430, which was developed for brown trout (lake form) in Michigan (Schneider, Laarman, and Gowing, 2000). Data were provided by D. Rankin (SC DNR).

	2006 (n=100)		*2007 (n=99)*	
Metric	***Length (mm)***	***Weight (g)***	***Length (mm)***	***Weight (g)***
Minimum	190	82	195	88
5th percentile	223	132	230	145
Mean	252	193	263	220
Median	254	195	264	219
95th percentile	276	251	291	294
Maximum	298	316	315	373

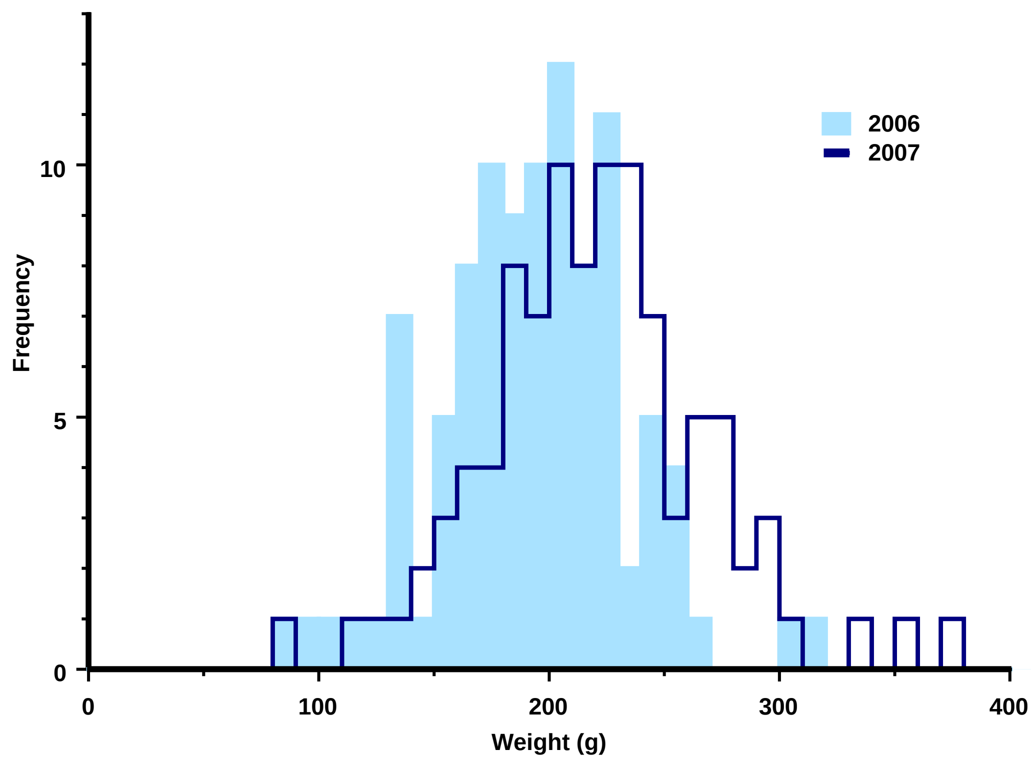

Figure 5. Size of brown trout stocked into Lake Jocassee, 2006-2007.

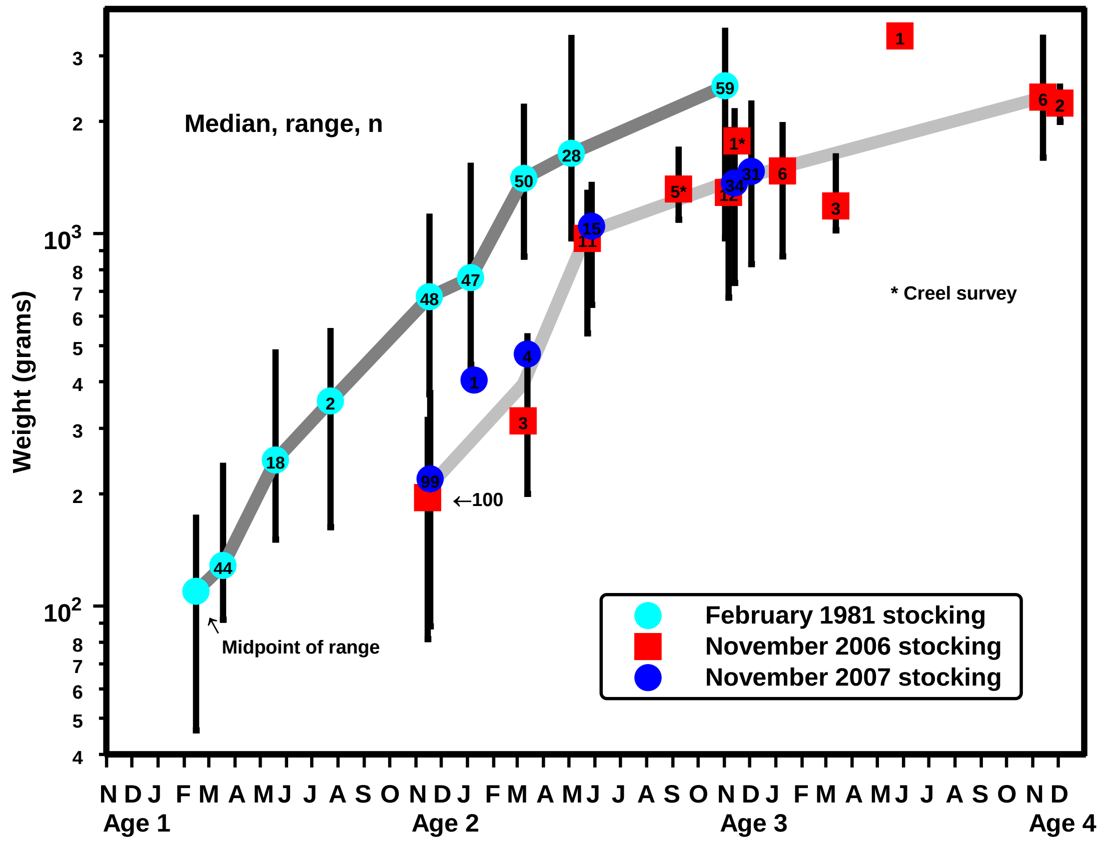

Figure 6. Growth of marked cohorts of brown trout in Lake Jocassee. Initial sizes were measured at time of stocking (Table 1, Figure 1); subsequent measurements were made on fish from gill net samples or creel surveys. Slopes of the lines are proportional to growth rates per unit weight. Statistics were not adjusted for net selectivity, so the medians may be biased. Data for second-year growth of the 2007 cohort were not yet available. All data were provided by D. Rankin (SC DNR).

Condition in May differed significantly from condition in the preceding March and following November samples (Figure 7). Other pairs of samples did not differ (simultaneous confidence intervals by Tukey method). Slowed growth of the age 2 fish in the summer and fall after stocking coincided with the annual deterioration of condition between May and November.

Survival

Because no direct estimates were available, we estimated survival of trout from the time of stocking to the time of attaining harvestable size indirectly. We subdivided the population into two size classes, based on whether or not the fish had grown to harvestable size. If the number of fish stocked and their survival rates are similar from one year to the next, the number of recruits to the harvestable size class in a year will be about the same as the number of deaths in the harvestable size class (Figure 8).

The creel census should estimate the number of deaths due to harvest annually. If the number of deaths due to causes other than harvest were small, the creel census would slightly underestimate the total number of deaths, as well as the number of recruits. However, the creel census does not include the night fishery, which is believed to be substantial (D. Rankin, SC DNR). Mortality of fish caught but released may also be substantial.

Based on creel surveys for years since the 15-inch size limit was imposed, the median harvest was equal to 2% of the number stocked in the previous year (Figure 4). Allowing for natural mortality, catch-and-release mortality, and underestimates of the harvest, we estimate that about 5% of stocked fish survive to harvestable size.

Annual survival appears also appears to be low for fish of harvestable size. Gill netting in November and December 2008 (25 net nights in five locations) yielded 81 brown trout, including 66 marked brown trout from the 2007 cohort and 8 marked brown trout from the 2006 cohort. These

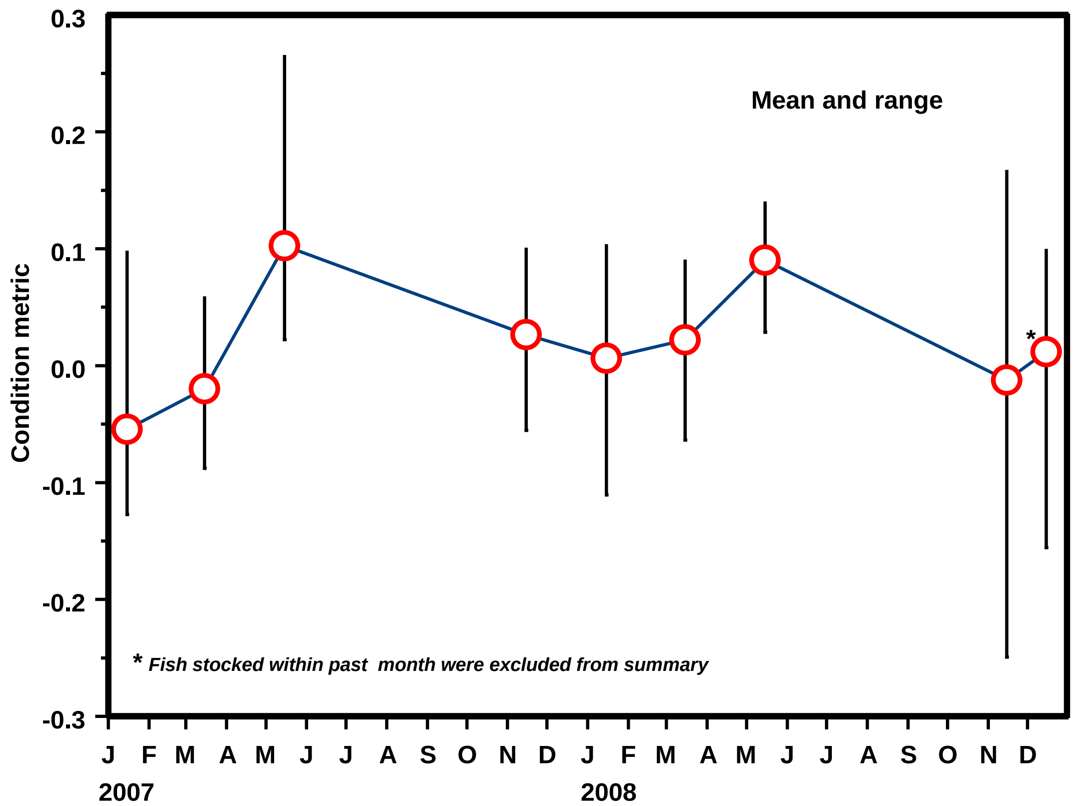

Figure 7. Condition of brown trout in Lake Jocassee, 2007-2008. Condition metric is described in text; a higher value indicates better condition. To eliminate recently stocked fish from analysis, fish <300 g were excluded. Fish stocked within past month in December 2008 sample were identified by weight <350 g. Number of fish in sample ranged from 9 to 43. Condition in May of each year differed significantly from condition in the preceding March and following November samples, but other pairs of samples did not differ (simultaneous confidence intervals by Tukey method). Data for analysis were provided by D. Rankin (SC DNR).

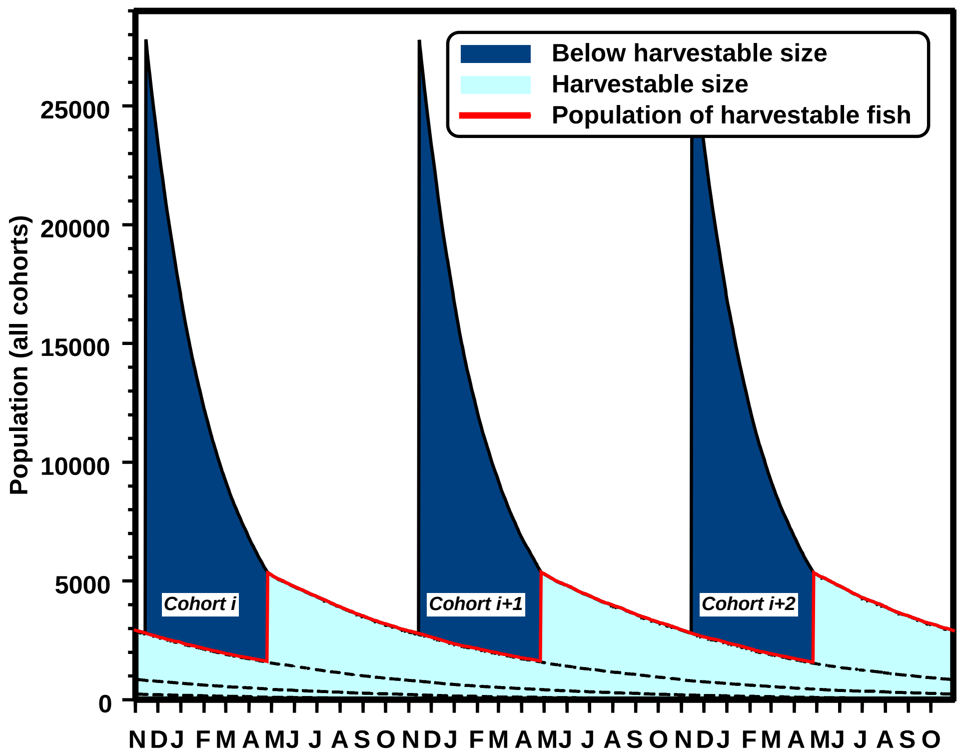

Figure 8. Simulated dynamics of a cohort-structured population. Number of fish stocked, growth rate, survival from stocking to attainment of harvestable size, and annual survival of harvestable size were consistent from year to year. This example was simulated with Scenario 5 (described below); cohorts approach extinction five years after stocking.

numbers yield an annual survival over the second year in the lake of 12% (95% confidence interval estimate: 5 to 20%). All of these fish had attained harvestable size, based on measured lengths. The data were not adjusted for selectivity of the nets, and the analysis assumes that fish from two cohorts were caught with equal efficiency.

We computed annual survival from catch curves for two earlier marked cohorts. The 1974 year class, stocked in December 1975, had 21% annual survival from age 3 (in November of sample year) to age 6 (r^2=0.999). The 1976 year class, stocked in January 1978, had 45% annual survival from age 3 to age 5 (r^2=0.87). January, March, May, and November samples were combined. Fish of age 2 were omitted, because they appear to be underrepresented in the first 4-6 months following stocking. (Fish stocked at age 2 in fall also appear to be underrepresented in samples taken during the first 4-6 months following stocking.) Numbers based on November samples only were too small for analysis. None of the other longitudinal series appeared to be suitable for catch curve analysis; evidently, very few trout survive past age 3.

Abundance of forage

Stocks of forage fish are routinely assessed in November and March by hydroacoustic sampling by Duke Power. Additionally, in November, the species and size composition are determined from purse seine samples by Duke Power. For 1989-2005, the median combined population of threadfin shad and blueback herring for Lake Jocassee was 4 million fish in November and 1 million fish in March (Figure 9). The median difference between populations in the fall and the following spring was 1.2 million fish (range 1.2-10.3 million, n=15 years). The median average weight for the combined population in November 2000-2005 was 5.6 g, and median standing stock was 20 metric tons (Table 2).

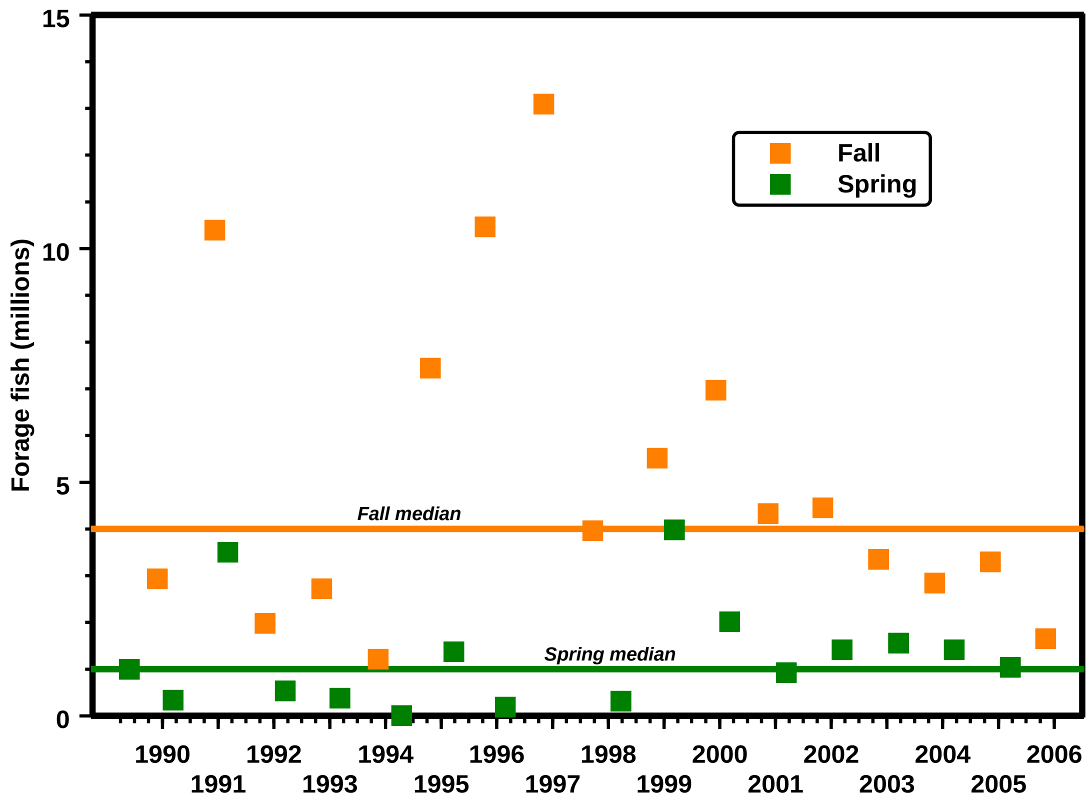

Figure 9. Spring and fall abundances of forage fish in Lake Jocassee, 1989-2005. Hydroacoustic survey data were provided by D. Coughlan (Duke Power).

Table 2. November standing stock of forage fish in Lake Jocasssee, 2000-2005. Population estimate is based on hydroacoustic survey; composition and mean weight are based on purse seine catch. Blueback herring were separated by size class in 2001 and 2002 only. Data were provided by D. Coughlan (Duke Power).

Year	*Population (millions)*	*Species*	*Composition*	*Mean weight (g)*	*Standing stock (metric tons)*
2000	4.3	All		4.3	18.6
		Threadfin shad	73%	2.6	8.1
		Blueback herring	27%	9.0	10.5
2001	4.5	All		5.2	23.0
		Threadfin shad	32%	2.3	3.2
		Blueback herring (<120 mm)	55%	3.2	7.8
		Blueback herring (>120 mm)	13%	21.1	12.0
2002	3.3	All		6.0	20.0
		Threadfin shad	48%	2.9	4.7
		Blueback herring (<120 mm)	32%	4.0	4.2
		Blueback herring (>120 mm)	20%	16.5	11.1
2003	2.8	All		3.7	10.5
		Threadfin shad	24%	3.4	2.3
		Blueback herring	76%	3.8	8.2
2004	3.3	All		7.6	25.0
		Threadfin shad	24%	4.3	3.4
		Blueback herring	76%	8.7	21.7
2005	1.7	All		8.4	13.8
		Threadfin shad	31%	4.8	2.5
		Blueback herring	69%	10.0	11.4

Similar assessments of forage fish by Duke Power in Lake Norman provide information about growth in a similar system. Lake Norman is a large oligotrophic reservoir in the Piedmont region of North Carolina (Buetow, 2008). Forage fish were collected by purse seining in July, September, and December of 2002. Average weights of threadfin shad and alewife, respectively, were 0.6 g and 1.4 g in July, 1.0 g and 3.4 g in September, and 2.3 g and 4.5 g in December. For both species, average weight approximately tripled from July to November (interpolated).

Brown Trout Population Model

To estimate forage requirements of the brown trout population, we built a cohort-structured model, assuming similar size at stocking and subsequent growth for all members of the cohort. The simulations were written in S-Plus (Insightful Corporation, Seattle, WA; code available from BET). The functions describing growth and forage requirements for an individual fish were adapted from the bioenergetics model by Dieterman et al. (2004).

In the simulations, an initial population and body size at time of stocking are specified. Bionenergetic functions, which depend on water temperature and a feeding rate parameter, determine subsequent growth in body size. Survival depends on whether cohort has attained harvestable size.

Bioenergetics

Bioenergetic models for brown trout have been developed for a variety of applications (Van Winkle et al., 1998; Elliott and Hurley, 1999; Hayes, Stark, and Shearer, 2001; Brown, 2004; Dieterman, Thorn, and Anderson, 2004). Dieterman et al. (2004) modeled brown trout in Minnesota streams using Fish Bioenergetics 3.0 (University of Wisconsin, Madison, WI). Negus et al. (2004) subsequently applied this model to brown trout in Lake Superior.

For the brown trout population in Lake Jocassee, we used bioenergetics equations from Fish Bioeenergetics 3.0 with parameters from Dieterman et al. (Table 3). We set prey energy density at 5,000 joules/g wet mass. This value lies near the middle of the range of values compiled for prey fishes by Hanson et al. (1997, Appendix B) and Negus et al. (2004, Table 12).

Processes considered in the Fish Bioenergetics 3.0 model are energy gains due to consumption and energy losses due respiration and waste, including egestion, excretion, and the cost of assimilation (specific dynamic action). The difference between consumption and waste is the net consumption. Net consumption is about 60% of total consumption. The difference between net consumption and respiration is available for allocation to growth or reproduction. These processes depend on water temperature, body mass of the fish, and the feeding rate parameter P.

With the feeding rate parameter set at P=1, consumption for a 1,000 g fish reaches a maximum at 17˚C; growth reaches a maximum at 14 ˚C (Figure 10). At P=0.5, co nsumption reaches a maximum at 17 ˚C; growth, at 12 ˚C. The break-even point, where net consumption equals respiration, occurs at just under 20˚C at P=1. Reducing P slows growth and shifts the growth maximum and break-even point to lower temperatures. Growth and consumption are higher for smaller fish, and lower for larger fish, but the maxima and break-even points occur at similar temperatures (model results not shown). Between ~10-16 ˚C, depending on P, the response of net growth to temperature is fairly flat.

When Lake Jocassee is unstratified, or weakly stratified, from January to April, surface temperature is a good estimate of the temperature experienced by brown trout. However, as discussed above, brown trout experience a range of temperatures when the lake is stratified. Individuals differ in thermal preferences, and the typical condition for the population is not well-

Table 3. Parameter values for bioenergetics functions. Equation numbers refer to Hanson et al. (1997); parameters were taken from Dieterman et al. (2004).

Process	***Parameter***	***Value***
Consumption (eq. 3)	CA	0.2161
	CB	-0.233
	CQ	3.8
	CTO	17.5
	CTM	17.5
	CTL	20.8
	CK1	0.23
	CK4	0.10
Respiration (eq. 1)	RA	0.0013
	RB	-0.269
	RQ	0.0938
	RTO	0.0234
	RTM	0
	RTL	25
	RK1	1
	RK4	0.13
	ACT	9.7
	BACT	0.0405
	SDA	0.172
Egestion/excretion (eq. 3)	FA	0.212
	FB	-0.222
	FG	0.631
	UA	0.0314
	UB	0.58
	UG	-0.299
Predator energy density (eq. 2)	Alpha 1	5591
	Beta 1	7.7183
	Cutoff	151
	Alpha 2	6582
	Beta 2	1.1246

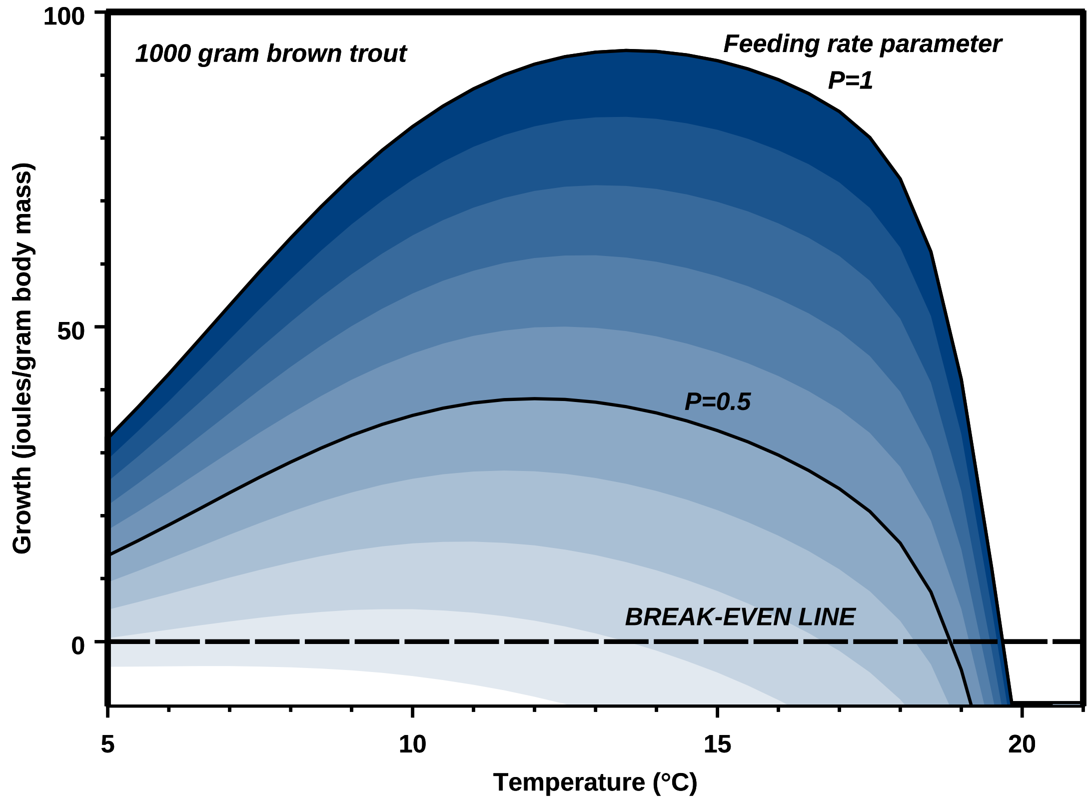

Figure 10. Growth of brown trout, as described by bioenergetics functions. Results are shown for a 1000-gram fish. Net consumption equals respiration at points along the break-even line.

specified. We constructed alternative functions to bracket a plausible range of thermal conditions. These functions are all based on sine curves fitted to surface temperature (Figure 11)

The first function assumes that the fish select the warmest temperature available in the lake, up to 18 ˚C, near the upper of the two temperature modes in observed in July (Barwick et al., 2004). The second function assumes that the fish select the warmest temperature, up to 14˚C, near the upper of the two modes in August. The third function assumes that the fish select the warmest temperature, up to 11˚C, near the lower modes in July and August and near the single mode in September. The three temperature functions have annual ranges of 10-18 ˚C, 10-14 ˚C, and 10-11 ˚C. Corresponding limits to vertical distributions in the lake are shown by the highlighted isotherms in Figure 3.

To estimate the feeding rate parameter P, we fitted simulated growth to observed growth of fish stocked in 2006 and 2007 (Figure 12) for each of the three temperature functions. Initial sizes in the simulations were 80, 130, 300, and 380 g. These values bracket the ranges and the 5^{th} and 95^{th} percentiles of the estimated weights of stocked trout in 2006 and 2007 (see Table 1, Figure 5).

P values were fitted to the nearest 0.05 unit to growth during the first year after stocking (Figure 12). The simulations reproduced both the medians and the ranges of sizes of fish at age 3 (in November; 47 observations); size at age 2.5 (in May; 27 observations) was underestimated. Simulations during the second year after stocking overestimated the November medians. The number of observations seemed too small (6 observations in November; 9 observations for the entire year) and the values to variable to support fitting a separate P value. The effect of reducing P after the first year is examined in the sensitivity analysis below.

To prevent fish from attaining unrealistically large sizes, we applied a logistic function with maximum of 8,000 g to curtail growth of fish between 4,000 and 8,000 g in weight. (The record

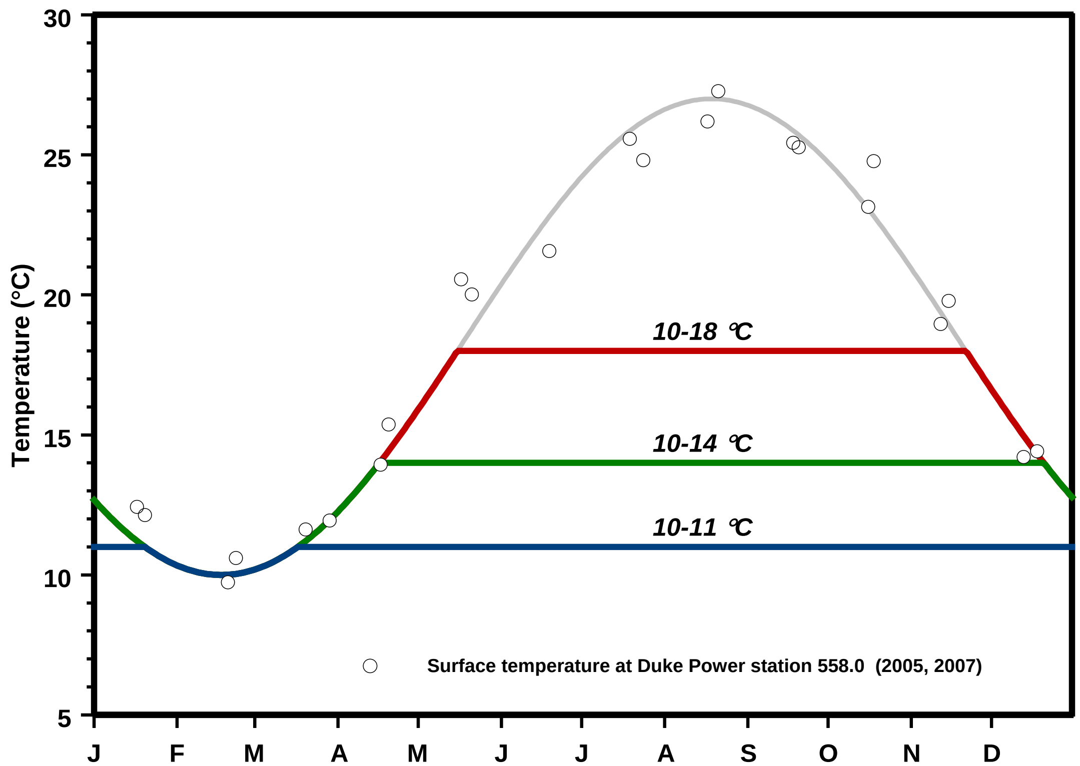

Figure 11. Annual temperature functions. Sine function was fitted to surface temperatures at Duke Power station 558.0 (data provided by Duke Power).

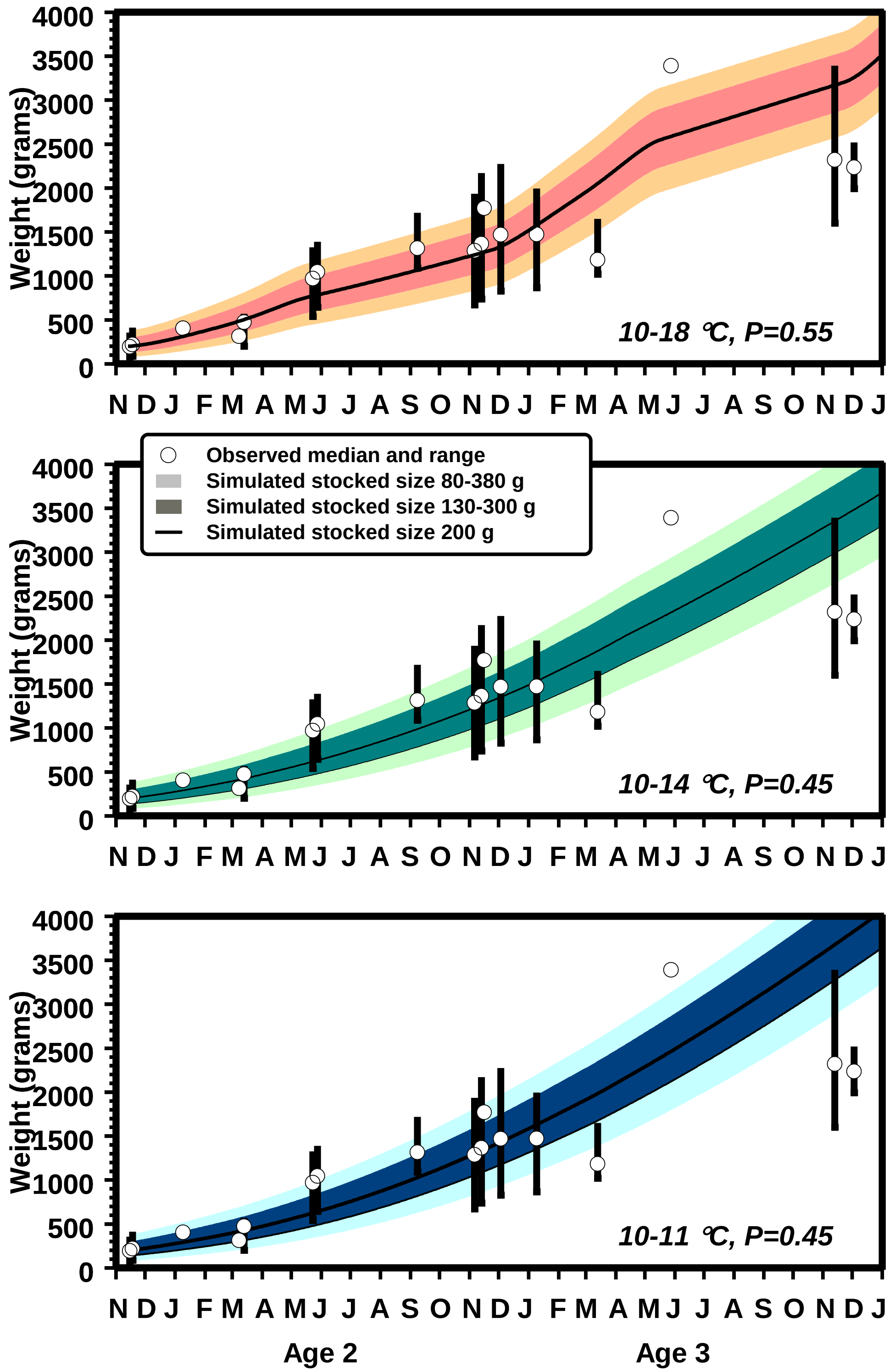

Figure 12. Simulated and observed growth of brown trout in Lake Jocassee. Fish were stocked at age 2. Simulated growth is shown for fish of 80-380 g (outer range) and 130-300 g (inner range) at stocking. Observed growth is shown for cohorts stocked in 2006 and 2007 (Figure 3).

weight for a brown trout from Lake Jocassee is 7.98 kg.) In simulations with the 10-18 ˚C annual temperature function and stocking at age 2 at 200 g, this logistic limitation began at age 4.25 (2.25 years after stocking). A size of 7,000 g was attained at age 6.5 (4.5 years after stocking). Subsequent growth was slow to negligible.

Simulations with the 10-18 ˚C annual temperature function and P=0.55 produced slower growth in summer than in cooler seasons. Simulations with the 10-14 ˚C function and P=0.45 and with 10-11 ˚C function and P=0.45 gave similar results, consistent with the flat response of growth to temperature in the range 10-14 ˚C for P in the range of 0.4-0.5 (Figure 10).

The time of attaining harvestable size (15 in, equivalent to 685 g) ranged from mid-February for a fish of 380 g at stocking in mid-November to mid-September for a fish of 80 g at stocking with the 10-18 ˚C annual temperature function. Corresponding ranges were early March to late September or early October for other two temperature functions.

Population dynamics

Initial populations for the cohorts were set at 25,000 fish stocked in mid-November at age 2, consistent with the current stocking program at Lake Jocassee. Unless noted otherwise, initial size was 200 g, near the median for the brown trout stocked in 2006 and 2007 (Table 1, Figure 5). The effect of size structure in the initial populations is examined in the sensitivity analysis below.

Survival rates were set depending on whether the members of the cohort were below or above the minimum size for harvest. We constructed scenarios with 5, 15, or 25% survival to harvestable size (S_1) and 10, 30, or 50% annual survival of harvestable fish (S_2). We present results in tabular form for all nine scenarios. We illustrate some results in more detail for three of the scenarios: VERY LOW (S_1=5%, S_2=10%), LOW (S_1=15%, S_2=30%), and MODERATE (S_1=25%, S_2=50%).

Survival rates in the VERY LOW scenario correspond to current estimates for the population in Lake Jocassee.

For fish below harvestable size, a daily per capita survival probability was computed from the percentage surviving to harvestable size and the number of days required to attain harvestable size. For a given percentage surviving to harvestable size, the daily survival probability thus varies with the initial size and the bioenergetic model. For fish of harvestable size, a daily per capita survival probability was computed from the annual survival probability. The population of fish was tracked in whole numbers. The number surviving each day was computed as a random binomial function of the daily survival probability.

Growth, forage requirement, and survival were computed daily for each cohort. Because the expected number of fish surviving after 10 years was small for the range of survival rates tested: (8.3 individuals out of 25,000 in the MODERATE survival scenario; 0.4 individuals in the LOW scenario; and <<1 in the VERY LOW scenario), we ended the simulations after ten years. Summary statistics were based on ten one-year age classes. For statistics such as mean weight at death, any fish alive after 10 years were included in the computations as though they had died on the last day of the simulation.

Sensitivity analyses

We tested sensitivity of the model to the temperature function in the VERY LOW, LOW, and MODERATE survival scenarios, using the annual forage requirement for a 10-cohort population as the metric. The annual forage requirement for a 10-cohort population was greatest with the 10-18 ºC annual temperature function. The alternatives did not have a substantial effect. The differences were negligible in the VERY LOW scenario, increasing to <10% in the MODERATE scenario with 10-14 ºC function and to <20% in the MODERATE scenario with the 10-11 ºC function. Because the 10-18 ºC function better represents the range of temperatures selected by marked brown trout in Lake Jocassee (Barwick et al., 2004), we chose it for the simulations. However, we note that the field study was based on fish mainly much larger than fish in age class 2 in the simulations (0.9-1.1 kg in July-September).

The annual temperature range that we chose does not reach 20 ºC, the value accepted as the upper limit for habitat suitable to brown trout in Lake Jocassee. The breakeven point for growth, as modeled, lies below 20 ºC for all values of the feeding rate parameter P. The actual location of this point for Lake Jocassee trout has not been determined.

Because the brown trout stocked into Lake Jocassee span a wide range of sizes, we examined the potential impact of size structure by subdividing the cohorts into subcohorts with different initial sizes. Again, we tested sensitivity of the model in the VERY LOW, LOW, and MODERATE survival scenarios, using the annual forage requirement for a population of 10 cohorts, initiated in 10 successive years, as the metric. We compared simulations initiated with cohorts of 25,000 200-g fish to simulations initiated with cohorts 25,000 fish divided equally among subcohorts of 157-g, 193-g, 219-g, and 254-g fish. These sizes represent the median of the combined stocking data for 2006 and 2007 (200 g) and the medians of the quartiles of the stocking data (157, 193, 219, and 254 g). The subcohorts attain harvestable size at different times, depending on initial weight. We applied the same daily survival rate to each subcohort; the value was computed to give the appropriate total reaching harvestable size from all of the subcohorts combined. The effect of size structure was not substantial. The annual forage requirement was greater by 10% or less for the simulations initiated with size-structured cohorts.

Finally, we examined the impact of reducing the feeding rate parameter P for fish after their second year in the lake. A value of P=0.45 (to the nearest 0.05 unit) gave the best fit to growth from simulated value at end of year 1 in lake (fish of age 3) to the median of the observations at the end of year 2 (fish of age 4). Reducing P from 0.55 to 0.45 after year 1 produced a 4% reduction in the annual forage requirement under the VERY LOW survival scenario, a 16% reduction under the LOW scenario, and a 25% reduction under the MODERATE scenario.

Results

The following results are based on simulations run with the 10-18 ºC annual temperature function and cohorts with initial populations of 25,000 200-g fish, stocked annually on 15 November at age 2.

Weight of fish removed and size at harvest

The mean size at death for fish of harvestable size increased with the annual survival of harvestable fish (Table 4). This mean size varied during year, with the minimum occurring when the youngest cohort attained harvestable size. In the VERY LOW survival scenario, the monthly means varied by a factor of two; the variation diminished with higher survival.

As simulated, 5 metric tons of brown trout were stocked annually. The weight of fish removed from the population before reaching harvestable size was 6.6-7.1 metric tons annually, depending on the survival scenario. The weight of harvestable fish removed, whether by harvest or natural causes, was 1.6-18.1 metric tons annually, depending on the survival scenario.

Forage requirements

Simulated seasonal and annual forage requirements for the brown trout population are summarized in Table 5 (biomass of forage fish) and Table 6 (number of forage fish). We divided the year into three four-month seasons: winter (mid-November to mid-March); spring-early summer (mid-March to mid-July); and later summer-fall (mid-July to mid-November). These seasonal

Table 4. Simulated expected mortality, mean weight at death, and annual weight removed from the brown trout population. S_1 is survival from stocking to harvestable size (15 in); S_2 is annual survival of harvestable fish (≥15 in).

Survival scenario	***Survival***		***Expected annual mortality***		***Mean weight at death (kg)***		***Annual weight removed (metric tons)***	
	S_1	***S_2***	***Fish <15 in***	***Fish ≥ 15 in***	***Fish <15***	***Fish ≥ 15 in***	***Fish <15 in***	***Fish ≥ 15 in***
1 VERY LOW	5%	10%	23,750	1,250	0.30	1.29	7.13	1.6
2	5%	30%	23,750	1,250	0.30	2.03	7.13	2.4
3	5%	50%	23,750	1,250	0.30	2.94	7.13	3.5
4	15%	10%	21,250	3,750	0.33	1.28	7.10	4.7
5 LOW	15%	30%	21,250	3,750	0.33	1.97	7.10	7.2
6	15%	50%	21,250	3,750	0.33	2.91	7.10	10.6
7	25%	10%	18,750	6,250	0.35	1.27	6.57	7.9
8	25%	30%	18,750	6,250	0.35	1.97	6.57	12.2
9 MODERATE	25%	50%	18,750	6,250	0.35	2.92	6.57	18.1

Table 5. Simulated seasonal and annual biomass of forage required by the brown trout population. S_1 is survival from stocking to harvestable size (15 in); S_2 is annual survival of harvestable fish (≥15 in). Winter spans mid-November to mid-March; spring, mid-March to mid-July; late summer-fall, mid-July to mid-November. All cohorts were initiated with fish of age 2 on 15 November.

Survival scenario	***Survival***		***Winter (metric tons)***			***Spring-early summer (metric tons)***			***Late summer-fall (metric tons)***			***Entire year (metric tons)***		
	S_1	***S_2***	***Age class 2***	***Age classes 3-11***	***All***	***Age class 2***	***Age classes 3-11***	***All***	***Age class 2***	***Age classes 3-11***	***All***	***Age class 2***	***Age classes 3-11***	***All***
1 VERY LOW	5%	10%	9.5	1.1	10.6	2.5	0.7	3.2	1.4	0.4	1.9	13.5	2.2	15.7
2	5%	30%	9.5	3.7	13.2	2.7	3.4	6.1	2.1	2.7	4.8	14.3	9.8	24.1
3	5%	50%	9.5	8.5	18.1	2.8	8.9	11.7	2.6	7.7	10.3	14.9	25.2	40.1
4	15%	10%	13.1	3.0	16.2	7.1	2.1	9.2	4.4	1.1	5.5	24.7	6.2	30.9
5 LOW	15%	30%	13.1	10.0	23.1	7.7	9.3	17.0	6.7	7.0	13.7	27.5	26.2	53.7
6	15%	50%	13.1	25.0	38.1	7.9	26.1	34.0	8.1	22.6	30.7	29.1	73.7	102.8
7	25%	10%	15.5	4.9	20.4	11.8	3.3	15.1	7.5	1.7	9.2	34.8	10.0	44.7
8	25%	30%	15.5	17.0	32.5	12.7	15.9	28.6	11.3	11.8	23.2	39.5	44.8	84.2
9 MODERATE	25%	50%	15.5	43.4	58.9	13.2	45.5	58.7	13.9	39.6	53.5	42.5	128.5	171.0

Table 6. Simulated seasonal and annual numbers of forage fish required by the brown trout population. S_1 is survival from stocking to harvestable size (15 in); S_2 is annual survival of harvestable fish (≥15 in). Winter spans mid-November to mid-March; spring, mid-March to mid-July; late summer-fall, mid-July to mid-November. All cohorts were initiated with fish of age 2 on 15 November.

Survival scenario	***Survival***		***Winter (millions)***			***Spring-early summer (millions)***			***Late summer-fall (millions)***			***Entire year (millions)***		
	S_1	***S_2***	***Age class 2***	***Age classes 3-11***	***All***	***Age class 2***	***Age classes 3-11***	***All***	***Age class 2***	***Age classes 3-11***	***All***	***Age class 2***	***Age classes 3-11***	***All***
1 VERY LOW	5%	10%	1.7	0.2	1.9	0.6	0.2	0.7	0.4	0.1	0.6	2.7	0.5	3.2
2	5%	30%	1.7	0.7	2.4	0.6	0.8	1.4	0.6	0.8	1.5	2.9	2.3	5.2
3	5%	50%	1.7	1.5	3.2	0.6	2.1	2.7	0.8	2.3	3.1	3.1	5.9	9.0
4	15%	10%	2.3	0.5	2.9	1.6	0.5	2.1	1.4	0.3	1.7	5.3	1.3	6.7
5 LOW	15%	30%	2.3	1.8	4.1	1.8	2.1	3.9	2.0	2.1	4.1	6.1	6.0	12.2
6	15%	50%	2.3	4.5	6.8	1.8	6.1	7.9	2.4	6.8	9.2	6.6	17.4	23.9
7	25%	10%	2.8	0.9	3.6	2.7	0.7	3.4	2.3	0.5	2.9	7.8	2.2	9.9
8	25%	30%	2.8	3.0	5.8	2.9	3.7	6.6	3.4	3.6	7.0	9.1	10.3	19.4
9 MODERATE	25%	50%	2.8	7.8	10.5	3.1	10.6	13.7	4.1	11.9	16.0	10.0	30.2	40.2

boundaries coincide with the times of brown trout stocking (November), forage fish assessments in Lake Jocassee (November and March), and forage fish assessment in Lake Norman (July and November or December). Forage requirements are also summarized for age class 2 (the most recently stocked fish) and age classes 3-11.

Converting the simulated prey requirements from biomass to numbers of prey required assumptions about initial prey size and growth during the season. For winter, we used the 2000-2005 median of the average size (5.6 g) in Lake Jocassee and assumed that growth during the season was negligible. This assumption seems plausible, given the temperatures and low productivity of the lake. For spring-early summer, size distributions of the forage fishes are likely to change substantially, decreasing as recruitment begins in late spring. Assuming that growth from July to November in Lake Jocassee was proportional to growth in Lake Norman, we set the average size in July at 1.87 g or one-third the average size in November. We assumed that recruitment began in mid-May and average weight decreased linearly from 5.6 g on 15 May to 1.87 g on 15 July. Finally, we assumed that the average weight increased linearly from 1.87 g on 15 July to 5.6 g on 15 November. The daily biomass of prey was divided by the average weight of forage fish on that day to estimate the number of forage fish required. These computations assume that predation by the brown trout is not size-selective. If the brown trout consume prey larger or smaller than the average size, the number of prey consumed changes inversely.

The annual forage requirement for the brown trout population depended strongly on survival (Tables 5 and 6, Figure 13), varying by an order of magnitude (16 to 171 metric tons or 3.2 to 40.2 million fish) over the range of values tested. In the VERY LOW survival scenario, age class 2 dominated the forage requirement, and the heaviest demand occurred immediately after stocking

(Tables 5 and 6, Figure 14). With increasing survival, the older age classes made greater contributions.

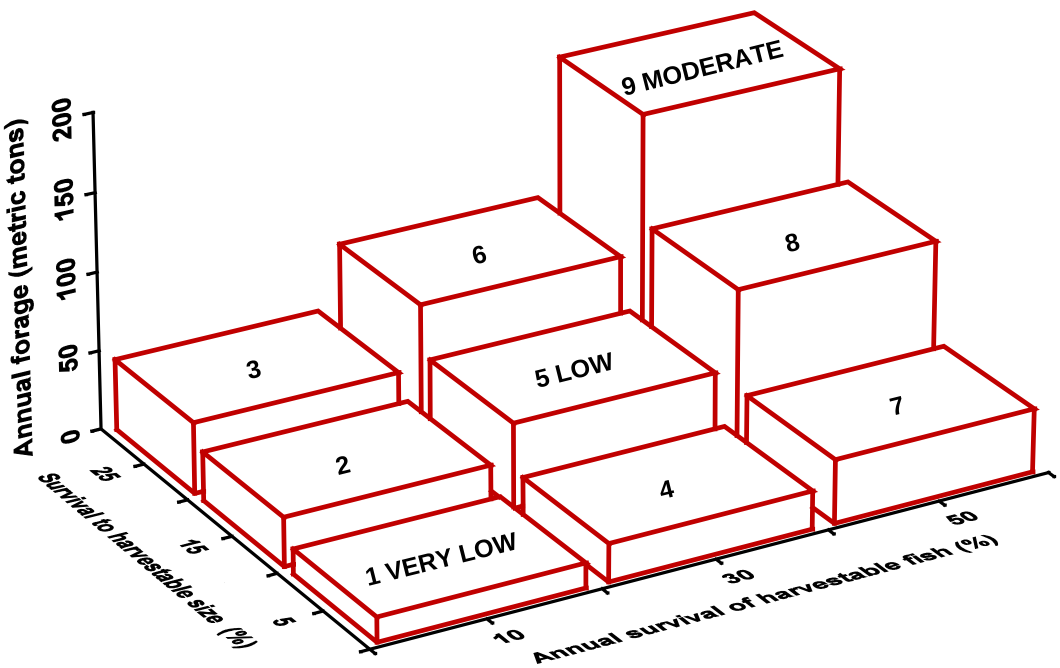

Figure 13. Simulated annual forage requirement. Blocks are labeled with scenario numbers. Data are presented in Table 5.

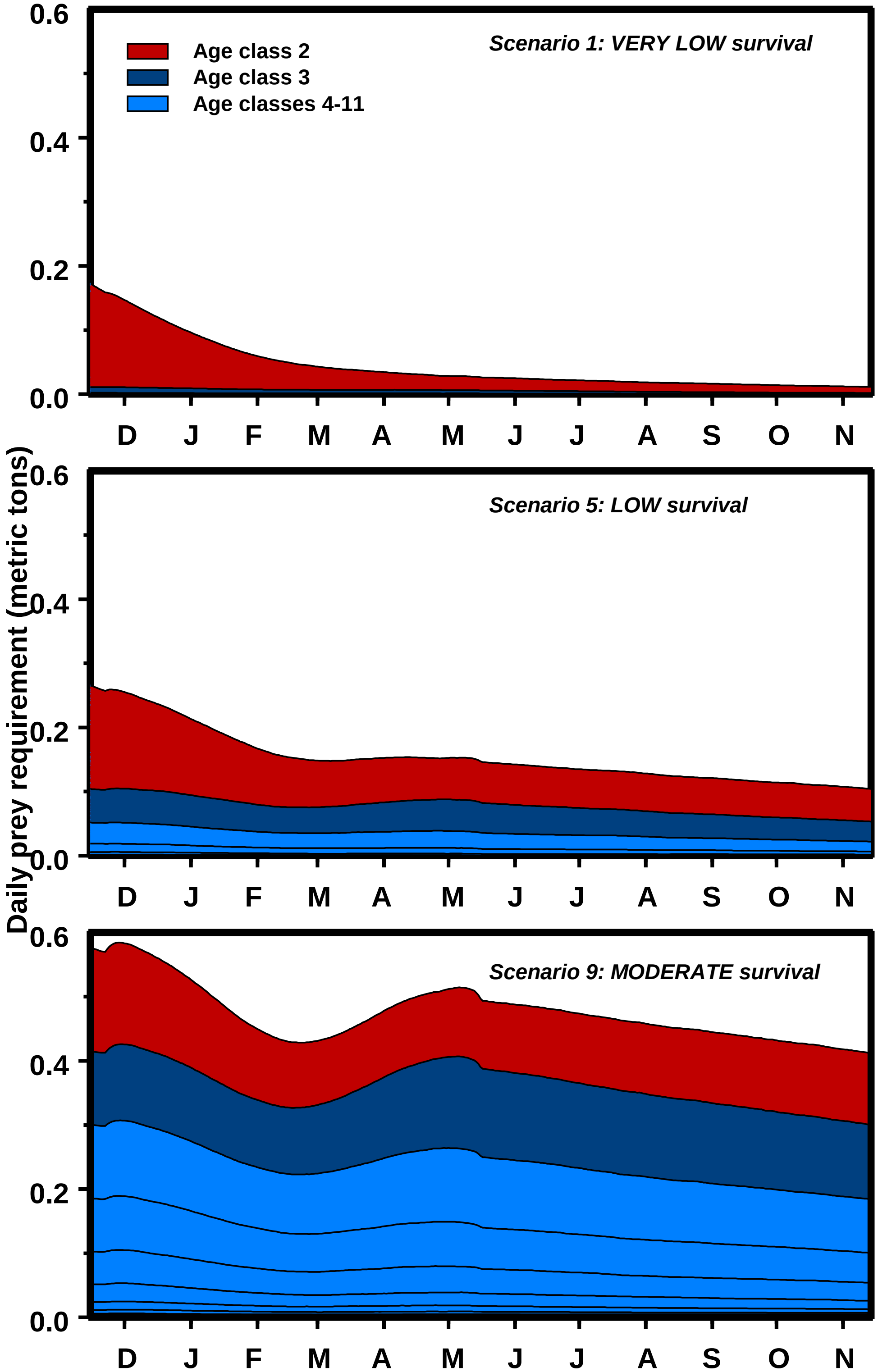

Figure 14. Simulated daily forage requirement. All cohorts were initiated with fish of age 2 on 15 November.

The simulated forage requirement is sensitive to the shape of the survival curve, particularly for age class 2. In Scenario 1, if most of the mortality occurred shortly after the cohort was stocked, rather than at a constant per capita rate, the winter forage requirement for the population could decrease by as much as 75%. If most of the mortality occurred shortly before the cohort attained harvestable size, the winter forage requirement for the population could increase by as much as 250%.

Comparison of forage requirements with forage populations in Lake Jocassee

We compared simulated forage requirements of brown trout with forage populations in Lake Jocassee on a seasonal basis. During winter, recruitment of forage fish is negligible. We used fall data from the annual hydroacoustic surveys (1989-2005, see Figure 9) to estimate the resource potentially available to brown trout for the entire season. Because threadfin shad and blueback herring spawn in late spring and early summer, we used spring data from hydroacoustic surveys to estimate the amount forage available during the spring only (mid-March to mid-May). We recomputed the forage requirement accordingly. There are few data on forage fish populations in Lake Jocasee in summer. Based on the abundance patterns for Lake Norman, we assumed that mid-July populations were four times greater than fall populations. Assuming further that recruitment after mid-July was negligible, we used these values to estimate the resource for brown trout during late summer-fall.

For Scenario 1 (VERY LOW survival), which we believe most closely describes the population in Lake Jocassee, the simulated forage requirement during winter was typically about half of the forage available in Lake Jocassee (Table 7, Figure 15). It exceeded the available forage in two of the 17 years. During spring, before recruitment to the forage population has begun, the simulated forage requirement was typically about a third of the forage available, but exceeded the available forage in

Table 7. Simulated forage requirements of brown trout for Scenario 1 (VERY LOW survival) during winter, spring, and late summer-fall, compared with forage fish populations in Lake Jocassee, 1989-2005. Percentages exceeding 100% are marked in red boldface. Note that spring spans two months only; early summer is not included.

Season	*Simulated requirement compared with forage population (1989-2005)*	
	Percentage (median, range)	***N of years >100%***
Winter (mid-November to mid-March)	48% (14%-**157%**)	2 of 17
Spring (mid-March to mid-May)	33% (8%-**4830%)**	4 of 16
Late summer-fall (mid-July to mid-November)	4% (1%-12%)	0 of 17

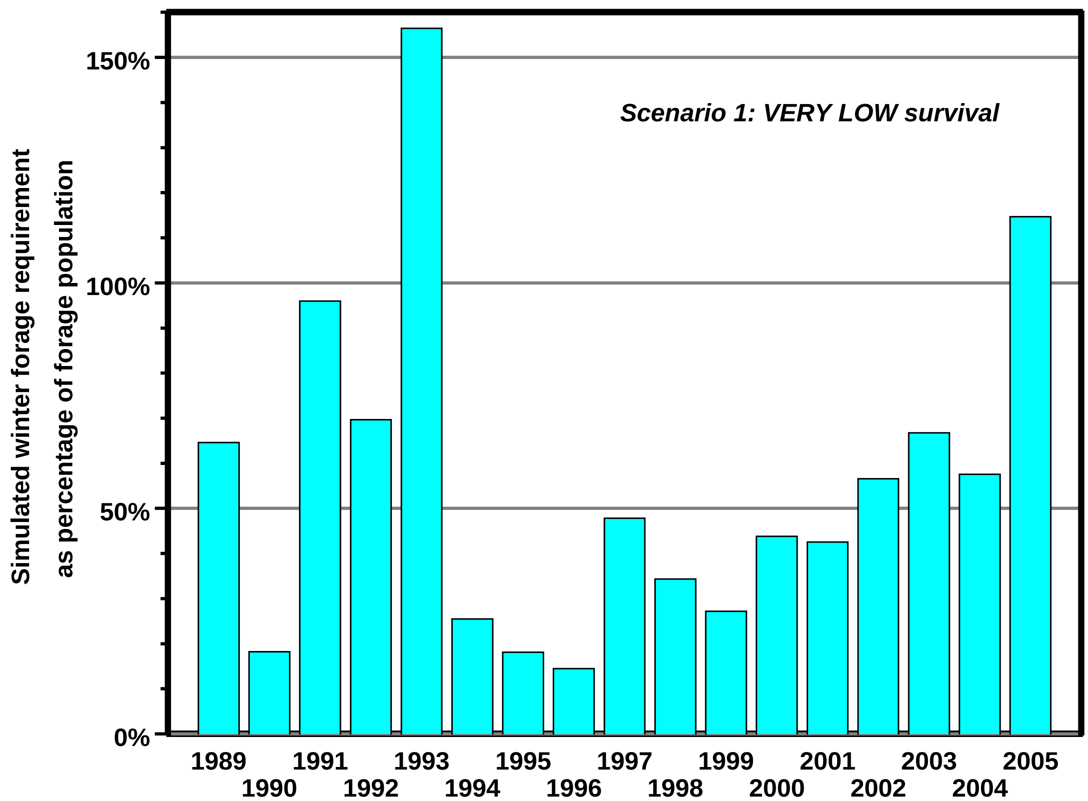

Figure 15. Simulated winter forage requirement as percentage of forage population, 1989-2005.

four of the 16 years. During late summer-fall, the simulated forage requirement was typically about 4% of the forage available and was always much less (12% at maximum) than the available forage.

The other scenarios predicted greater demands on the winter forage populations (Table 8). For Scenario 5 to 9, winter forage requirements exceeded the forage populations in many or most years. In a typical year, represented by the median fall forage population, forage would be completely consumed by mid-February in Scenario 5 and by mid-December in Scenario 9, if the brown trout were able to sustain the modeled feeding rate (Figure 16). Given the potential impact of these demands on the dynamics of the forage populations, we did not extend the comparisons for Scenarios 2 to 9 to the other seasons.

The model predicts the amount of forage required to sustain the modeled feeding rate and corresponding growth, but does not account for density-dependencies of feeding rates. Under the conditions otherwise identical to those modeled in Scenarios 1-9, attainment of harvestable size was delayed by more than a year when the feeding rate parameter was reduced by about one-third (from P=0.55 to P=0.35). Attainment of harvestable size did not occur when the feeding rate parameter was reduced by one-half. A substantial reduction in forage, such as predicted in winter, would likely affect energy expenditure on foraging, as well as feeding rates, with additional consequences for growth, condition, and possibly survival.

Table 8. Simulated forage requirements of brown trout for all scenarios during winter, compared with forage fish populations in Lake Jocassee, 1989-2005. Percentages exceeding 100% are marked in red boldface. S_1 is survival from stocking to harvestable size (15 in); S_2 is annual survival of harvestable fish (≥15 in). Winter spans mid-November to mid-March.

Survival scenario	***Survival*** S_1	***Survival*** S_2	***Simulated requirement compared with forage population (1989-2005)*** *Percentage (median, range)*	*N of years >100% (of 17)*
1 VERY LOW	5%	10%	48% (14%-**157%**)	2
2	5%	30%	60% (18%-**195%**)	3
3	5%	50%	81% (25%-**267%**)	6
4	15%	10%	73% (22%-**238%**)	5
5 LOW	15%	30%	**104%** (31%-**340%**)	9
6	15%	50%	**172%** (52%-**563%**)	12
7	25%	10%	92% (28%-**301%**)	8
8	25%	30%	**146%** (44%-**479%**)	12
9 MODERATE	25%	50%	**266%** (80%-**869%)**	16

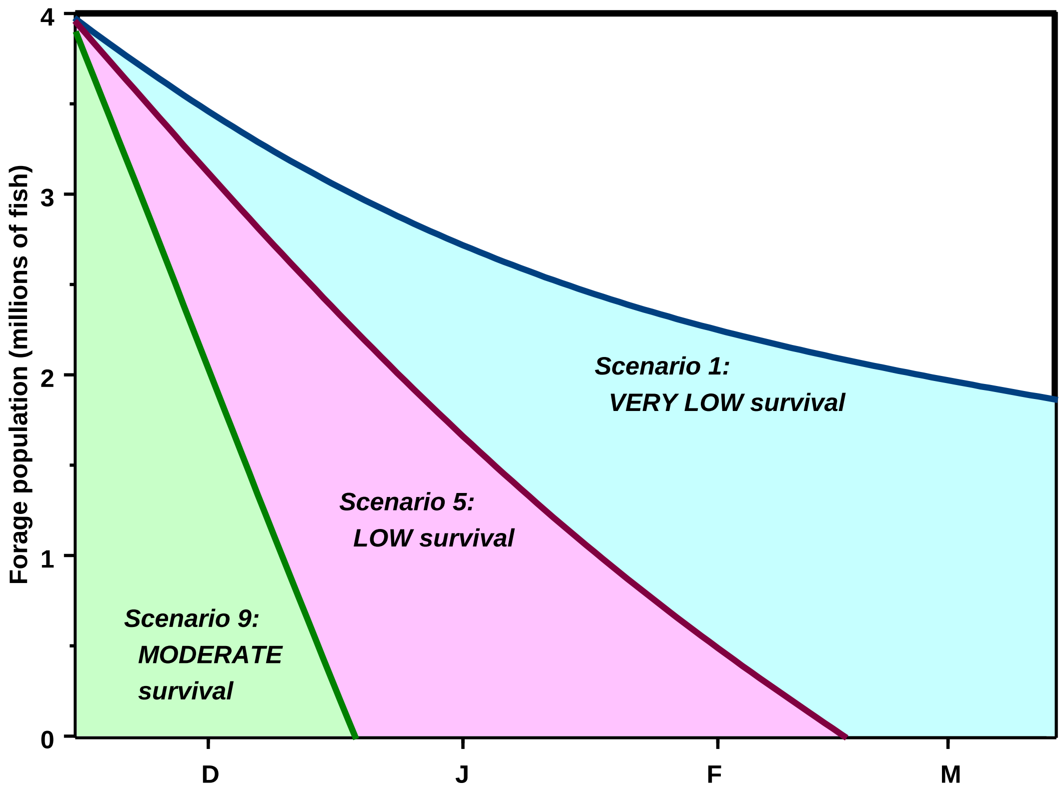

Figure 16. Impact of simulated brown trout predation on the median winter forage fish population in Lake Jocassee. Initial population of forage fish is 4 million, the median from November hydroacoustic surveys (1989-2005) in Lake Jocassee. Decline in forage fish population is due only to predation by brown trout; no other source of mortality is estimated.

Discussion

During most of the winter season (defined as mid-November to mid-March for these analyses), temperatures throughout the water column are thermally suitable (<20 °C) for brown trout (see Figure 3). The entire forage population should thus be accessible, and vulnerable, to the trout. In Scenario 1, which we believe most closely describes the population in Lake Jocassee, the winter forage requirement (1.9 million fish) is large enough to account for a substantial portion of the typical winter decline in forage fish (median decline of 2.6 million fish in 1989-2005). During winter, the brown trout in Lake Jocassee grow (see Figure 6), but relative body condition remains unchanged (see Figure 7).

Forage populations are at an annual low in spring (mid-March to mid-May for these analyses), prior to reproduction and recruitment. However, the number of forage fish, relative to simulated forage requirements for Scenario 1, was adequate in most years. The entire water column remains thermally suitable for brown trout through mid-May (see Figure 3); and nearshore aggregations of forage fish may further enhance availability of the forage fish to the trout. It is plausible that these aggregations permit the improvement in condition, and possibly faster growth, observed between March and May.

With the forage populations replenished by recruitment, conditions for the brown trout should remain favorable from mid-May through mid- to late June. By late June, the upper strata of the lake warm to temperatures above the range preferred by the trout. This constriction of habitat, which reduces access of trout to the forage fish, becomes substantial after mid-July: the upper 20-30 m of the water column is thermally unsuitable.

During late summer-fall, the supply of forage substantially exceeded the simulated requirements for Scenario 1. However, thermal stratification probably isolates the brown trout from a substantial portion of this resource. We suggest that this isolation of the trout from their forage explains the consistent deterioration of condition between May and November (see Figures 2, 7).

Thus, the field data, combined with simulation results from the VERY LOW survival scenario, give a picture of a population that experiences a short season of abundant forage in spring and, possibly, early summer. During late summer-fall, forage is abundant, but thermal stratification limits access by the trout. During the winter season, forage is initially abundant, but becomes depleted, due in part to predation by the trout. The depletion of forage may limit improvement in condition over the winter in some years, although it does not severely curtail growth. The seemingly paradoxical improvement of condition in early spring is considered above.

Substantial winter depletion of the resource is predicted under the most stringent of the survival scenarios, and the simulation results suggest that the forage base in Lake Jocassee has limited capacity to support improvements in the brown trout fishery. Increasing the annual harvest by a factor of 3 or 5 by raising survival to harvestable size (Table 4, Scenarios 4 and 7) would increase the winter forage requirement by 60 or 90% (Table 5). These requirements would exceed the forage supply in 5 years (Scenario 4) or 8 years (Scenario 7) of the 17-year record (Table 8). Alternatively, increasing the mean weight at death of harvestable fish by a factor of 1.6 to 2.3 by raising the annual survival of harvestable fish (Table 4, Scenarios 2 and 3) would increase the winter forage requirement by 30 to 70% (Table 5). These requirements would exceed the forage supply in 3 years (Scenario 4) or 6 years (Scenario 7) of the 17-year record (Table 8).

Other piscivores will further reduce the forage available in Lake Jocassee. In terms of total biomass, redeye bass is similar in abundance to brown trout in the gill net samples (130% of brown trout biomass in 2007; 60% in 2008; data from D. Rankin, SC DNR). Rainbow trout are probably not sampled so efficiently in the gill net samples (25% of brown trout biomass in 2007; 7% in 2008; data from D. Rankin, SC DNR). In the creel surveys, however, rainbow trout were similar in abundance to brown trout (93 %of brown trout biomass in 2006; 137% in 2007). Evaluation of the effects of these other species would require additional bioenergetic simulations.

Entrainment by the Bad Creek Pumped Storage Station probably has a negligible effect on the forage populations under routine conditions. Reported entrainment rates for the station are 5-18 fish/hr under routine conditions, but range up to 467 fish/hr under special conditions, such as water levels more than 4.3 m below full pool (Barwick et al., 1994). Pumping typically occurs at night and over weekends, when consumer demand for power ie lower. If we assume pumping at an average rate of 12 hr/day, the routine entrainment rates would result in removal of 7,000-26,000 forage fish during the winter season. Given that fall forage populations were 1.2-13.1 million fish (Figure 9), the impact of routine pumping should be negligible. The elevated rates observed under special conditions, if applied at 12 hr/day for the entire season, would result in removal of 120,000 forage fish during the winter season. Thus, except in years of exceptionally low fall forage populations, the impact of elevated entrainment would be small, even if the special conditions occurred throughout the season.

We caution that results from these analyses should not be interpreted to give precise predictions about the brown trout population in Lake Jocassee. Among the various uncertainties, perhaps the most important concerns survival of brown trout from stocking to harvestable size. The estimated rate was unexpectedly low. Because the youngest age class accounts for such a high proportion of the resource demand in the most realistic survival scenario, the timing of their mortality greatly affects the forage requirement.

Knowing when the stocked fish disappear is important; knowing why is even more important to broader management issues. Because the available forage seems adequate in most winters (unless the bulk of the preharvest mortality occurs late in the season), predation, illegal harvest, catch-and-release mortality of deep-caught trout, or failure to adapt to the wild are possible explanations.

If we are correct in our inferences about low survival of stocked fish, the losses must provide a substantial subsidy to some component of the system. If the fish are lost shortly after stocking, the subsidy is 4.75 metric tons, equivalent to 20-50% of the November standing stock of forage fish (see

Table 2). In Scenario 1, that quantity increases to 6.6 metric tons, equivalent to 25-70% of the November standing stock. Whether these young trout are consumed by older trout, by other piscivores, or by detritivores, their impact in the system may be substantial.

Recommendations

1) Investigate the fate of stocked brown trout during the 6-month period after stocking. Tagging fish with radiotransmitters may prove useful.
2) Obtain additional data to refine estimates of changes in growth and condition. Additional samples in April and in summer are needed.
3) If the spring stocking program resumes, use different marks for spring- and fall-stocked cohorts for at least two years; assess growth and survival.

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Appendix F

SARP Project Status Report

Restoration of Southern Appalachian Brook Trout in Jocassee Gorges, South Carolina

SARP Project Status Report

Restoration of Southern Appalachian Brook Trout in Jocassee Gorges, South Carolina

(Agreement # 090114-01)

March 2015

Submitted by: Dan Rankin

__A. Project Description:__ The Eastern Brook Trout (*Salvelinus fontinalis*) has been in decline for over a century, not only in South Carolina but throughout the eastern United States. A previous SARP/EBTJV Assessment of Jocassee Gorges area streams revealed only one viable brook trout population. We propose to restore self-sustaining populations of southern Appalachian strain of the Eastern Brook Trout to Reedy Cove Creek, Willis Creek, Laurel Branch, and Howard Creek. Restoration of three streams will involve "chop-and-drop" additions of large wood (LWD) to mobilize sediment, restore pool habitat, expose gravel spawning substrate, and increase productivity. This habitat enhancement phase will be followed-up by adding brook trout from source streams. These restoration techniques have been highly successful in other SC streams.

Howard Creek restoration will involve removal of non-native trout using piscicides, followed by habitat restoration and stocking of brook trout. Howard Creek restoration is contingent upon NEPA scoping and approval by USDA Forest Service. Alternate Jocassee Gorge stream(s) of equal habitat (stream distance restored) may be substituted for if conditions dictate.

B. Status Update:

1. Genetics Assessment of Brook Trout Source Populations

A team of SCDNR Biologists, Technicians, Clemson University Intern Students, and Furman University Volunteers collect brook trout in Falls Creek, Greenville County, S.C.

Restoration of the southern Appalachian Strain (or genotype) of brook trout in South Carolina is contingent upon selection of appropriate source populations that represent both the native genotype, and are sufficiently adapted for the receiving habitat. Source populations also need to maintain adequate genetic diversity. To guide this project we have collaborated with Clemson University and researchers at the University of Massachusetts-Amherst to update information on genetics of potential source populations in S.C. (see attached study agreement). Tissue samples from nine S.C. brook trout populations were collected and prepared thus far. Tissue samples have been analyzed by researchers. A copy of the preliminary genetics study report from Clemson University is included in this progress report.

A bucket of brook trout sampled from Falls Creek, S.C., await work-up and tissue collection (fin clip) as part of a comprehensive genetics study to determine the best restoration source populations in S.C.

2. Howard Creek Brook Trout Restoration Progress Update

Restoration of brook trout in Howard Creek requires NEPA scoping for US Forest Service Property due to proposed use of Antimycin (Fintrol) to remove non-native fish. SCDNR has worked with USFS on the development of an Environmental Assessment (EA) for this project. EA development is progressing on schedule for our projected summer 2015 renovation. SCDNR staff, along with volunteer support from Trout Unlimited, has cleared access trails on Howard Creek and are currently working to assess stream gradient, discharge studies, and preparatory work for Antimycin applications. SCDNR staff is also currently coordinating with Biologists from Great Smokey Mountains National Park (GSMNP) to plan and implement this project. GSMNP staff will provide in-kind assistance on the project to allow for staff training. SCDNR staff also coordinated with Clemson University to plan pre-and post-Antimycin application sampling of non-target aquatics in Howard Creek. Proposed Howard Creek restoration will involve: removal of non-native rainbow trout using Antimycin (summer 2015), addition of southern Appalachian brook trout (summer 2015), habitat enhancement by addition of large wood (winter 2015), and possible addition of limestone to increase alkalinity.

Comprehensive planning and NEPA scoping is underway on Howard Creek, S.C. between resource partners at USDA Forest Service and SCDNR

3. Big Laurel and Little Laurel Creek Habitat Enhancement and Restoration to Support Brook Trout

SCDNR staff added over 150 pieces of "Large Wood" (LWD) to a 1.5 kilometer reach of Laurel Creek and over 100 pieces of LWD to a 1 km reach of Little Laurel Creek on Jocassee Gorges Property. Large trees were directionally felled and then cut, bucked, rolled, and pulled into Laurel Creek. A previous SARP/EBTJV sponsored assessment of habitat in this stream (and other Jocassee streams) revealed a deficiency of LWD and available pool habitat. Gravel spawning substrate was also potentially limited. Dropping LWD into headwater streams has proven an effective tool to enhance habitat and cover for brook trout. Large wood also increases scour of excessive coarse sand bedload sediment, thus exposing and increasing critical gravel spawning substrate for brook trout.

SCDNR Crew Members Kenson Kanczuzewski, Joey Hazel, Jon Davis, and Vic Blackwell add a big log to Laurel Creek, S.C. to enhance habitat for brook trout.

Addition of LWD has also proven to enhance invertebrate populations, the primary food source for brook trout. Addition of LWD in King Creek, S.C. resulted in a 50% increase in macro-invertebrate abundance, with no compromise to species diversity.

Native southern Appalachian adult brook trout will be trans-located from appropriate source stream(s) into Laurel Creek in late summer-early fall 2015, prior to fall spawning season. SCDNR biologists and technicians will monitor for successful reproduction in summer 2016. Additional adult brook trout will be planted in Big and Little Laurel Creeks prior to fall 2016 spawning season as needed.

SCDNR brook trout habitat enhancement on Laurel Creek in progress

Appendix G

Progress Report on a Project Titled

"Genetic Assessment of Eastern Brook Trout Populations in South Carolina"

Progress Report on a Project Titled

“Genetic Assessment of Eastern Brook Trout Populations in South Carolina”

Submitted to South Carolina Department of Natural Resources

Yoichiro Kanno and Kasey C. Pregler

Department of Forestry and Environmental Conservation

Clemson University

March 31, 2015

SUMMARY

This brief progress report describes the current status of the project entitled "Genetic Assessment of Eastern Brook Trout Populations in South Carolina" (project period from 01/28-2015 to 12/31/2015). To date, 499 young-of-the-year (YOY) individuals from seven stream patches (Crane Creek, Falls Creek, Headforemost Creek, Jacks Brook, Kings Creek, Matthews Creek and Pig Pen Brook) have been genotyped with 12 loci and preliminary analyses of genetic diversity are described in this progress report. Genetic diversity was generally low relative to other studies of brook trout. Matthews Creek appears to retain the highest genetic diversity among the seven streams, whereas Jacks Brook and Headforemost Creek have the lowest genetic diversity and some loci were fixed with a single allele. Numbers of breeders (N_b) varied from 14 (Crane Creek) to 115 (Matthews Creek) based on the linkage disequilibrium method applied on single-generation samples, but these values need to be assessed further by taking into possible spatial structure within patches due to movement barriers. A discriminate analysis of principle components indicated that Jacks Branch and Kings Creek are genetically similar. Our microsatellite data contain richer information compared to a previous allozyme study conducted in South Carolina in the 1990's and our continued work should characterize genetic diversity and integrity of brook trout populations more accurately.

METHODS

Sample Collection

Samples for this study were collected between July 2014 and November 2014 by South Carolina Department of Natural Resources fisheries biologists. Brook trout were sampled using backpack electrofishing from 7 stream patches in upstate South Carolina in Oconee, Pickens, and Greenville Counties. Study stream patches included Crane Creek, Falls Creek, Headforemost Creek, Jacks Brook, Kings Creek, Matthews Creek and Pig Pen Brook. Effort was made to sample lower, middle and upper sites within each patch in order to obtain a representative sample of individuals (Whiteley et al. 2012). Smaller patches contained only two sites (Crane Creek, Headforemost Creek, and Jacks Branch) and a large patch contained five sites (Matthews Creek). All captured individuals were measured for total length and weight, and non-lethal anal or caudal fin clips were retained in dry coin envelopes. We sub-sampled a total of 499 YOY individuals and genetic samples were shipped out to Dr. Andrew Whiteley's laboratory at University of Massachusetts Amherst for laboratory analysis. Samples were genotyped using 12 microsatellite markers: *Sfo*C113, *Sfo*C88, *Sfo*D100, *Sfo*D75, *Sfo*C24, *Sfo*C115, *Sfo*C129, *Sfo*B52, *Sfo*C86, *Sfo*D91a, *Sfo*C38 (King et al. 2003) and *Ssa*D237 (King et al. 2005).

Statistical Analysis

Genotype data were analyzed using program GENEPOP (Raymond & Rousset 1995) to generate summary statistics and allelic diversity; including number of alleles, the proportion of observed (*Ho*) and expected (*He*) heterozygotes, and to assess the conformity of loci to Hardy-Weinberg equilibrium. We used a Bonferroni-corrected p-value (alpha value of 0.05 divided 12 loci = 0.0041) for Hardy-Weinberg tests due to multiple testing. Number of breeders (N_b) was inferred at both the stream patch and site (upper, middle, or lower) level using the linkage disequilibrium method in program NeEstimator 2.01 (Do et al. 2013) using a monogamous mating system and a minimum allele frequency of 0.02, following the method of Whiteley et al. (2013). Although inference of N_b at the patch level is of primary interest, we estimated N_b at the site level as well because the linkage disequilibrium method is sensitive to spatial population structure within a study area and we have not had a chance to examine meta-population structures of brook trout within patches due to movement barriers. When the linkage disequilibrium method is applied for single-cohort samples (e.g. YOY only), the model output produces the number of spawners that gave rise to the cohort (N_b). To evaluate genetic clustering among stream patches, a discriminate analysis of principle components (DAPC) was performed using the adagenet package (Jombart 2008) in program R (R Development Core Team 2013). A DAPC was performed using the 7 stream patches as the predetermined number of clusters (k). A second DAPC was performed where clusters were determined using the *find.cluster* function for k ranging from 1 to 40. Clusters were evaluated using Bayesian Information Criterion (BIC) to determine the appropriate k value. A DAPC analysis was performed for each grouping using the *dapc* function for the best k identified as described above. We retained all axes of the principal component analysis to explain the variation within the data, and created an ordination plot with the first and second components to visualize the clusters.

RESULTS & DISCUSSION

The total number of alleles per locus in a population ranged from 1 (present in at least 1 locus at every stream patch except Matthews Creek) to 13 at *Ssa*D-237 (Matthews Creek). Locus *Sfo*C-38 had the lowest allelic diversity across stream patches. Mean expected heterozygosity ranged from 0.2083 (Jacks Branch) to 0.6172 (Matthews Creek), and mean F_{is} ranged from -0.1241 (Jacks Brook) to 0.1147 (Falls Creek) (Table 1). Tests of deviation from Hardy-Weinberg proportions were significant in7 of 69 tests (Bonferroni corrected p-value < 0.0041) (Table 1). King Creek had the most significant cases at 3 of the 12 loci. Our genetic clustering results showed that of the 7 stream patches, 6 appear to be distinct clusters; the k-means clustering BIC results provided evidence for 6 distinct clusters rather than 7 (Figure 1). The Jacks Branch and King Creek clusters were genetically indistinguishable from each other (Figure 2). Number of breeders was low ($N_b < 25$) across stream patches, except for Matthews Creek ($N_b = 115.4$) and Pig Pen Brook ($N_b = 53.1$) (Table 2). At the site scale (lower, middle, or upper, N_b is variable and ranges from 6.4-318.1 (Table 3). Confidence intervals are very wide at the stream site scale, with infinite upper 95 % confidence interval values. These results suggest data may not be appropriate to accurately estimate N_b at this scale.

Future work will include genetic samples from the remaining streams, as well as hatchery fish (to test hatchery introgression). Genetic diversity varies among streams, with Matthews Creek characterized with notably high diversity so far and Headforemost Creek and Jacks Branch possessing very low diversity. Our set of 12 microsatellite loci contain more rich information relative to a previous allozyme study in South Carolina (see Table 4 of Guffey no date). This property should result in a more accurate ranking of stream sites based on genetic diversity and robust assessment of hatchery introgression down the road.

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Table 1. Summary statistics and allelic diversity for 12 microsatellite loci for brook trout collected across 7 stream patches in South Carolina. Number of individuals genotyped (*n*), number of alleles (*A*), observed (*Ho*) and expected (*He*) heterozygosity, inbreeding coefficient (*Fis*), and p-values for Fisher's exact test for Hardy-Weinberg equilibrium (*HW*).

	C-113	C-88	D-100	D-75	C-24	C-115	C-129	D-237	B-52	C-86	D-91a	C-38
Crane Creek (*n* = 60)												
Ho	0.75	0.7	0.7166	0.6833	0.55	0.8166	0.7	0.8667	0.6333	0.3	0.8667	0
He	0.7213	0.7075	0.7142	0.6719	0.5964	0.8187	0.6309	0.8306	0.5514	0.3145	0.7365	0
A	5	5	4	6	4	8	4	11	5	3	7	1
Fis	-0.4	0.0108	-0.0034	-0.0171	0.0786	0.0026	-0.1105	-0.0437	-0.15	0.0466	-0.1785	NA
HW	0.8442	0.4667	0.1196	0.3460	0.0342	0.0008	0.3819	0.0743	0.2945	0.2309	0.0000	NA
Falls Creek (*n* = 75)												
Ho	0.5333	0.24	0.1733	0.6666	0.1333	0.5333	0.24	0.0666	0	0.7333	0.08	0.16
He	0.5500	0.3376	0.1851	0.7572	0.1703	0.6331	0.3164	0.0900	0	0.6582	0.0780	0.1626
A	4	3	3	7	2	6	4	3	1	3	3	2
Fis	0.0306	0.2905	0.0642	0.1203	0.2186	0.1585	0.2428	0.2611	NA	-0.115	-0.0254	0.0164
HW	0.2048	0.0260	0.5424	0.0363	0.1110	0.0220	0.0281	0.1407	NA	0.4694	1.0000	1.0000
Headforemost Creek (*n*= 82)												
Ho	0.4512	0	1	0	0	0.3292	0.4634	0.5609	0.5243	0	0.1707	0
He	0.4969	0	1	0	0	0.4194	0.4041	0.5015	0.4736	0	0.1569	0
A	2	1	2	1	1	2	2	3	2	1	2	1
Fis	0.0926	NA	NA	NA	NA	0.216	-0.1476	-0.1194	-0.108	NA	-0.0889	NA
HW	0.5105	NA	NA	NA	NA	0.0663	0.2750	0.3010	0.3581	NA	1.0000	NA
Jacks Branch (*n* = 30)												
Ho	0	0.4	0.6	0.6333	0	0.0666	0.8	0.0666	0	0	0.4	0
He	0	0.3254	0.4881	0.4943	0	0.0655	0.6096	0.0655	0	0	0.4519	0
A	1	2	2	2	1	2	3	2	1	1	2	1
Fis	NA	-0.234	-0.234	-0.2874	NA	-0.0175	-0.3194	-0.0175	NA	NA	0.1168	NA
HW	NA	0.5610	0.2631	0.1506	NA	1.0000	0.0443	1.0000	NA	NA	0.6776	NA
Kings Creek (*n* = 85)												
Ho	0.6470	0.5882	0.6470	0.6705	0.4588	0.2588	0.5764	0.6470	0.5176	0.3647	0.7882	0
He	0.6865	0.6159	0.7162	0.7309	0.5274	0.3044	0.6230	0.7477	0.4636	0.4340	0.7745	0
A	5	4	9	5	3	5	4	9	4	4	9	1
Fis	0.0578	0.0452	0.0971	0.083	0.1308	0.1507	0.0752	0.1353	-0.1173	0.1605	-0.0178	NA
HW	0.1706	0.4766	0.0737	0.0002	0.1690	0.0032	0.6965	0.0285	0.0733	0.1025	0.0022	NA
Matthews Creek (*n* = 104)												
Ho	0.6826	0.8269	0.4134	0.875	0.5096	0.7788	0.4903	0.7403	0.7211	0.2788	0.6923	0.4903
He	0.6769	0.7329	0.4308	0.8482	0.4246	0.7177	0.4557	0.7729	0.6793	0.3199	0.7706	0.5384
A	6	6	7	12	3	7	5	13	8	3	10	4
Fis	-0.0086	-0.1289	0.0406	-0.0316	-0.2014	-0.0856	-0.0763	0.0423	-0.0618	0.129	0.1021	0.1506

HW	0.1645	0.7913	0.0198	0.1204	0.0809	0.0516	0.8322	0.3518	0.7009	0.1491	0.0493	0.2189
Pig Pen Brook (*n* = 63)												
Ho	0.6894	0.7142	0.3174	0.5714	0.5873	0.5555	0.6825	0.9047	0.2857	0	0.7936	0.1587
He	0.6820	0.7346	0.3302	0.5518	0.5862	0.5591	0.6100	0.7288	0.2678	0	0.7255	0.1471
A	4	5	5	3	3	4	4	9	14	1	7	2
Fis	-0.0242	0.028	0.039	-0.0358	-0.0017	0.0065	-0.1199	-0.2439	-0.0674	NA	-0.0948	-0.0796
HW	0.1278	0.0002	0.5797	1.0000	0.1999	0.3649	0.1635	0.0000	0.3527	NA	0.0229	1.0000

Table 2. Number of breeders (N_b) and 95% confidence interval for each stream patch based on the linkage disequilibrium method in Program NeEstimator 2.0.

Stream	N_b	95%- L	95% - U
Crane Creek (*n* = 60)	14.4	12.2	16.8
Falls Creek (*n* = 75)	19.3	14.8	24.8
Headforemost Brook (*n* = 82)	18.7	4.3	50.6
Jacks Branch (*n* = 30)	18.7	3.6	135.7
King Creek (*n* = 85)	23.4	19.7	27.7
Matthews Creek (*n* = 104)	115.4	95.8	141.2
Pig Pen Brook (*n* = 63)	53.1	40.3	71.7

Table 3. Number of breeders (N_b) and 95% confidence interval for each site (upper, middle, or lower) within a stream patch based on the linkage disequilibrium method in Program NeEstimator 2.0.

Stream	*Ne*	95%-L	95%-U
Crane Creek Lower (*n* = 29)	23	17.4	31.2
Crane Creek Upper (*n* = 31)	17	11.6	24.6
Falls Creek Lower (*n* = 25)	9	4.1	14.8
Falls Creek Middle (*n* = 25)	11.5	3.6	29.8
Falls Creek Upper (*n* = 25)	18.5	11.2	32.4
Headforemost Creek Lower (*n* = 25)	6.4	1.7	29.9
Headforemost Creek Upper (*n* = 57)	28.5	4.3	224.5
Jacks Branch Lower (*n* = 22)	27.2	3.7	Infinite
Jacks Branch Upper (*n* = 8)	220.1	1.9	Infinite
King Creek Lower (*n* = 31)	30.2	22	43
King Creek Middle (*n* = 28)	18.9	12.3	30
King Creek Upper (*n* = 26)	17	10.8	27.5
Matthews Creek 2 (*n* = 20)	318.1	93.3	Infinite
Matthews Creek 3 (*n* = 20)	51.2	33.1	95.5
Matthews Creek 4 (*n* = 24)	52.1	35.5	86.5
Matthews Creek 5 (*n* = 20)	62.6	33.9	199
Matthews Creek 6 (*n* = 20)	27.7	18.1	47.4
Pig Pen Brook Lower (*n* = 29)	37.1	24.4	62.9
Pig Pen Brook Middle (*n* = 21)	7.5	3.8	12.1
Pig Pen Brook Upper (*n* = 13)	80.8	24.5	Infinite

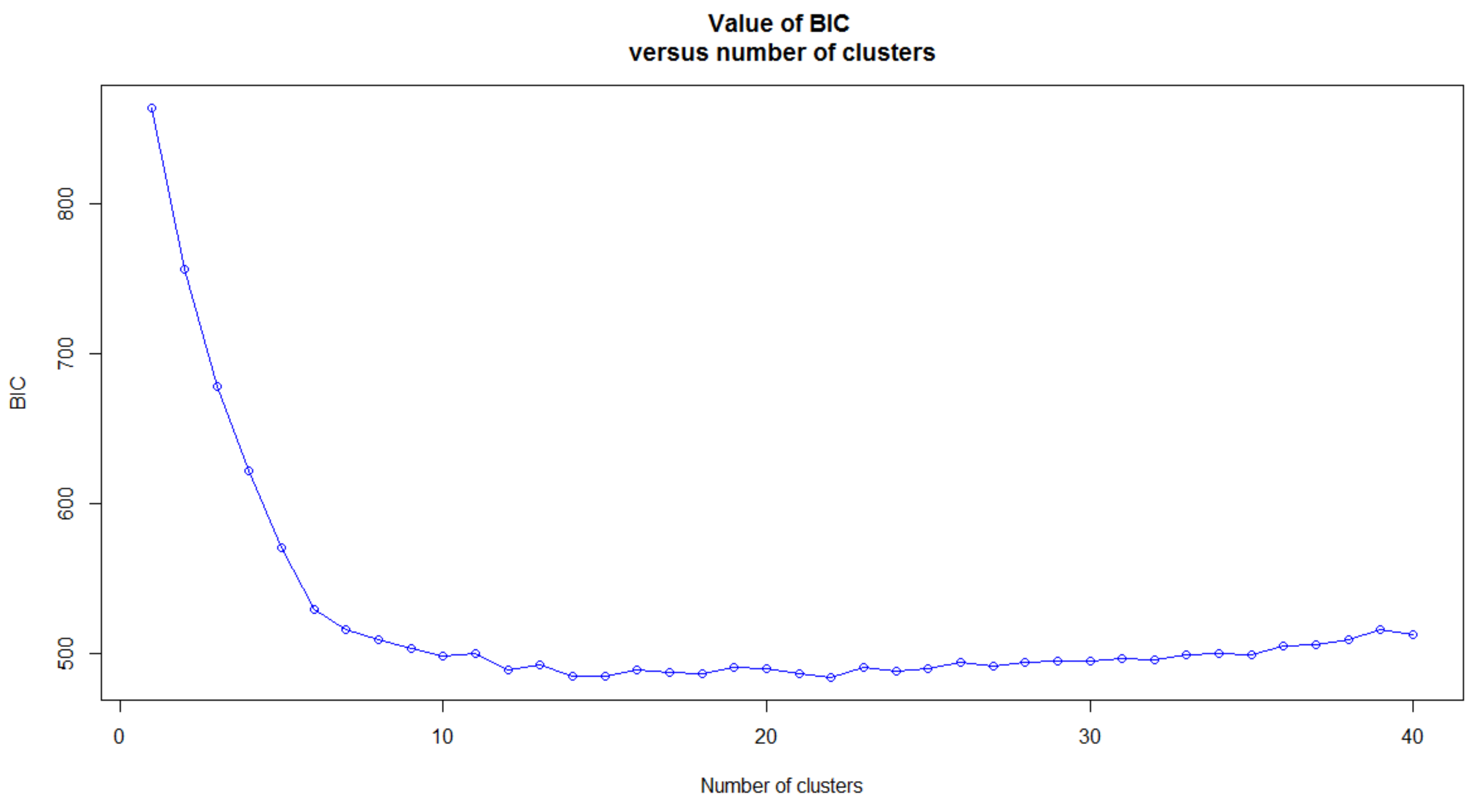

Figure 1. Changes in mean Bayesian Information Criterion (BIC) values in k-means clustering

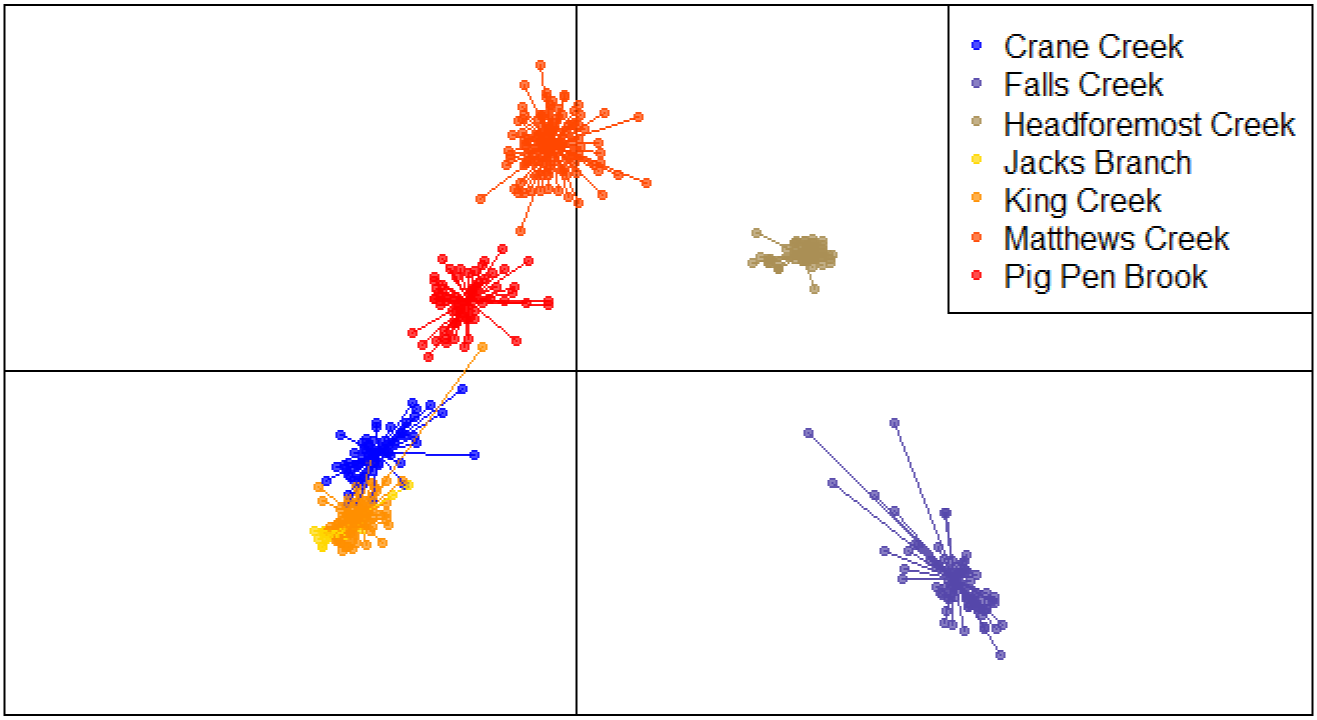

Figure 2. Ordination plot (first and second axes) of discriminant analysis of principal components (DAPC) for 7 genetic clusters (representing the 7 stream patches). Dots represent individuals

Document Content(s)

FEDERAL ENERGY REGULATORY COMMISSION
Washington, D. C. 20426

OFFICE OF ENERGY PROJECTS

Project No. 2740-047—South Carolina
Bad Creek Pumped Storage Project
Duke Power

May 21, 2012

Mr. Jeffrey G. Lineberger, PE
Director, Hydro Strategy
Duke Energy Carolinas LLC
EC12Y/POB 1006
Charlotte, NC 28201-1006

Subject: Modification to the Keowee-Toxaway Fishery Resources Ten Year Work Plan for 2006-2015

Dear Mr. Lineberger:

This acknowledges receipt of your modification to the Keowee-Toxaway Fishery Resources Ten Year Work Plan (Plan) for 2006-2015, filed pursuant to ordering paragraph (B) of the Order Modifying and Approving Keowee-Toxaway Fishery Resources Ten Year Work Plan for 2006-2015 Pursuant to Memorandum of Understanding (MOU).[1] Ordering paragraph (B) requires the licensee to file a report with the Commission detailing any modifications of the MOU or Plan as required by changes in project operations or facilities that may effect fish entrainment or mortality. In addition, the licensee is required to file with the Commission a final report by December 1, 2015, regarding the status of the Plan and include resource agency comments on the final report.

Your filing states that you had originally agreed to pay the South Carolina Department of Natural Resources (SCDNR) $54,000 per year to conduct simultaneous creel surveys for three consecutive years on Lakes Jocasse and Keowee following the second full year of completion of the runner upgrades at the Jocasse Hydro Pumped Storage Project No. 2503 in accordance with Item 5 of the Plan. Based on the recent requirement for a fish entrainment study at the Jocasse station, both Duke Energy and SCDNR mutually agreed that the three year consecutive surveys were no longer warranted and a less robust creel sampling frequency would be sufficient for the duration of the Plan. The sampling frequency is noted in Item 3 of the Plan. Therefore Item 5 has been deleted.

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[1] 115 FERC ¶62, 072 (Issued April 14, 2006)

By email communication dated March 28, 2012, SCDNR concurred with the changes in the Plan by removing Item 5 and modifying the creel survey frequency as noted in Item 3.

Your report partially meets the requirements of ordering paragraph (B) of the aforementioned order regarding the filing of any changes to the MOU or Plan. The requirement to file the final report regarding the status of the Ten Year Fishery Resources Work Plan with the Commission by December 1, 2015, still applies.

Thank you for your continued cooperation and if you have any questions regarding this letter, please contact me at (212) 273-5917.

Sincerely,

Joseph G. Enrico
Aquatic Resources Branch
Division of Hydropower Administration
and Compliance

OEP/DHAC Enrico, J:jge 5/21/2012 041
cc: DHAC ELIBRARY ENRICO

Water Strategy, Hydro Licensing,
and Lake Services

Duke Energy
526 S. Church Street / EC12Y
Charlotte, NC 28202

January 16, 2017

The Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street N.E.
Washington, DC 20426

Re: Duke Energy Carolinas, LLC
Bad Creek Project - Project No. 2740
Bad Creek Fishery Resources Work Plan January 2007- December 2017

Dear Secretary Bose:

In an order dated May 1, 1997, the Federal Energy Regulatory Commission (Commission) approved a Memorandum of Understanding (MOU) and Ten-Year Work Plan pursuant to article 32(b)(1) of the license for the Bad Creek Hydroelectric Project (Project). The MOU, signed by Duke Power (Duke Energy) and the South Carolina Department of Natural Resources (SCDNR), addressed mitigation needs associated with fish losses caused by the operation of the Bad Creek Pumped Storage Station. This original Ten-Year Work Plan expired at the end of 2005 with a second plan covering the years 2006 – 2015 filed with the Commission and approved on April 4, 2006. Upon expiring at the end of 2015, the Ten-Year Work Plan was extended an additional year to cover 2016 while a new plan was in development.

As required in the May 1, 1997 order, Duke Energy hereby files for Commission approval of the enclosed signed copy of "Bad Creek (formerly the Keowee-Toxaway) Fishery Resources Work Plan (Plan) January 2017 – July 2027." This Plan, developed jointly by Duke Energy and SCDNR, identifies specific management strategies, studies and other cooperative efforts between Duke Energy and the SCDNR that will protect and enhance the fishery resources of Lake Jocassee, Lake Keowee, and tributaries to these lakes. The term of this new Plan will cover the period through expiration of the current Project license.

Enclosed please also find enclosed correspondence between Duke Energy and the United States Fish and Wildlife Service (USFWS) regarding the updated work plan. The USFWS concurred with the Plan.

Please contact Alan Stuart at (980) 373-2079 (Alan.Stuart@duke-energy.com) if you have questions or require additional information.

Sincerely,

Jeffrey G. Lineberger, P.E.
Director, Water Strategy and Hydro Licensing
Duke Energy

Enclosures

cc w/enclosures: Alan Stuart, Duke Energy
Mike Abney, Duke Energy
Matt McKinney, Duke Energy
Bill Marshall, SCDNR
Thomas McCoy, USFWS

Bad Creek Pumped Storage Project
FERC No. 2740
License Article 32(b)(l)

FISHERY RESOURCES WORK PLAN

JANUARY 1, 2017 - JULY 31, 2027

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

AND

DUKE ENERGY CAROLINAS, LLC

South Carolina Department of Natural Resources

______________________ Date: 12-8-2016
Alvin A. Taylor
Director, South Carolina Department of Natural Resources

Duke Energy Carolinas, LLC

______________________ Date: 12/5/2016
Steven D. Jester
Vice President, Water Strategy, Hydro Licensing and Lake Services

Revised: December 2, 2016

BAD CREEK FISHERY RESOURCES
WORK PLAN (JANUARY 1, 2017 – JULY 31, 2027)

INTRODUCTION

A license to operate the Bad Creek Pumped Storage Project (Project) for 50 years was issued by the Federal Energy Regulatory Commission (FERC) to Duke Power Company (now Duke Energy Carolinas, LLC; Duke Energy) on August 1, 1977. License Article 32 required Duke Energy to file a revised Exhibit S within one year of license issuance. Exhibit S of the license application addressed fish and wildlife protection, mitigation and enhancement (PM&E) measures. Revised Exhibit S was to include a) a detailed wildlife mitigation plan; b) an outline of studies to be conducted to assess project effects on 1) fish entrainment and resultant mortality, 2) coldwater fish habitat in Lake Jocassee, and 3) trout migration, spawning and rearing; and c) a detailed mitigation plan with proposed measures to be taken by Duke Energy to mitigate the adverse impacts of Project operations on Lake Jocassee and stream fisheries. Studies to address Article 32(b)(1) were to be conducted at the beginning of Project operations and results filed within three years of the commencement of project operation. Duke Energy developed the revised Exhibit S in consultation with the South Carolina Wildlife and Marine Resources Department (now South Carolina Department of Natural Resources; SCDNR), and on August 15, 1979, FERC issued an Order approving the revised Exhibit S.

As a result of the fish entrainment and mortality studies conducted under Article 32(b)(1), a Memorandum of Understanding (MOU) for the Keowee-Toxaway Fishery Resources (now known as the Bad Creek MOU) was developed between Duke Energy and SCDNR. This agreement, signed in 1996, describes a cooperative framework and directs planning and management efforts towards fisheries management in lakes Keowee and Jocassee and their tributaries for the term of the Project license and recognizes the commitment that both SCDNR and Duke Energy have made to maintain the high quality fisheries found in these reservoirs and streams. The Bad Creek MOU identified a number of eligible activities that included fisheries surveys and inventories, water quality and other habitat evaluations, stocking, angler access improvements, youth fishing rodeos, and impact assessments.

Under the Bad Creek MOU, 10-year work plans were developed and implemented during 1996-2005 and 2006-2015, and a wide variety of studies and management activities were conducted. Several activities conducted under previous work plans of the Bad Creek MOU were identified as PM&E measures appropriate for transfer to the Keowee-Toxaway Hydroelectric Project (FERC No. 2503) and are now addressed under the Keowee-Toxaway Relicensing Agreement associated with the FERC license issued in 2016. These included an agreement on measures to reduce fish entrainment at the Jocassee Pumped Storage Station, an agreement to maintain pelagic trout habitat in Lake Jocassee and an agreement to maintain the lower Eastatoe Creek angler access area. The work conducted by both Duke Energy and SCDNR during the past 20 years under the Bad Creek MOU has contributed directly to the enhancement of the resources, through activities such as annual trout stocking and access improvements, and provided additional information with which to better understand the aquatic resources in lakes Keowee and Jocassee.

Per the Bad Creek MOU, activities may include a wide variety of actions including, but not limited to, trout stocking, population monitoring, habitat monitoring, habitat protection and enhancement, fisheries studies, and other activities considered important to the successful management of the Keowee-Toxaway area fishery resources. All studies and other activities identified in this plan will be jointly planned by Duke Energy and the SCDNR team that has worked cooperatively over the years on the Keowee-Toxaway fishery resources.

Item 1: Agreement on Minimizing Fish Entrainment via Bad Creek Pumped Storage Project

Duke Energy and the SCDNR have worked cooperatively to evaluate fish entrainment at the Bad Creek Pumped Storage Station. Site-specific studies provided information that identified operational periods associated with low and high entrainment rates, and this information was used to develop the operational guidelines presented in the work plan.

Work Plan

During this work plan period, Duke Energy will operate its facilities to minimize, to the extent practicable, the period during which Lake Jocassee pool elevations are below 335 m (1099 ft) above mean sea level (AMSL) (i.e., 89 ft local datum with the full pond elevation of 1110 ft AMSL referenced as 100.0 ft local datum). When pool elevations in Lake Jocassee fall below 335 m (1099 ft) AMSL [89 ft local datum], Duke Energy will implement operational changes, based upon hydro unit availability and other operational considerations, to minimize fish entrainment[1]. These operational protocols were developed during the original work plan and include turning off lights near the intake so as not to attract fish to the area and utilizing a unit startup and shutdown sequence that minimizes fish entrainment. These operational protocols may continue to evolve as additional information is gathered.

If the pool elevation in Lake Jocassee falls below 335 m (1099 ft) AMSL [89 ft local datum] and is projected to remain below this level for 30 consecutive days, Duke Energy will notify the SCDNR. After such notification, Duke Energy will notify the SCDNR when the Jocassee pool elevation rises above 335 m (1099 ft) AMSL [89 ft local datum] for seven (7) consecutive days. No additional notifications to the SCDNR will be necessary if Jocassee pool elevations fluctuate above and below 335 m (1099 ft) AMSL [89 ft local datum] unless Duke Energy has previously notified the SCDNR the lake elevation rose above 335 m (1099 ft) AMSL [89 ft local datum] for seven (7) consecutive days. If Jocassee pool elevations are projected to remain below 335 m (1099 ft) AMSL [89 ft local datum] for 60 consecutive days, Duke Energy will initiate consultation with the SCDNR and the US Fish and Wildlife Service to determine if additional measures to minimize impacts are appropriate.

Function

[1] Protocols include turning lights off and implementing a start-up and shut-down pumping sequence at Bad Creek Pumped Storage Station. The pumping protocol includes bringing Unit 4 on first and then Units 2, 3 and 1 sequentially. Unit order is reversed during the shutdown sequence.

Minimize entrainment related to the operation of Bad Creek Pumped Storage Station during pump back operations.

Establish communications protocols between Duke Energy and the SCDNR during low water periods.

Item 2: Hydroacoustic Monitoring of Small Pelagic Fish in Jocassee and Keowee

Hydroacoustic monitoring of fish populations began in 1997 in Lake Jocassee and in 1999 in Lake Keowee by Duke Energy to assess pelagic prey fish abundance and distribution in the reservoirs. Pelagic fish (threadfin shad and blueback herring) comprise the primary prey for trout and other sportfish and understanding their relative abundance is important to assessing the overall quality of the fisheries in both lakes.

The extensive database developed under this work item will be very helpful in monitoring Project impacts to pelagic prey species associated with entrainment mortality resulting from Bad Creek operations, including the new runner upgrades planned for installation, and this sampling program should be continued through this work plan.

Work Plan

- Duke Energy will provide resources and conduct this monitoring work.
- This monitoring is scheduled annually, and sampling will be conducted in the fall on both lakes Jocassee and Keowee through 2027.
- Duke Energy will provide the SCDNR copies of study reports prepared in conjunction with this activity.

Function

The collection of these data will allow effective on-going monitoring of forage populations which are the primary food of trout and other predatory sportfish in Lake Jocassee and Lake Keowee. These data will also be used to detect any noticeable changes in pelagic species as a result of runner upgrades at Bad Creek Pumped Storage Station.

Item 3: Electrofishing of Littoral Fish Populations in Jocassee and Keowee

Duke Energy has monitored littoral fish populations in Lake Keowee since 1972 and Lake Jocassee since 1974 to provide a fish community assessment. Electrofishing is used to assess the status of littoral fish populations in these reservoirs. Littoral fish populations include important sportfish such as largemouth, spotted and smallmouth bass, and other sunfish; and other species that are important prey, such as sunfish, cyprinids, clupeids, and others. Catch-per-unit-effort (numbers of individuals/3,000 m and weight (kg)/3,000 m), numbers of species, and condition for largemouth and spotted bass was determined for each sampling area. Sampling was conducted in the spring once every three years in the previous work plans.

It is important to continue this monitoring effort because the results can be used to 1) determine species composition and to detect changes; 2) obtain catch per unit effort data (i.e. numbers per hour) that may be used to detect increasing or decreasing population trends; and 3) evaluate the relative condition of largemouth and spotted bass. For these reasons, this work should be continued through this work plan.

Work Plan

- Duke Energy will conduct this work.
- Duke Energy will provide the SCDNR copies of study reports prepared in conjunction with this activity.
- This monitoring will continue every three years (2017, 2020, 2023 and 2026) of the work plan period.
- No changes in the sampling design will be made for Lake Jocassee.
- Sampling on Lake Keowee will follow the current Oconee Nuclear Station sampling design with data provided to SCDNR.

Function

This survey provides data to describe and characterize the littoral fish populations (e.g., sunfish, minnows, suckers, catfish, etc.) in lakes Keowee and Jocassee. The data includes species composition and estimates of standing stocks, age and growth, and condition (largemouth and spotted bass), which is information needed to monitor fish populations and establish harvest regulations to maintain a sustainable fishery.

Item 4: Cost Share for Trout Stocking

Lake Jocassee is recognized as a regional trout fishery, and maintaining this fishery is an important interest of SCDNR. In partnership with Duke Energy, the SCDNR has established and manages a trout fishery in Lake Jocassee which is unique in South Carolina. This fishery is supported by annual stocking of trout produced at the SCDNR Walhalla Fish Hatchery.

Work Plan

- Duke Energy will provide $80,000 (in 2017 dollars) per year to the SCDNR for use in growing and stocking trout in Lake Jocassee and tributaries to Lake Jocassee. This funding will begin in 2017 and continue through 2027 and will be adjusted annually based on the Consumer Price Index.

- This funding may be utilized for all activities involved with rearing and stocking trout and hatchery maintenance.

- The SCDNR will provide Duke Energy with a written summary of stocking activities at the annual coordination meeting.

Function

Help ensure trout are available for maintaining the quality fishery in Lake Jocassee.

Item 5: Cost Share for Fisheries Research and Enhancements

The Bad Creek MOU lists a number of activities eligible for cost-sharing, including fisheries research, water quality studies, trout habitat studies, stream surveys, creel surveys, fish and habitat management, development of bank and stream-side access, and stream protection and enhancement.

In previous work plan periods, SCDNR has elected to conduct sportfish creel surveys on lakes Jocassee and Keowee. Creel surveys provide unique information to describe the fishery from an angler perspective, including estimates of fishing effort, harvest and success. These data provide information useful in tracking angling trends, developing fishing regulations, and measuring angler satisfaction. SCDNR will continue creel surveys on a six-year interval rather than the three-year interval as conducted previously. Funding for four creel surveys, two per lake, would not exceed $390,000 total over the 2017-2027 period of this work plan.

The Bad Creek MOU has provided funding for a number of other fisheries studies conducted during the past 20 years. These studies have addressed a number of resource issues, including seasonal trout habitat use, the strength of the forage base, an evaluation of predator (trout) /prey balance (bio-energetics) which has been used to determine stocking rates, stream assessment, and brook trout restoration. All of these studies have provided the science needed to improve management of aquatic resources.

These studies previously funded under the Bad Creek MOU include:

- Trout telemetry in Lake Jocassee (helped better understand critical summer habitat for trout).
- Gill net monitoring – this is a long-term monitoring program to assess littoral and pelagic populations (abundance, length and age distributions, species composition, stocking assessments of smallmouth bass), with emphasis on trout and imperiled redeye bass, among other sportfish populations.
- Redeye bass genetics studies – two studies to date (one genetics study on reservoir populations), more recently a genetics and habitat study on stream populations. Both studies focused on impact of hybridization with non-native Alabama Bass. (Multiple peer-reviewed publications from this work.)
- Whitewater River – study of exploitation on wild trout – included both creel and population dynamics components.
- Bio-energetics study of trout in Lake Jocassee (guided trout stocking program).
- Assessment of streams on Jocassee Gorges to identify and prioritize potential native brook trout restoration. In-stream habitat was documented on all headwater streams

using the Basin Visual Estimation Technique method. In-stream habitat deficiencies were documented. In-depth water chemistry was assessed at 40 sites across the Keowee-Toxaway headwater streams, and longitudinal fish population sampling was conducted in all streams.

- Brook trout habitat and populations were restored in three streams including nine miles of brook trout habitat (Carrick Creek, Emory Creek, and Laurel Fork Creek).
- Comparison of growth and survival of diploid vs. triploid brown trout in Lake Jocassee – in progress.
- Brook trout genetics study – in progress. A contemporary genetics study of brook trout populations was conducted to identify source populations for restoration of additional Jocassee Gorges streams. Additional studies may be indicated to evaluate genetic diversity, assortative mating, and other potential concerns in restored populations.
- Southeast Aquatic Resource Partnership (SARP) brook trout restoration project – in progress. Bad Creek MOU funding was used to leverage funds from SARP, Trout Unlimited, other non-profits, and Clemson University. This project includes restoration of brook trout habitat (and fish) in Howard Creek, Big Laurel Creek, Little Laurel Creek, Side-of-Mountain Creek, and Reedy Cove Creek. This includes an additional nine+ miles of brook trout restoration.
- Population dynamics assessment of black bass species in Lake Jocassee and Lake Keowee to monitor: length and age distributions, total annual mortality, relative condition, recruitment, and yield-per-recruit modelling of populations to determine most effective regulation scenarios. This monitoring is important in evaluating the success of spring spawning lake level stabilization regimes to maintain largemouth bass populations and fisheries in both lakes.

As in previous work plans, SCDNR requests funding be provided to continue at least three applied fishery research or monitoring studies or special management projects over the next 11 years (2017-2027). These activities will be determined by the SCDNR in consultation with Duke Energy. Possible studies include but are not limited to the following:

- Redeye bass studies and management
- Additional trout stream restoration
- Black bass exploitation studies (levels of natural mortality in bass populations are known, but the proportion of annual mortality due to angling exploitation is not known)
- Jocassee trout survival/mortality/exploitation studies (Major knowledge gaps exist regarding survival rates of stocked trout from the time of planting until fish recruit to the fishery. This limits the ability to apply the previously developed bio-energetics model for determining stocking rates, etc.)
- Habitat protection/ access improvement/erosion control
- Evaluation of habitat enhancement projects conducted under Keowee-Toxaway Habitat Enhancement Program[2] or other funding initiatives in the Keowee-Toxaway Lakes.

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[2] The Keowee-Toxaway Habitat Enhancement Program (HEP) is a program funded through Duke Energy's Lake Use Permitting Program. The HEP supports projects designed to protect, enhance and create fish and wildlife species in the Keowee-Toxaway watershed (including the Bad Creek Project).

Work Plan

- SCDNR will submit study/management activity requests to Duke Energy for review and concurrence.

- Funding for approved projects may be utilized for the purchase of supplies, equipment and personnel needed to conduct this work.

- Other funding sources, such as the Keowee-Toxaway Habitat Enhancement Program, may also be utilized for cost-sharing these activities.

- Duke Energy will provide a one-time payment of $120,000 in 2017 to support Bad Creek MOU research and monitoring activities by SCDNR as described above.

- Duke Energy will provide funding ($390,000 total with no applied escalation) for the four creel surveys. Unless changed with the consent of Duke Energy, funding will be provided according to the following schedule:
    - 2019 Lake Jocassee $ 90,000
    - 2020 Lake Keowee $ 105,000
    - 2025 Lake Jocassee $ 90,000
    - 2026 Lake Keowee $ 105,000

- Duke Energy will provide any relevant data from routine water quality monitoring in Howard Creek at the annual coordination meeting.

- The SCDNR will provide Duke Energy with a written summary of activities conducted under this item at the annual coordination meeting of Duke Energy and SCDNR staff.

Function

Collect data to better manage the aquatic resources in Lake Jocassee and Lake Keowee. Provide vital information on fishing effort, harvest, and success of sportfish as well as socioeconomic data. Use study data to formulate stocking strategies, size and creel limits, and to monitor potential impacts of commercial uses of the reservoirs (i.e., power production) on the fishery. Share the results of these studies and routine environmental monitoring work as requested.

From: Thomas McCoy
To: Stuart, Alan Witten
Cc: Bill Marshall; Dick Christie; Melanie Olds
Subject: RE: Bad Creek (formerly Keowee-Toxaway) Fisheries Work Plan
Date: Friday, January 06, 2017 7:19:11 AM
Attachments: image001.png

*** Exercise caution. This is an EXTERNAL email. DO NOT open attachments or click links from unknown senders or unexpected email. ***

Hi Alan,

I reviewed the Bad Creek Fisheries Work Plan and have one comment to provide.

Could we have a copy of the study result reports as noted below in the email provided?

Thank you for the opportunity to review and provide comment.

Tom McCoy
Field Supervisor/FERC Coordinator
Department of the Interior -??U.S. Fish and Wildlife Service
South Carolina Ecological Services Field Office
176 Croghan Spur Road, Suite 200
Charleston, South Carolina 29407
Main Phone Line: 843.727.4707???????? Direct Phone Line: 843.300.0431
Fax: 843.300.0204
E-mail:??thomas_mccoy@fws.gov
??
Please visit our Web Page for information about our office:??www.fws.gov/charleston??
??

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From: Stuart, Alan Witten [mailto:Alan.Stuart@duke-energy.com]
Sent: Thursday, December 22, 2016 9:31 AM
To: Tom MCCoy (Thomas_MCCoy@fws.gov)
Cc: Bill Marshall (marshallb@dnr.sc.gov); Dick Christie (dchristie@comporium.net)
Subject: Bad Creek (formerly Keowee-Toxaway) Fisheries Work Plan

??

After the holidays are fine !!?? Let's say by January 23rd though to establish a date.

??

Dear Tom,

??

Duke Power and the South Carolina Department of Natural Resources (SCDNR) entered into a Memorandum of Understanding ??(MOU) in 1996 regarding the management of fishery resources in the Keowee-Toxaway ??region. ?? This MOU, which met the requirements of Article 32 (b)(1) of ??the Bad Creek Pumped Storage Project's FERC License, required the development and implementation of work plans identifying specific work activities. ?? The first work plan developed under the MOU in consultation with SCDNR and the United States Fish and Wildlife Service (USFWS) expired at the end of 2005 and a new plan was developed in 2006 and expired in

2015 (activities extended through 2016).
??
Duke Power and SCDNR have been working for the past year to develop a new work plan that meets the objectives of the MOU. The enclosed signed work plan represents the results of this effort. This work plan identifies specific management activities, funding initiatives, and communications protocols which both Duke Power and SCDNR believe are important to the effective management of the Keowee-Toxaway fishery resources. The 2017-2027 work plan continues many of the management activities implemented during the prior work plans.
??
Historically, USFWS requested that they be provided copies of reports prepared in conjunction with work plan activities. Duke Power has provided copies of reports developed in accordance with the 1996-2005 ?????and 2006-2015 work plans to the and agrees to continue doing so during the new work plan period.
??
Please let me know of any questions or comments you have on the attached work plan.?? Once we receive your comments, we will file the new plan with the FERC.
Thanks !
Alan
??

DUKE ENERGY

Alan W. Stuart
Senior Project Manager
Duke Energy Carolinas, LLC
Water Strategy, Hydro Licensing and Lake Services
526 S. Church Street, - EC12Y | Charlotte, NC 28202
Office 980-373-2079 | Cell 803-640-8765
??

158 FERC ¶ 62,214
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Duke Energy Carolinas LLC | Project No. 2740-047

ORDER MODIFYING AND APPROVING KEOWEE-TOXAWAY FISHERY RESOURCES TEN YEAR WORK PLAN FOR 2017-2027 PURSUANT TO MEMORANDUM OF UNDERSTANDING

(Issued March 21, 2017)

1. On January 17, 2017, Duke Energy Carolinas LLC (licensee), filed their Ten-Year Fishery Resources Work Plan (Work Plan) for 2017-2027 pursuant to the Memorandum of Understanding (MOU) for the Bad Creek Hydroelectric Pumped Storage Project.[1] The original Work Plan was approved by order dated April 14, 2006, and expired at the end of 2016.[2] The project is located on Bad Creek and West Bad Creek in Oconee County, South Carolina. The project does not occupy Federal Lands.

Background

2. The approved Exhibit S of the license addressed fish and wildlife protection, mitigation and enhancement (PM&E) measures for the project. The licensee developed a revised Exhibit S in consultation with the South Carolina Wildlife and Marine Resources Department (now South Carolina Department of Natural Resources (South Carolina DNR)), and developed a MOU for the Keowee-Toxaway fishery resources (now known as the Bad Creek MOU). This agreement, described a cooperative framework and directs planning and management efforts towards fisheries management in lakes Keowee and Jocassee and their tributaries for the term of the license. The agreement recognizes the commitment that both South Carolina DNR and Duke Energy LLC have made to maintain the high quality fisheries found in these reservoirs and streams.

3. Under the previous Bad Creek MOU, 10-year work plans were developed and implemented during 1996- 2005 and 2006-2015, and a wide variety of studies and management activities were conducted. Several activities conducted under previous work plans of the Bad Creek MOU were identified as PM&E measures appropriate for transfer to the Keowee-Toxaway Hydroelectric Project (FERC No. 2503) and are now addressed under the Keowee-Toxaway Relicensing Agreement associated with the FERC

[1] 59 FPC ¶ 1,266 (1977).
[2] Order Granting Extension of time issued January 13, 2016 (unpublished).

license issued in 2016. The previous Work Plan was extended until 2016 while the new plan was being developed. The work conducted by both Duke Energy LLC and South Carolina DNR during the past 20 years under the Bad Creek MOU has contributed directly to the enhancement of fishery resources in Lakes Keowee and Jocassee and the Jocassee Pumped Storage Project.[3]

Description of the New Plan

4. The Work Plan identifies specific management activities, funding initiatives, and communications protocols which both Duke Power LLC and South Carolina DNR believe are important to the effective management of the Keowee-Toxaway fishery resources. The 2017-2027 Work Plan continues many of the management activities implemented during the prior work plans. In its Work Plan the licensee and South Carolina DNR propose to continue to cooperatively monitor the fishery in Lakes Jocassee and Keowee while annually reviewing the results of the monitoring. If any significant changes are observed in fish populations in Lake Keowee or Lake Jocassee, the licensee and South Carolina DNR propose to meet to determine the cause of the changes and any necessary measures to correct them. The Work Plan is composed of five items: 1) agreement on minimizing fish entrainment via the Bad Creek Pump Storage station; 2) hydroacoustic monitoring of small pelagic fins in Jocassee and Keowee Lakes; 3) electrofishing of littoral fish populations in Jocassee and Keowee Lakes; 4) cost sharing for trout stocking; and 5) cost sharing for fisheries research and enhancements. Under each item there are work plans and functions which describe the work to be performed, measures to be implemented and expected results.

5. In item No. 1, the licensee will operate its facilities to minimize, to the extent practicable, the period during which Lake Jocassee pool elevations are below 335 meters (m) (1099 ft.) above mean sea level (AMSL) (i.e. 89 ft. local datum with the full pond elevation of 1110 ft. AMSL referenced as 100.0 ft. local datum). When pool elevations in Lake Jocassee fall below 335 m (1099 ft.) AMSL (89 ft. local datum), the licensee will implement operational changes, based upon hydro unit availability and other operational considerations, to minimize fish entrainment. In item No. 2 the licensee will continue hydroacoustic monitoring of fish populations that began in 1997. The monitoring will be performed annually and sampling will be done in the fall on both Lakes Jocassee and Keowee through 2027. The collection of this data will allow monitoring of forage populations which are the primary food for trout and other predatory sportfish in the

[3] The Jocassee Pumped Storage Station is part of the Keowee-Toxaway Hydroelectric Project (FERC No. 2503) and together with the Bad Creek Pumped Storage Project, utilizes the same reservoir, Lake Jocassee. Additionally, the Keowee-Toxaway Project did not contain any license requirement to study fish entrainment or mortality.

lakes. In item No. 3, electrofishing will be used to assess the status of littoral fish populations in these reservoirs. Monitoring will continue every three years (2017, 2020, 2023 and 2026) of the Work Plan period. The function of this item is to provide data to describe and characterize the littoral fish populations (e.g., sunfish, minnows, suckers, catfish, etc.) in Lakes Keowee and Jocassee. In item No. 4 the licensee will provide $80,000 (in 2017 dollars) per year to the South Carolina DNR for use in growing and stocking trout in Lake Jocassee and tributaries to Lake Jocassee. This funding will begin in 2017 and continue through 2027 and will be adjusted annually based on the Consumer Price Index (CPI). This will assist in ensuring that trout are available for maintaining the quality sport fishery in Lake Jocassee. In item No. 5 South Carolina DNR will submit study/management activity funding requests to the licensee for review and concurrence. The licensee will provide a one-time payment of $120,000 in 2017 to support Bad Creek MOU research and monitoring activities by South Carolina DNR and will provide further funding ($390,000 total with no applied escalation) according to the following schedule: in 2019 Lake Jocassee $90,000; in 2020 Lake Keowee $105,000; in 2025 Lake Jocassee $90,000; in 2026 Lake Keowee $105,000. The purpose is to collect data to better manage the aquatic resources in Lake Jocassee and Lake Keowee as well as provide vital information on fishing effort, harvest, and success of sportfish as well as socioeconomic data.

Agency Consultation

6. The Keowee-Toxaway Fishery Resources Work Plan for 2017-2027 was developed in cooperation with the South Carolina DNR in accordance with the MOU. In addition the Work Plan was also sent to the FWS for comment on December 22, 2016. The licensee then received comments from FWS via electronic mail on January 6, 2017 stating that they concurred with the items listed in the Work Plan and would like to receive copies of any reports resulting from the Work Plan activities.

Discussion and Conclusion

7. The revised Ten Year Fishery Resources Work Plan (January 2017 - December 2027) sets forth specific studies, habitat protection and improvement measures, and other activities for the long-term effective management of the Keowee-Toxaway fishery resources. Some activities, such as monitoring trout habitat and creel surveys, have been ongoing for years. Other activities will provide new data to help sustain and enhance the fishery as it experiences increased fishing pressure.

8. If project operations or facilities are modified and affect fish entrainment or mortality, or if the MOU or Work Plan are amended, the licensee should file, with the Commission, a report detailing the modifications along with any resource agency comments. At the end of the Ten Year Fishery Resources Work Plan, the Licensee should file a final report, by December 31, 2027, regarding the status of the Work Plan and include any resource agency comments. Since the filling of Lakes Keowee and

Jocassee in the 1970's, the licensee and resource agencies have worked cooperatively to ensure the quality of the reservoir and tributary fisheries. The Work Plan is consistent with maintaining these common objectives. The Work Plan, as modified by ordering paragraph (b), meets the requirements of the MOU and should therefore be approved.

The Director orders:

(A) The Ten Year Fishery Resources Work Plan (Work Plan) for the Bad Creek Pumped Storage Hydroelectric Project, filed on January 17, 2017 by Duke Power LLC (licensee), pursuant to a Memorandum of Understanding (MOU), as modified in paragraph (B), is approved.

(B) The licensee shall file with the Commission, a report detailing any modifications of the MOU or Work Plan as required by changes in project operations or facilities that may affect fish entrainment or mortality. Additionally, the licensee shall file with the Commission a final report by December 31, 2027 regarding the status of the Ten Year Fishery Resources Work Plan and include any resource agency comments on the final report.

(C) This order constitutes final agency action. Any party may file a request for rehearing of this order within 30 days from the date of its issuance, as provided in (§) 313(a) of the Federal Power Act, 16 U.S.C. § 825*l* (2012), and the Commission's regulations at 18 CFR § 385.713 (2016). The filing of a request for rehearing does not operate as a stay of the effective date of this order, or of any other date specified in this order. The licensee's failure to file a request for rehearing shall constitute acceptance of this order.

Thomas J. Lovullo
Chief, Aquatic Resources Branch
Division of Hydropower
Administration and Compliance

156 FERC ¶ 62,122
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Duke Energy Carolinas, LLC Project No. 2503-154

ORDER ISSUING NEW LICENSE

(Issued August 16, 2016)

INTRODUCTION

1. On August 27, 2014, Duke Energy Carolinas, LLC (Duke Energy) filed, pursuant to sections 4(e) and 15 of the Federal Power Act (FPA),[1] an application for a new license to continue operation and maintenance of its Keowee-Toxaway Hydroelectric Project No. 2503 (Keowee-Toxaway Project or project). The project consists of two developments: the Jocassee Development and the Keowee Development. The project's authorized capacity being licensed is 867.6 megawatts (MW). The project is located on the Toxaway, Keowee, and Little Rivers in Transylvania County, North Carolina, and Oconee and Pickens Counties, South Carolina.[2] The project does not occupy federal land.

2. As discussed below, this order issues a new license for the project.

BACKGROUND

3. On September 26, 1966, the Federal Power Commission, predecessor to the Federal Energy Regulatory Commission (Commission), issued the original 50-year license for the Keowee-Toxaway Project, which will expire on August 31, 2016.[3]

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[1] 16 U.S.C. §§ 797(e) and 808 (2012).

[2] The Keowee-Toxaway Project is located on the Toxaway, Keowee, and Little Rivers, tributaries of the Savannah River, a navigable waterway of the United States. 8th Annual Report of the Federal Power Commission, 100 (1928). Tributaries of navigable waterways are Commerce Clause streams within the meaning of section 23(b)(1) of the FPA. Because the project is located on a stream over which Congress has jurisdiction under the Commerce Clause, affects interstate commerce through its connection to an interstate power grid, and was constructed after 1935, it is required to be licensed by the Commission pursuant to section 23(b)(1) of the FPA. *See* 16 U.S.C. § 817(1)(2012).

[3] *Duke Power Co.*, 36 F.P.C. 675 (1966) (issuing an original 50-year license *(continued ...)*

4. With its relicensing application, on August 27, 2014, Duke Energy filed a Relicensing Agreement, adopting its terms as the relicensing proposal. The Relicensing Agreement, which was signed by Duke Energy and 16 other entities,[4] included operating provisions later incorporated into the Operating Agreement between the U.S. Army Corps of Engineers (Corps), the Southeastern Power Administration (SEPA), and Duke Energy, which was executed on October 17, 2014.

5. On February 5, 2015, the Commission issued a public notice that was published in the *Federal Register* accepting the application for filing, indicating the application was ready for environmental analysis, and establishing an April 6, 2015, deadline for filing motions to intervene and protests, comments, recommendations, terms and conditions, and prescriptions.[5] The notice also solicited comments on the Relicensing Agreement. The U.S. Department of the Interior (Interior), National Marine Fisheries Service (NMFS), North Carolina Department of Environment and Natural Resources (North Carolina DENR),[6] and South Carolina DNR filed notices of intervention.[7] None of the intervenors oppose the project. Interior, the U.S. Fish and Wildlife Service (FWS), South Carolina Department of Natural Resources (South Carolina DNR), South Carolina Department of Parks, Recreation, and Tourism (South Carolina Parks), South Carolina Wildlife Federation, Commissioners of Public Works of the City of Greenville, South Carolina (Greenville Water), Oconee County Administration, Advocates for Quality

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effective September 1, 1966).

[4] These entities include: Advocates for Quality Development, Inc.; Anderson Area Chamber of Commerce, City of Seneca, South Carolina; Commissioners of Public Works of the City of Greenville, South Carolina; Friends of Lake Keowee Society, Inc.; Oconee County, South Carolina; Pickens County, South Carolina; Pickens County Water Authority; South Carolina Department of Archives and History; South Carolina Department of Natural Resources; South Carolina Department of Parks, Recreation, and Tourism; South Carolina Wildlife Federation; The Cliffs at Keowee Vineyards Community Association, Inc.; The Reserve at Lake Keowee; Upstate Forever; and Warpath Development, Inc.

[5] 80 *Fed. Reg.* 7855 (February 12, 2015).

[6] North Carolina DENR's name was changed to the North Carolina Department of Environmental Quality in 2015.

[7] Under Rule 214(a)(2) of the Commission's Rules of Practice and Procedure, Interior, NMFS, North Carolina DENR, and South Carolina DNR became parties to the proceeding upon the timely filing of their notices of intervention. 18 C.F.R. § 385.214(a)(2) (2015).

Development, Inc., Friends of Lake Keowee Society, Inc. (FOLKS), Upstate Forever, Warpath Development, Inc., Congressman Jeff Duncan, Mr. Ronald E. Davis, Mr. James Vaughan, and Mr. Douglas Barker on behalf of 1,286 individuals who signed a petition (jointly, Petitioners) filed comments on the Relicensing Agreement and comments and recommendations on the application. Duke Energy filed reply comments on May 21, 2015.

6. Commission staff issued a draft Environmental Assessment (EA) on October 1, 2015, analyzing the effects of the proposed project and alternatives to it. Comments on the draft EA were filed by: Duke Energy; FWS; South Carolina DNR; Oconee County, South Carolina (Oconee County Administration); Advocates for Quality Development, Inc.; FOLKS; and Upstate Forever. On March 28, 2016, Commission staff issued a final EA.[8]

7. The interventions, comments, and recommendations have been fully considered in determining whether, and under what conditions, to issue this license.

PROJECT DESCRIPTION

A. Project Area

8. The Savannah River Basin drainage encompasses approximately 10,577 square miles, the majority of which is in South Carolina and Georgia. The Keowee-Toxaway Project lies in the upper Savannah River Basin on the Toxaway, Keowee, and Little Rivers in Transylvania County, North Carolina, and Pickens and Oconee Counties, South Carolina.[9] The confluence of the Toxaway and Whitewater Rivers forms the Keowee River which is inundated by Lake Jocassee. The Keowee and Little Rivers join downstream of the project to form the Seneca River, which is inundated by the Corps' Hartwell Lake. The Seneca River then joins 12-mile Creek to form the Savannah River, which flows southeasterly from Hartwell Lake to the Atlantic Ocean.

9. The two project developments are, from upstream to downstream, the 710.1-MW Jocassee Development on the Keowee River at river mile (RM) 366.5 and the 157.5-MW Keowee Development on the Keowee River at RM 328.8. Downstream of Lake Keowee, the Corps operates three developments on the Savannah River. From upstream to downstream, the developments are: Hartwell Lake and Dam at RM 289; Russell Lake

[8] Unless otherwise specified, references in this order to the EA are to the final EA.

[9] *See* EA at 31. Only small portions of the extreme upper ends of Jocassee Lake are in North Carolina. The rest of the project is located in South Carolina.

and Dam at RM 259; and J. Strom Thurmond Lake and Dam at RM 222. Thurmond Dam is the last major dam on the Savannah River as it flows to the Atlantic Ocean.[10]

B. Project Facilities

1. Jocassee Development

10. The Jocassee Development is a pumped storage facility that includes Jocassee Dam and reservoir (Lake Jocassee). Lake Jocassee, which serves as the pumped storage facility's upper reservoir, was formed by construction of Jocassee Dam, which impounds the Keowee River just downstream of the confluence of the Whitewater and Toxaway Rivers. Lake Jocassee has a shoreline length of 92.4 miles and a surface area of 7,980 acres at full pool elevation of 1,110 feet.[11] The usable storage capacity is 225,387 acre-feet between elevations 1,110 and 1,080 feet.

11. Jocassee Dam is a 385-foot-high, 1,800-foot-long, earth and rock-fill dam. Two cylindrical concrete/steel intake structures, located in Lake Jocassee at the north section of the dam, lead to two power tunnels that bifurcate and pass flows to four turbines in the powerhouse. The cylindrical intake structures have eight screened water intakes positioned between elevations 1,043 and 1,067 feet. Two earthfill saddle dikes, located on the western shore of Lake Jocassee, serve to contain Lake Jocassee.

12. The Jocassee powerhouse is located at the east toe of Jocassee Dam and is situated mostly underground. The powerhouse contains four reversible pump-turbine units, each with an authorized installed capacity of 177.525 MW. The total authorized installed capacity of the powerhouse is 710.1 MW. The maximum hydraulic capacity of the units is 36,200 cubic feet per second (cfs), and the maximum pumping rate is 31,720 cfs. Flows pass from the powerhouse into a 200-foot-long tailrace section that empties directly into Lake Keowee. Power generated by each turbine passes through a step-up transformer located at the powerhouse.

13. Lake Jocassee also serves as the lower reservoir for Duke Energy's Bad Creek Pumped Storage Hydroelectric Project No. 2470 (Bad Creek Project).

2. Keowee Development

14. The Keowee Development includes Keowee Dam, Little River Dam, four saddle dikes, the Oconee Nuclear Station intake dike, Lake Keowee, a gated spillway, the Keowee powerhouse, an excavated tailrace, and an intake structure. Keowee Dam is

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[10] *See* EA at 33.

[11] All elevations are feet above mean sea level (AMSL) unless otherwise noted.

located about 12 miles downstream of Jocassee Dam. Duke Energy's Oconee Nuclear Station is located on the shores of Lake Keowee immediately west of Keowee Dam.

15. Lake Keowee was formed by the construction of the Keowee and Little River Dams, which impound the Keowee and Little Rivers, respectively. A 2,000-foot-long by 100-foot-deep excavated canal, located a half mile north of the Oconee Nuclear Station, connects the impounded waters of the Keowee and Little Rivers to form Lake Keowee. Lake Keowee has a surface area of 17,660 acres, and 388 miles of shoreline at a full pond elevation of 800 feet. The gross storage capacity of the lake at full pond is 869,338 acre-feet. Usable storage capacity is 364,884 acre-feet between elevations 775 and 800 feet; however, drawdowns are limited to 794.6 feet due to operating constraints at the Oconee Nuclear Station. This results in an operating range of 5.4 feet and a storage capacity of 90,319 acre-feet.

16. Keowee Dam is a 165-foot-high by 3,500-foot-long earthfill dam located on the Keowee River at RM 328.8. One cylindrical concrete/steel intake structure, located in Lake Keowee at the east section of the dam, leads to a power tunnel that bifurcates and passes flows to two turbines in the powerhouse. The cylindrical intake has eight screened water intakes positioned at different elevations in the reservoir.

17. The Little River Dam is a 1,800-foot-long, 165-foot-high earthfill dam located on the Little River at RM 3. The dam has no gates or water release structures. Four earthfill saddle dikes, located 1.5 miles north of Little River Dam on the eastern edge of Lake Keowee, serve to contain Lake Keowee.

18. The Oconee Nuclear Station intake dike is an earthfill dike located approximately three-fourths of a mile southwest of Keowee Dam in the intake channel for the Oconee Nuclear Station. The 1,200-foot-long dike has a top elevation of 825 feet, and serves to impound Lake Keowee within the intake channel. The dike has no gates or water release structures.

19. A 176-foot-wide concrete gated spillway is located at the east end of Keowee Dam. The spillway includes an entrance channel with concrete wingwalls and concrete side walls, and four Tainter gates capable of releasing up to 106,000 cfs. Flows from the Tainter gates pass into a concrete channel that empties into Hartwell Lake.

20. A powerhouse is located at the base of Keowee Dam. The powerhouse contains two Francis turbine/generator units, each with an authorized installed capacity of 78.75 MW. The total authorized installed capacity of the powerhouse is 157.5 MW. The maximum combined hydraulic capacity of the units is 24,920 cfs. Flows pass from the powerhouse into a 200-foot-long tailrace section that empties into the Corps' Hartwell Lake. Power generated by each turbine passes through a step-up transformer, located at the powerhouse.

C. Project Recreation Facilities

21. Under the current license, Duke Energy owns and leases to the South Carolina Parks one developed recreation site at Lake Jocassee. This site, Devils Fork State Park, has 7 boat ramps, 2 picnic areas, hiking trails, and a campground with 84 sites. Double Spring Campground, a geographically separate section of Devils Fork State Park also owned by Duke Energy and leased by South Carolina, provides 20 additional camping sites. Duke Energy also owns and maintains three undeveloped project recreation sites at Lake Jocassee: the Bootleg, Grindstone, and Handpole Ridge Access Areas.

22. At Lake Keowee, Duke Energy owns, operates, and maintains, or provides for the maintenance of 10 developed project recreation sites, including the Crow Creek Access Area and the World of Energy Picnic Area, which are currently located outside of the project boundary but included in the existing Commission-approved Recreation Management Plan (Recreation Plan) for the project.[12] These recreation sites provide recreation opportunities that include boating, fishing, wildlife and scenic viewing, swimming, and recreational vehicle and tent camping.

D. Project Boundary

23. The existing project boundary encompasses 28,044 acres, including Lake Jocassee and Lake Keowee, project infrastructure, and all but two of the project recreation sites (Crow Creek Access Area and World of Energy Picnic Area). Except for areas occupied by project facilities and project recreation sites, the project boundary generally follows the 1,110- to 1,120-foot contour elevation around Lake Jocassee, and the 800- to 810-foot contour elevation around Lake Keowee.

24. Under the Relicensing Agreement, Duke Energy will modify the project boundary by incorporating 55 acres associated with the existing Crow Creek Access Area, 27 acres associated with the proposed High Falls II Access Area, 10 acres associated with the proposed Mosquito Point Access Area, and 25 acres associated with expansion of the existing Double Springs Campground at Devils Fork State Park. Duke Energy also will modify the project boundary to include lands necessary to support maintenance of Saddle Dike #1 at Lake Jocassee and the dam and spillway channel at Lake Keowee, and to correct previous mapping errors identified during the relicensing process.

25. With Duke Energy's proposed modifications, the total land within the project boundary would increase by 121 acres, to 28,165 acres. Duke Energy owns all of the land proposed for inclusion in the project boundary.

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[12] *Duke Energy Carolinas, LLC* 132 FERC ¶ 62,045 (2010).

E. Current Project Operation

1. Jocassee Development

26. The Jocassee Development is operated as a pumped storage facility, with the pump-turbine units used for generating power during peak demand periods (typically during the day), and for pumping water back through the power tunnels into Lake Jocassee (typically during the night). The average annual energy production from the Jocassee Development is 953,715 megawatt-hours per year (MWh/year). The average annual pumping energy used at the Jocassee Development is 1,076,966 MWh/year. The Jocassee Development is operated remotely from Duke's Hydro Operating Center in Charlotte, North Carolina.

27. Lake Jocassee is licensed to operate between 1,080 and 1,110 feet; however, the normal operating range, when not in drought conditions, has typically been far less. Lake Jocassee has operated at or above 1,094 feet more than 80 percent of the time. Daily fluctuations in the reservoir have ranged from 1.5 to 2.9 feet. The reservoir level is typically maintained by passing flows through one or more of the four turbine/pump units. During extreme flood events, when the reservoir elevation cannot be maintained using generation flows, the Tainter gates on the emergency spillway can be partially or fully opened. The emergency spillway, which has a capacity of 20,000 cfs, has not been used during the history of the project.

2. Keowee Development

28. The Keowee Development is a conventional hydropower facility, operated manually by staff on site. Average annual energy production from the Keowee Development is 64,543 MWh. Energy generated from the Keowee Development provides energy to the grid and standby emergency power for the 2,538-MW Oconee Nuclear Station located adjacent to Keowee Hydro Station. Lake Keowee provides cooling water to the Oconee Nuclear Station, and municipal water to the cities of Seneca and Greenville, South Carolina.

29. Lake Keowee is licensed to operate between elevations of 775 and 800 feet. However, based on Nuclear Regulatory Commission requirements for the Oconee Nuclear Station and other agreements, Duke Energy typically operates Lake Keowee between elevations 794.6 and 799.5 feet. On a daily average basis, Lake Keowee fluctuates less than 1 foot, rarely exceeding a fluctuation of 1.8 feet during high energy demand periods. Gross storage is 869,338 acre-feet and usable storage is 90,319 acre-feet.

30. During extremely low flow periods Duke Energy operates the project under a Low Inflow Protocol (LIP). For maintenance or emergency situations, Duke Energy operates

under a Maintenance and Emergency Protocol (MEP). Both plans are incorporated into the Operating Agreement signed by the Corps, SEPA, and Duke Energy.[13]

31. During high inflow events, Duke Energy uses the two generating units at the Keowee Development to pass inflow. The maximum hydraulic capacity of the Keowee powerhouse is 24,920 cfs. When inflow exceeds this amount, Duke Energy partially or fully opens the Tainter gates on the spillway to maintain the reservoir elevation.

F. Proposed Project Operation and Environmental Measures

32. Duke Energy proposes to operate and maintain the project in accordance with the Relicensing Agreement, which is summarized below. The Relicensing Agreement also includes measures that are not intended to be incorporated into the new license.

1. Reservoir Levels

33. Duke Energy will continue to operate Lake Jocassee within the existing upper elevation of 1,110 feet and lower elevation of 1,080 feet. For periods of normal inflow, when neither the proposed LIP nor proposed MEP is being implemented, Duke Energy will operate Lake Jocassee at a normal minimum elevation of 1,096 feet.

34. Duke Energy will operate Lake Keowee at the existing upper elevation of 800 feet. The lower elevation will be increased from 775 feet to 790 feet. The 790-foot elevation limit will be implemented by December 1, 2019, to allow time for the Oconee Nuclear Station to be modified to allow for project operations at that level.[14] The interim low-level elevation for Lake Keowee will be 794.6 feet, which Duke Energy currently maintains. For periods of normal inflow, when neither the LIP nor MEP has been implemented, Duke Energy will operate at a normal minimum elevation of 796 feet.

2. Low Inflow Protocol (LIP)

35. Duke Energy will implement the LIP[15] at both the Jocassee and Keowee Developments (*see* Appendix D of the Relicensing Agreement, attached as Appendix B

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[13] Duke Energy began implementing the LIP and MEP on December 1, 2013, which is the effective date of the executed Relicensing Agreement.

[14] The proposed operation will require the Oconee Nuclear Station to be modified to withdraw water from Lake Keowee at the lower elevation of 790 feet.

[15] The LIP sets forth a formal set of procedures for operating the project during droughts based on reservoir storage and watershed inflow triggers that advance through four stages of conservation and management as the duration and severity of drought conditions increases. The LIP establishes the Keowee-Toxaway Drought Management *(continued ...)*

of this order). The LIP is a set of procedures for operating the project during droughts based on weather and watershed inflow triggers that advance through five stages of conservation and management as the duration and severity of a drought condition increases. The LIP limits weekly flow releases from Keowee Dam to amounts specified by the applicable LIP stage in effect. The LIP allows Duke Energy to draw its lakes below the normal minimum elevations during low inflow or drought periods. Under the most severe drought conditions, Lake Jocassee will be maintained at a minimum elevation of 1,080 feet, and Lake Keowee will be maintained at a minimum elevation of 790 feet.

3. Maintenance Emergency Protocol (MEP)

36. Duke Energy will implement the MEP at both the Jocassee and Keowee Developments (see Appendix E of the Relicensing Agreement, attached as Appendix C of this order). Circumstances under which the MEP will be in effect include hydro unit outages, dam safety emergencies, maintenance activities, and flood events. Under normal operation, Lake Jocassee will be maintained between 1,106 and 1,110 feet, using the four development turbines. The MEP provides that during flood conditions, if turbine flow fails to manage reservoir elevations, Duke Energy will either partially or fully open one or both Tainter gates at Jocassee Dam to balance inflow. Similarly, if the reservoir elevation of Lake Keowee cannot be maintained with turbine flow alone, Duke Energy will open the spillway gates at Keowee Dam to match inflow. The MEP lists the parties that will be notified and/or consulted under such conditions, and provides guidelines on how to do so.

4. Water Quality

37. Duke Energy will continuously monitor dissolved oxygen (DO) concentrations in the tailwaters of the Jocassee and Keowee Developments during August for the term of the new license to demonstrate compliance with South Carolina's water quality standards. Duke Energy will submit the monitoring results to the South Carolina Department of Health and Environmental Control (South Carolina DHEC) and the Commission annually.

5. Species Protection Agreements

38. Currently, no federally listed threatened or endangered species are known to occur within the project boundary or to be affected by the project. However, Duke Energy does

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Advisory Group. The Advisory Group and the activities of the group are elements of the LIP that would not be enforceable by the Commission because the Commission cannot enforce the provisions of a settlement against parties it does not regulate. *See, e.g., Avista Corporation,* 93 FERC ¶ 61,116 at 61,329 (2000).

propose restrictive land use classifications and vegetation management provisions within its Shoreline Management Plan (SMP) to limit effects on any potentially-occurring federally listed species within the project's area of influence. Duke Energy also proposes to develop and implement species protection plans to protect federally listed threatened or endangered species if and when such species are identified within the project's area of influence during the new license term. Therefore, at this time, Duke Energy has not prepared any species protection plans for federally listed species.

6. Recreation Management

39. Duke Energy will implement the Recreation Management Plan (recreation plan), filed with its license application,[16] that describes operational and enhancement measures to be implemented at project recreation sites at Lake Jocassee and Lake Keowee. These measures are summarized below.

40. To enhance recreational opportunities and meet the needs of new user types at the Jocassee Development, the recreation plan includes proposals to add diver access, a new courtesy dock, a new boat and trailered parking area, access for non-motorized boating, and bank fishing signage at Devils Fork State Park. Duke Energy will also expand the project boundary at Double Springs Campground by approximately 25 acres and construct 12 new campsites and restroom facilities.

41. To enhance recreational opportunities at the Keowee Development, the recreation plan includes proposals to: (1) add bank fishing signs at all existing project recreation sites; (2) construct new parking areas at 3 recreation sites; (3) construct new trails at 2 recreation sites; (4) construct new camping facilities with 10 primitive campsites, 5 bank fishing stations, and 10 camping cabins at Mile Creek County Park; and (5) construct a canoe/kayak launch, fishing pier, and portage at 15-Acre Lake, a project recreation site located at Keowee-Toxaway State Park. The recreation plan also identifies 2 areas, the 37-acre High Falls II Access Area and the 10-acre Mosquito Point Access Area, which will be reserved for future public recreation. Duke Energy will also stabilize eroding shorelines at 3 project recreation sites: Fall Creek, High Falls II, and Mosquito Point Access Areas.

42. The recreation plan also includes a provision for Duke Energy to consult with South Carolina Parks and South Carolina DNR every 12 years on a plan to conduct a Recreation Use and Needs Study and update the recreation plan, as necessary.[17]

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[16] The recreation plan was filed as Appendix E4 of the license application.

[17] The Relicensing Agreement also requires Duke Energy to revise the RMP no later than December 31, 2033.

7. Shoreline Management

43. Duke Energy will implement the SMP filed with its license application,[18] which includes: (1) shoreline classification maps; (2) lake use restrictions for each shoreline classification type based on existing uses, environmental criteria, and potential future uses; and (3) shoreline management guidelines that address permitting requirements for non-project use of project lands and waters.

44. Duke Energy also will consult with FWS, South Carolina Parks, and South Carolina DNR to review and revise the SMP 10 years following license issuance, and every 10 years thereafter.

8. Historic Properties Management

45. Duke Energy proposes to implement an Historic Properties Management Plan (HPMP) to protect cultural resources at the project.

SUMMARY OF LICENSE REQUIREMENTS

46. Except as indicated below, this license requires the Duke Energy-proposed operational and environmental measures discussed above to protect and enhance water quality, fish, wildlife, recreation, and cultural resources at the project.

47. To enhance public use of the reservoirs and address the potential overuse of existing recreation sites, the license requires Duke Energy to revise the recreation plan to provide for construction of recreation amenities at Crow Creek Access Area and Mile Creek County Park; include monitoring provisions for capacity and condition of Warpath Access Area; identify the existing World of Energy Picnic Area as a project recreation site; and provide for the stabilization of 6,250 feet of shoreline on certain islands in Lake Keowee to protect the use of the islands for day-use recreation. The license also requires that all proposed improvements made to project recreation sites through Duke Energy's Access Area Improvement Initiative (AAII)[19] be identified in the recreation plan.

48. To address the potential effects of lowering reservoir elevations at Lake Keowee during extremely low inflow conditions on shoreline residents' ability to use their boat docks, the license requires Duke Energy to modify its proposed SMP to extend the

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[18] The SMP was filed as Appendix E5 of the license application.

[19] The AAII is a program established by Duke Energy to provide opportunities for tribes, state and local governments, and businesses to lease project recreation sites for operating and maintaining new and existing public recreation facilities.

provision for exemptions to the maximum size limit for private facilities (e.g., boat docks) from the time of license issuance through December 31, 2020.

49. To protect cultural resources, the license requires Duke Energy to implement the HPMP filed on November 5, 2014, pursuant to a Programmatic Agreement (PA) that was executed on May 8, 2015, by the North Carolina State Historic Preservation Officer (SHPO) and on May 19, 2015, by the South Carolina SHPO.[20]

WATER QUALITY CERTIFICATION

50. Under section 401(a)(1) of the Clean Water Act (CWA),[21] the Commission may not issue a license authorizing the construction or operation of a hydroelectric project unless the state water quality certifying agency has either issued water quality certification for the project or has waived certification by failing to act on a request for certification within a reasonable period of time, not to exceed 1 year. Section 401(d) of the CWA provides that the certification shall become a condition of any federal license that authorizes construction or operation of the project.[22]

A. North Carolina

51. Only a small portion of the upper end of Lake Jocassee is located in North Carolina. Because no project releases occur in North Carolina, water quality certification from that state is not required.[23]

B. South Carolina

52. On March 31, 2015, Duke Energy filed an application with South Carolina DHEC for certification pursuant to the CWA for the Keowee-Toxaway Project, which South Carolina DHEC received on April 1, 2015. On October 29, 2015, South Carolina DHEC issued a certification for the Keowee-Toxaway Project that includes the conditions set

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[20] Commission staff found Duke Energy's proposed HPMP needed revisions, and Duke Energy filed a revised HPMP on November 5, 2014. The executed PA, which Duke Energy signed, incorporates the HPMP, which supersedes the one filed with the license application and mentioned in the Relicensing Agreement.

[21] 33 U.S.C. § 1341(a)(1) (2012).

[22] 33 U.S.C. § 1341(d) (2012).

[23] *See* letter from North Carolina Division of Water Quality (now known as the North Carolina Division of Water Resources) dated April 7, 2011, and filed with the license application.

forth in Appendix A of this order and incorporated into the license by Ordering Paragraph (D).

53. The South Carolina certification includes three conditions to protect water quality and ensure the project complies with state water quality standards, two of which are general or administrative and are not discussed further.[24] The remaining condition requires Duke Energy to implement the Relicensing Agreement's proposed license articles A-2.0 and A-7.0, which are reproduced for reference in Appendix A of this order.

54. Under article A-7.0 of the Relicensing Agreement, Duke Energy must continuously monitor DO concentrations during the month of August, for the term of the license, in both the Jocassee and Keowee Developments' tailwaters to demonstrate compliance with South Carolina's water quality standards.

55. In the EA,[25] Commission staff did not recommend water quality monitoring in the tailrace of each development during August because: (1) existing water quality in the reservoirs and tailwaters is meeting or exceeding levels consistent with state water quality standards, and is consistent with levels supporting designated uses, and no issues have been raised concerning pH and total dissolved gas; (2) water quality modeling results indicate that under the proposed project operation suitable DO levels and water temperatures would exist for the propagation of aquatic life in the Keowee Development releases; (3) there are no proposed changes in project operation that would alter water quality from existing conditions in the Jocassee Development tailwaters; and (4) the fishery at the project is considered excellent.[26] Nonetheless, because South Carolina DHEC's certification requires Duke Energy to monitor DO, the requirement is included in this license.

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[24] The general terms and conditions stipulate that: (1) Duke Energy take all measures necessary to prevent contaminants resulting from project operation and maintenance activities from entering adjacent waters or wetlands; and (2) any applicant to Duke Energy for a large water intake or major water withdrawal from the project must comply with the Surface Water Withdrawal, Permitting, Use And Reporting Act, S.C. Code Ann. §§ 49-4-10 et seq.

[25] *See* EA at 232.

[26] Lake Jocassee supports a productive cold-water fishery for brown and rainbow trout.

COASTAL ZONE MANAGEMENT

56. Under section 307(c)(3)(A) of the Coastal Zone Management Act (CZMA),[27] the Commission cannot issue a license for a project within or affecting a state's coastal zone unless the state CZMA agency concurs with the license applicant's certification of consistency with the state's coastal zone management program, or the agency's concurrence is conclusively presumed by its failure to act within 6 months of its receipt of the applicant's certification.

57. By letter dated November 31, 2013,[28] South Carolina DHEC notified Duke Energy that because the project is not located within the Coastal Management Zone for South Carolina, nor would the project affect South Carolina coastal resources, a consistency certification is not required.

SECTION 18 FISHWAY PRESCRIPTION

58. Section 18 of the FPA[29] provides that the Commission shall require the construction, maintenance, and operation by a licensee of such fishways as may be prescribed by the Secretary of the Interior or the Secretary of Commerce, as appropriate.

59. By letter filed March 30, 2015, the Secretary of the Interior requested that the Commission reserve authority to prescribe fishways. Consistent with Commission policy, Article 405 of this license reserves the Commission's authority to require fishways that may be prescribed by Interior for the Keowee-Toxaway Project.

THREATENED AND ENDANGERED SPECIES

60. Section 7(a)(2) of the Endangered Species Act (ESA) of 1973[30] requires federal agencies to ensure that their actions are not likely to jeopardize the continued existence of federally listed threatened and endangered species, or result in the destruction or adverse modification of their designated critical habitat.

61. In a letter filed on August 5, 2015, FWS identified 16 federally listed species including a mussel species, a lichen species, 9 plant species, 4 mammal species, and a

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[27] 16 U.S.C. § 1456(c)(3)(A) (2012).

[28] *See* Duke Energy's August 27, 2014 License Application, Exhibit E1 at Appendix E7.

[29] 16 U.S.C. § 811 (2012).

[30] 16 U.S.C. § 1536(a) (2012).

reptile species that are known to occur in one or more of the three counties in the project area. The mussel species is the endangered Appalachian elktoe. The lichen species is the endangered rock gnome lichen. The plant species are: the endangered smooth coneflower, persistent trillium, mountain sweet pitcher plant, spreading avens, black-spored quillwort; and the threatened small whorled pogonia, dwarf-flowered heartleaf, swamp pink, and Virginia spiraea. The mammal species are: the endangered Carolina northern flying squirrel, Indiana bat, and gray bat; and the threatened northern long-eared bat. The reptile species is the threatened bog turtle.[31]

62. FWS has designated critical habitat for Appalachian elktoe and Indiana bat, but no critical habitat occurs in the project area.[32]

63. In the EA,[33] staff determined that relicensing the project would have no effect on the Appalachian elktoe, rock gnome lichen, persistent trillium, mountain sweet pitcher plant, spreading avens, black-spored quillwort, small whorled pogonia, dwarf-flowered heartleaf, swamp pink, Virginia spiraea, Carolina northern flying squirrel, and bog turtle because none of these species have been identified within the project boundary or in areas that could be affected by project-related activities. Therefore, no further action under the ESA is required for these species. By letter filed November 12, 2015, FWS concurred with the "no effect" determination for these species.

64. In the EA,[34] staff also determined that relicensing the project would not be likely to adversely affect the smooth coneflower, Indiana bat, gray bat, and northern long-eared bat because there is no evidence that potentially suitable habitat within the project boundary is currently being used by these species. None of these species have been identified within the project boundary or in areas that could be affected by project-related activities. Staff found that the vegetation management measures included in Duke Energy's SMP would benefit these species by minimizing disturbances to native vegetation. By letter filed November 12, 2015, FWS concurred with the "not likely to adversely affect" determination for these species.[35] Therefore, no further action under the ESA is required for these species.

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[31] Bog turtles are listed as threatened in the U.S. except in Georgia, North Carolina, South Carolina, and Virginia, where they are listed as threatened due to similarity of appearance (i.e., T (S/A)). *See* EA at 7.

[32] *See* EA at 137 and 142.

[33] *See* EA at 142-146.

[34] *See* EA at 143 and 146-149.

[35] In its November 12, 2015 letter, FWS concurred with Commission staff's *(continued ...)*

NATIONAL HISTORIC PRESERVATION ACT

65. Under section 106 of the National Historic Preservation Act (NHPA)[36] and its implementing regulations,[37] federal agencies must take into account the effect of any proposed undertaking on properties listed or eligible for listing in the National Register of Historic Places (defined as historic properties) and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment on the undertaking. This process generally requires the Commission to consult with the SHPO to determine whether and how a proposed action may affect historic properties, and to seek ways to avoid or minimize any adverse effects.

66. To satisfy these responsibilities, the Commission executed a PA with the North Carolina SHPO on May 8, 2015, and the South Carolina SHPO on May 19, 2015, and invited Duke Energy, Eastern Band of Cherokee Indians, United Keetoowah Band of Cherokee Indians in Oklahoma, Catawba Indian Nation, and Cherokee Nation to concur with the stipulations of the PA. Duke Energy and the Catawba Indian Nation concurred. The PA requires Duke Energy to implement the HPMP, filed on November 5, 2014, for the term of any new license issued for this project. Execution of the PA demonstrates the Commission's compliance with section 106 of the NHPA. Article 408 requires Duke Energy to implement the PA and HPMP.

RECOMMENDATIONS OF FEDERAL AND STATE FISH AND WILDLIFE AGENCIES PURSUANT TO SECTION 10(J) OF THE FPA

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finding that the project, with staff's recommended measures, is not likely to adversely affect these species. In support, FWS referenced proposed measures to implement a shoreline management plan and to develop a species protection plan to address any project-related effects if a particular federally listed species is found to occur within the project boundary. As discussed in the EA, staff did not include the species protection plans as part of the staff alternative. Rather, under the Relicensing Agreement, Duke Energy will develop the plans in the future if they are found to be necessary. Because the plans are not currently needed to protect federally listed species, the license does not require them.

[36] Section 106 of the National Historic Preservation Act of 1966, as amended, 54 U.S.C. § 306108, Pub. L. No. 113-287, 128 Stat. 3188 (2014). (The National Historic Preservation Act was recodified in Title 54 in December 2014.)

[37] 36 C.F.R. Part 800 (2015).

67. Section 10(j)(1) of the FPA[38] requires the Commission, when issuing a license, to include conditions based on recommendations submitted by federal and state fish and wildlife agencies pursuant to the Fish and Wildlife Coordination Act,[39] to "adequately and equitably protect, mitigate damages to, and enhance fish and wildlife (including related spawning grounds and habitat)" affected by the project. No agency filed section 10(j) recommendations for the Keowee-Toxaway Project.

SECTION 10(a)(1) OF THE FPA

68. Section 10(a)(1) of the FPA[40] requires that any project for which the Commission issues a license be best adapted to a comprehensive plan for improving or developing a waterway or waterways for the use or benefit of interstate or foreign commerce; for the improvement and utilization of waterpower development; for the adequate protection, mitigation, and enhancement of fish and wildlife; and for other beneficial public uses, including irrigation, flood control, water supply, recreation, and other purposes.

A. Reservoir Elevations and Project Operating Regimes

69. Duke Energy operates the Keowee-Toxaway Project in coordination with the Bad Creek Project. Water from Lake Jocassee (lower reservoir) is pumped into the Bad Creek Reservoir (upper reservoir) and is then used by the Bad Creek Project to generate power daily during peak demand periods. Duke Energy owns both the Bad Creek and Keowee-Toxaway Projects and proposes to continue operating them in a coordinated manner during the term of the new license.

70. When the Commission does not license related projects together, as is the case here, the Commission may authorize projects separately, but coordinate the projects' operations pursuant to section 10(a). Therefore, Article 401 requires that the Jocassee Reservoir be available to the Bad Creek Project for its pumped-storage operations.

71. Duke Energy proposes to operate the project in accordance with the 2014 Operating Agreement signed by the Corps, SEPA, and Duke Energy, and as described above. In the EA,[41] staff concluded that the proposed operating levels at Lake Keowee and Lake Jocassee would continue to provide protection for water quality, aquatic biota,

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[38] 16 U.S.C. § 803(j)(1) (2012).

[39] 16 U.S.C. §§ 661 *et seq*. (2012).

[40] 16 U.S.C. § 803(a)(1) (2012).

[41] *See* EA at 68-69.

aquatic habitat, and recreation resources by minimizing fluctuations of the water surface in each lake; thus, Article 402 requires these operating elevations.

72. Petitioners commented that Duke Energy's provisions for lowering the minimum reservoir elevation of Lake Keowee from the existing effective minimum of 794.6 feet to 790 feet would result in greater frequency and duration of lower lake levels and lead to a decline in value of lakefront homes. They recommended that the minimum reservoir elevation for Lake Keowee be set at 793 feet. However, as proposed by Duke Energy, Lake Keowee's reservoir level should actually be higher (i.e., 796 feet) under normal inflows, and would fall below 796 feet only during periods of drought when the LIP is triggered. In the EA,[42] staff concluded that elevations below 793 feet would occur infrequently and have minimal effects on the local economy of Lake Keowee. Therefore, Article 403 requires the proposed LIP.

73. In the EA,[43] staff recommended the MEP to define project operations during emergencies. Article 404 requires the proposed MEP.

B. Water Quality Monitoring

74. Interior recommends that Duke Energy install permanent water quality monitoring stations in the tailwaters, bypassed reaches, and reservoirs of the project. Interior recommends that the water quality monitoring include, at a minimum, collecting data on DO, water temperature, turbidity, pH, and total dissolved gas on an hourly basis. In the EA,[44] Commission staff did not recommend this provision, concluding that: (1) existing water quality in the reservoirs and tailwaters are at levels meeting or exceeding those established by state water quality standards; (2) water quality modeling results indicate that under the proposed project operation suitable DO levels and water temperatures would exist for the propagation of aquatic life in the Keowee Development releases; (3) no proposed changes in project operations would alter water quality from existing conditions in the Jocassee Development tailwaters; and (4) the fishery at the project is considered excellent. Interior did not object to this approach.[45] Based on the reasons outlined above, the license does not include Interior's recommended water quality monitoring provisions.

C. Recreation Management

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[42] *See* EA at 230-232.

[43] *See* EA at 223-224.

[44] *See* EA at 233.

[45] *See* letter from Interior filed October 30, 2015.

75. Under section 6.2 of the Relicensing Agreement, Duke Energy will implement the recreation plan it filed with its license application. The recreation plan includes a list of proposed enhancement measures, conceptual plans, and management strategies for the 12 existing and 2 proposed new project recreation sites. As discussed in the EA,[46] these enhancement measures would protect, improve, and enhance recreation resources within the project boundary. However, in the EA,[47] staff recommended modifications to the recreation plan because some of the proposals either require action by third-party entities that cannot be enforced by the Commission or lack adequate specificity. These modifications to the recreation plan are discussed below.

1. Requirements for Third-Party Lessees

76. The recreation enhancement measures proposed by Duke Energy for Mile Creek County Park and Crow Creek Access Area are contingent on the actions of third-party entities, over which the Commission has no jurisdiction. As described in its proposal, Duke Energy would only construct campsites, camping cabins, and sheltered fishing stations at Mile Creek County Park if Pickens County, South Carolina agrees to operate and maintain the facilities. At the Crow Creek Access Area, Duke Energy's proposal assumes The Reserve at Lake Keowee will construct the previously Commission-approved[48] project recreation facilities (including lighting, expanded parking, a courtesy dock, picnic area, and bank fishing trail). Duke Energy indicated that if the facilities are not constructed by The Reserve at Lake Keowee, Duke Energy would install bank fishing signage and maintain the sight as-is, without the additional recreation enhancement measures.

77. However, as Commission staff found in the EA,[49] these facilities are needed now. Therefore, Article 406 requires Duke Energy to construct the recreation amenities proposed for both Mile Creek County Park and Crow Creek Access Area. Further, in order to ensure that project recreation sites are improved, operated, and maintained in ways that are consistent with project purposes, Article 406 requires Duke Energy to ensure that all future improvements made to project recreation sites by lessees as part of the AAII must be consistent with the recreation plan, identified in as-built drawings of project recreation facilities, and approved by the Commission where appropriate.

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[46] *See* EA at 170.

[47] *See* EA at 225-226 and 229.

[48] *Duke Energy Carolinas, LLC* 132 FERC ¶ 62,045 (2010).

[49] *See* EA at 225-226.

2. Warpath Access Area

78. The Warpath Access Area is a 63-acre project recreation site containing a 38-space trailered vehicle parking area, 3 concrete boat ramps, and 2 courtesy docks. Duke Energy's proposed recreation plan contains provisions for significant reconfiguration of the existing facilities, including constructing a campground, swim beach, picnic areas, and cabins. These facilities were proposed by Warpath Development, Inc. through the AAII and approved by Commission staff in 2006 as a non-project use of project lands and waters[50] and again in 2008 as part of the Recreation Management Plan for the Keowee-Toxaway Project.[51] Effective March 4, 2016, however, Duke Energy terminated Warpath Development, Inc.'s lease of the Warpath Access Area, and Duke Energy now proposes to only install bank fishing signage at the site.

79. During the Recreation Use and Needs Study conducted as part of the relicensing, the Warpath Access Area was the only site where use exceeded capacity on holiday weekends, despite less-crowded alternatives. It was also the second-most preferred boat launch area because of its location and availability of parking. As discussed in the EA,[52] staff found that, given Duke Energy's estimates for future recreation growth, the high level of use at Warpath Access Area could result in adverse effects on environmental resources (i.e., vehicular or pedestrian use of un-designated areas) or reduce the quality of the recreation experience at the site. Duke Energy's proposal to maintain the site as-is and install bank fishing signage would not address capacity issues associated with boat launch use during the peak recreation season.

80. Commission staff did not recommend that Duke Energy construct the amenities proposed in the 2008 recreation plan,[53] which would require significant reconfiguration of the site and change the character of the existing recreation experience. Staff determined that such amenities do not meet the need identified in Duke Energy's Recreation Use and Needs Study. Rather, staff recommended that the recreation plan be modified to include a provision to monitor capacity and facility condition at the Warpath Access Area annually during the summer recreation season. This change will give Duke Energy flexibility to address negative effects of boat launch overuse, without making significant changes to the access area that may not be warranted at this time. Therefore, Article 406 requires that the recreation plan be modified to include provisions for

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[50] *Duke Power Co., LLC*, 115 FERC ¶ 62,327 (2006).

[51] *Duke Energy Carolinas, LLC*, 132 FERC ¶ 62,045 (2010).

[52] *See* EA at 227-228.

[53] *See* EA at 222.

monitoring the capacity and condition of the Warpath Access Area over the term of the recreation plan.

3. World of Energy Picnic Area

81. Duke Energy did not include the World of Energy Picnic Area in its proposed recreation plan. However, the Commission-approved 2008 recreation plan recognizes the World of Energy Picnic Area as a project recreation site and identifies it as a popular destination for bank fishing. In addition, the order approving the 2008 plan required that Duke Energy bring the World of Energy Picnic Area into the project boundary.[54] To date, Duke Energy has not incorporated the World of Energy Picnic Area into the project boundary and did not include it in its proposed recreation plan.

82. As discussed in the EA,[55] although World of Energy is located on Duke Energy-owned lands associated with Oconee Nuclear Station, the site provides access to Lake Keowee and includes water-based recreation facilities including a boat dock and fishing pier. Enclosing the recreation facilities at World of Energy Picnic Area within the project boundary and modifying the recreation plan to include World of Energy Picnic Area as a project recreation site will ensure the area is operated and maintained over the term of the new license. Therefore, Article 203 requires Duke Energy to file revised exhibit G drawings enclosing, within the project boundary, all lands associated with the recreation facilities at the World of Energy Picnic Area, and Article 406 requires modifications to the recreation plan to include World of Energy Picnic Area as a project recreation site.

4. Shoreline Stabilization

83. As part of the recreation plan, Duke Energy proposed to stabilize a total of about 3,000 linear feet of shoreline associated with three project recreation sites: the existing Fall Creek Access Area and the new High Falls II and Mosquito Point Access Areas. In the EA,[56] Commission staff recommended that Duke Energy also include, in its recreation plan, provisions for stabilizing an additional 6,250 linear feet of shoreline associated with certain islands in Lake Keowee that have been designated by Duke Energy for day-use recreation in both the proposed recreation plan and SMP. Staff concluded that stabilizing the shorelines would protect the islands from potential erosion and make them safer to use. Therefore, Article 406 requires Duke Energy to modify the

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[54] *Duke Energy Carolinas, LLC*, 132 FERC ¶ 62,045 (2010).

[55] *See* EA at 225.

[56] *See* EA at 228.

recreation plan to include a provision to stabilize the islands' shorelines (i.e., 6,250 linear feet) to protect them for day-use recreation.[57]

D. Shoreline Management Plan

84. Duke Energy proposes to implement an SMP filed with the license application. As discussed in the EA,[58] the SMP would allow for residential and commercial development of the project's reservoir shorelines while maintaining areas for natural resource protection and recreation. In the EA, Commission staff recommended approving the SMP with the modifications described below.

1. Provisions for Dock Expansions

85. The SMP contains a provision allowing existing dock owners to apply for permits to expand their private docks by up to 200 square feet beyond the SMP's maximum of 1,000 square feet. The SMP limits the timeframe to apply for such dock expansions to a single 365-day period. Petitioners commented that this timeframe was unnecessarily narrow, and that dock owners may not know if dock expansions would be necessary or helpful in reaching deeper water before the 365-day window expired.

86. In the EA,[59] staff found a 365-day timeframe for accepting permit applications to be problematic. In the license application, Duke Energy's proposal for allowing dock modifications was tied to the proposal to restrict the minimum elevation to 790-foot during extreme low-flow events. Currently, Oconee Nuclear Station's operational constraints limit the reservoir elevation to 794.6 feet. Operational changes to Oconee Nuclear Station will be complete by December 1, 2019; however, as described in the SMP, the 365-day period could begin (and end) in advance of implementation of the new minimum reservoir elevation. Therefore, Article 407 requires the SMP be modified to allow dock owners[60] to apply for exemptions to modify or expand their docks by up to 200 square feet to reach deeper water through December 31, 2020.

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[57] Although Duke Energy proposed to stabilize the shoreline of certain islands in Lake Keowee as an off-license measure in the Relicensing Agreement, the islands are used by the public and designated by Duke Energy in the recreation plan and SMP for day-use recreation. Therefore, the stabilization of their shorelines is properly included as a condition of the license.

[58] *See* EA at 185.

[59] *See* EA at 229.

[60] As described in the SMP, this provision applies only to existing dock owners as of December 1, 2013.

2. Annual Reporting

87. Duke Energy's proposed SMP contains updated procedures that allow for minor changes to the shoreline management guidelines, shoreline classification maps, and associated lake use restrictions to protect newly discovered resources such as archeological or historic sites, Threatened or Endangered Species, Special Concern Species, or to correct mapping errors. To facilitate Commission administration of the license, in the EA,[61] staff recommended modifying the SMP to require annual reporting to document any changes made to the SMP and its component maps, restrictions, and guidelines. Article 407 requires this modification.

ADMINISTRATIVE PROVISIONS

A. Annual Charges

88. The Commission collects annual charges from licensees for administration of the FPA. Article 201 provides for the collection of such funds.

B. Exhibit F and G Drawings

89. The Exhibit F drawings are approved and made part of the license (ordering paragraph (B)). The Commission requires licensees to file sets of approved project drawings in electronic file format. Article 202 requires the filing of these drawings.

90. The Exhibit G drawings filed with the license application do not enclose the World of Energy Picnic Area which is a project recreation facility. Therefore, the Exhibit G drawings are not approved, and Article 203 requires Duke Energy to file a revised Exhibit G drawing(s) that encloses the World of Energy Picnic Area within the project boundary.

C. Amortization Reserve

91. The Commission requires that for new major licenses, non-municipal licensees must set up and maintain an amortization reserve account upon license issuance. Article 204 requires the establishment of the account.

D. Headwater Benefits

92. Some projects directly benefit from headwater improvements that were constructed by other licensees, the United States, or permittees. Article 205 requires the licensee to reimburse such entities for these benefits if they were not previously assessed and reimbursed.

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[61] *See* EA at 230.

E. Project Modifications Resulting from Environmental Requirements

93. Article 301 requires the licensee to provide the Commission's Division of Dam Safety and Inspections' Atlanta Regional Office with proposed project modifications resulting from environmental requirements.

F. Commission Notification of LIP Operations

94. Ordering Paragraph (D) requires implementing the LIP. The LIP requires that the Commission be notified once LIP stage 1 has been reached, and each subsequent stage. Article 403 specifies that the Commission be notified within 10 days of each change in operation once Stage 1 of the LIP is reached.

G. Use and Occupancy of Project Lands and Waters

95. Requiring a licensee to obtain prior Commission approval for every use of occupancy of project land would be unduly burdensome. Therefore, Article 409 allows the licensee to grant permission, without prior Commission approval, for the use and occupancy of project lands for such minor activities as landscape planting. Such uses must be consistent with the purposes of protecting and enhancing the scenic, recreational, and environmental values of the project.

STATE AND FEDERAL COMPREHENSIVE PLANS

96. Section 10(a)(2) of the FPA[62] requires the Commission to consider the extent to which a project is consistent with federal or state comprehensive plans for improving, developing, or conserving a waterway or waterways affected by the project.[63] Under section 10(a)(2)(A) of the FPA, federal and state agencies filed 53 comprehensive plans that address various resources in North Carolina and South Carolina. Of these, the Commission staff identified and reviewed 16 comprehensive plans that are relevant to this project.[64] No conflicts were found.

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[62] 16 U.S.C. § 803(a)(2)(A) (2012).

[63] Comprehensive plans for this purpose are defined at 18 C.F.R. § 2.19 (2015).

[64] The list of applicable plans can be found in Appendix F of the EA for the project.

APPLICANT'S PLANS AND CAPABILITIES

97. In accordance with sections 10(a)(2)(C) and 15(a) of the FPA,[65] this order includes an evaluation of Duke Energy's record as a licensee for these areas: (A) conservation efforts; (B) compliance history and ability to comply with the new license; (C) safe management, operation, and maintenance of the project; (D) ability to provide efficient and reliable electric service; (E) need for power; (F) transmission services; (G) cost effectiveness of plans; and (H) actions affecting the public. The finding for each area is provided below.

A. Conservation Efforts

98. Section 10(a)(2)(C) of the FPA requires the Commission to consider the extent of electricity consumption efficiency improvement programs in the case of license applicants primarily engaged in the generation or sale of electric power, like Duke Energy. Duke Energy has provided conservation services for its electricity customers since 1971. Duke Energy has several programs to promote conservation and energy efficiency for residential, commercial, industrial, and agricultural customers, including: (1) making available special electric rates to customers who modify or build their homes to meet insulation and other energy conservation requirements and to large industrial customers that shift usage from peak times; (2) providing the public with energy saving tips through local advertisements; (3) making available an online energy audit suitable for individual residences or small business; and (4) providing on-site energy needs assessments along with recommendations on how to solve energy-related problems for larger businesses. These programs show that Duke Energy is making an effort to conserve electricity and has made a satisfactory good faith effort to comply with section 10(a)(2)(C) of the FPA.

B. Compliance History and Ability to Comply with the New License

99. Based on a review of Duke Energy's compliance with the terms and conditions of the existing license, Commission staff finds that Duke Energy's overall record of making timely filings and compliance with its license is satisfactory. Therefore, staff believes Duke Energy can satisfy the conditions of a new license.

C. Safe Management, Operation, and Maintenance of the Project

100. Commission staff has reviewed Duke Energy's management, operation, and maintenance of the Keowee-Toxaway Project pursuant to the requirements of 18 C.F.R. Part 12 and the Commission's Engineering Guidelines. Staff concludes that the dams and other project works are safe, and that there is no reason to believe that Duke Energy

[65] 16 U.S.C. §§ 803(a)(2)(C) and 808(a) (2012).

cannot continue to safely manage, operate, and maintain these facilities under a new license.

D. Ability to Provide Efficient and Reliable Electric Service

101. Commission staff has reviewed Duke Energy's plans and its ability to operate and maintain the project in a manner most likely to provide efficient and reliable electric service. Staff's review indicates that Duke Energy has devices that monitor structural movement or stress, seepage, uplift, and equipment failure at the project. Duke Energy regularly inspects the project turbine generator units to ensure they continue to perform in an optimal manner, schedules maintenance to minimize effects on energy production, and, since the project has been in operation, has undertaken several initiatives to ensure the project is able to operate reliably into the future. Staff concludes that Duke Energy is capable of operating the project to provide efficient and reliable electric service in the future.

E. Need for Power

102. The Keowee-Toxaway Project provides hydroelectric generation to meet part of North Carolina and South Carolina's power requirements, resource diversity, and capacity needs. The project, as licensed, will have an installed capacity of 867.60 MW, and generate approximately 1,018,258 MWh of electricity annually.

103. To assess the need for the project's power, Commission staff looked at the needs in the operating region in which the project is located. The project will be located in the Southeastern Electric Reliability Council (SERC) region, which is one of eight regional reliability councils of the North American Electric Reliability Corporation (NERC). NERC annually forecasts electrical supply and demand nationally and regionally for a 10-year period. According to NERC's December 2015 forecast report,[66] peak season energy demand in the SERC region will increase from 44,934 MW in 2016 to 50,502 MW in 2025, an increase of about 1.2 percent per year over the ten-year period. Commission staff concludes that the project's power, and its contribution to the region's diversified generation mix, will help meet a need for power in the region.

F. Transmission Services

104. The project's transmission facilities include the generator leads, station transformers, buses, and switch yards located near some of the project's developments, and in some cases transmission lines connecting the project to the point of interconnection with the grid. Neither Duke Energy proposes, nor does this license

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[66] North American Electric Reliability Corporation. 2015 Long Term Reliability Assessment. December 2015.

require, any changes that would affect this project's, or other transmission services in the region.

G. Cost Effectiveness of Plans

105. Duke Energy proposes operational measures in accordance with a 2014 Operating Agreement that includes provisions for operating under normal conditions, low inflow conditions (LIP), and for maintenance or emergencies (MEP). Duke Energy also proposes several measures and plans to enhance fish and wildlife, terrestrial, recreation, and cultural resources at the project. Based on Duke Energy's record as an existing licensee, Commission staff concludes that these proposals are likely to be carried out in a cost-effective manner.

H. Actions Affecting the Public

106. Duke Energy provided extensive opportunity for public involvement in the development of its application for a new license for the Keowee-Toxaway Project. In addition to using the project to help meet local power needs, during the previous license period Duke Energy provided facilities to enhance the public use of project lands and facilities, and operated the project with consideration for the protection of downstream uses of the Toxaway, Keowee, and Little Rivers.

PROJECT ECONOMICS

107. In determining whether to issue a new license for an existing hydroelectric project, the Commission considers a number of public interest factors, including the economic benefits of project power. Under the Commission's approach to evaluating the economics of hydropower projects, as articulated in *Mead Corp.*,[67] the Commission uses current costs to compare the costs of the project and likely alternative power with no forecasts concerning potential future inflation, escalation, or deflation beyond the license issuance date. The basic purpose of the Commission's economic analysis is to provide a general estimate of the potential power benefits and the costs of a project, and of reasonable alternatives to project power. The estimate helps to support an informed decision concerning what is in the public interest with respect to a proposed license.

108. In applying this analysis to the Keowee-Toxaway Project, Commission staff considered three options: no action, Duke Energy's proposal, and the project as licensed herein.[68] Under the no action alternative, the project would continue to operate as it does

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[67] 72 FERC ¶ 61,027 (1995).

[68] Details of staff's economic analysis for the project as licensed herein and for various alternatives are included in the EA issued on March 28, 2016, at section 4.0, *Developmental Analysis*.

now. The project generates an average of 1,018,258 MWh of electricity annually. Multiplying staff's estimate of average generation by the alternative power cost of $142.72/MWh[69] yields a total value of the project's power of $145,325,782 in 2015 dollars. The average annual project cost is about $38,254,656, or $37.57/MWh. To determine whether the proposed project is currently economically beneficial, staff subtracts the project's cost from the value of the project's power. Therefore, the project costs $107,071,126, or $105.15/MWh, less to produce power than the likely alternative cost of power.

109. As proposed by Duke Energy, the project would have an authorized capacity of 867.6 MW, and an average annual generation of 1,191,013 MWh valued at $148,519,321, or about $124.70/MWh. The average annual project cost is about $39,592,353, or $33.24/MWh. Therefore, subtracting the project's cost from the value of power, in the first year of operation, the project would produce power at a cost of $108,926,968 or $91.45/MWh, less than the likely alternative cost of power.

110. As licensed herein, with the mandatory conditions and staff measures, the project would have an authorized capacity of 867.6 MW, and an average annual generation of 1,191,013 MWh valued at $148,519,321, or about $124.70/MWh. The average annual project cost is about $39,611,581 or $33.25/MWh. Therefore, subtracting the project's cost from the value of power, in the first year of operation, the project would produce power at a cost of $108,907,740 or $91.44/MWh, less than the likely alternative cost of power.

111. In considering public interest factors, the Commission takes into account that hydroelectric projects offer unique operational benefits to the electric utility system (ancillary service benefits). These benefits include the ability to help maintain the stability of a power system, such as by quickly adjusting power output to respond to rapid changes in system load, and to respond rapidly to a major utility system or regional blackout by providing a source of power to help restart fossil-fuel based generating stations and put them back on line.

COMPREHENSIVE DEVELOPMENT

112. Sections 4(e) and 10(a)(1) of the FPA[70] require the Commission to give equal consideration to the power development purposes and to the purposes of energy

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[69] The alternative power cost was estimated for 2015, and includes the value of energy generated plus a value for dependable capacity. The value of energy is a composite of on-peak and off-peak rates.

[70] 16 U.S.C. §§ 797(e) and 803(a)(1) (2012).

conservation; the protection, mitigation of damage to, and enhancement of fish and wildlife; the protection of recreational opportunities; and the preservation of other aspects of environmental quality. Any license issued must be such as in the Commission's judgment will be best adapted to a comprehensive plan for improving or developing a waterway or waterways for all beneficial public uses. The decision to license this project, and the terms and conditions included herein, reflect such consideration.

113. The EA for the project contains background information, analysis of effects, and support for related license articles. Based on the record of this proceeding, including the EA and the comments thereon, licensing the Keowee-Toxaway Project as described in this order would not constitute a major federal action significantly affecting the quality of the human environment. The project will be safe if operated and maintained in accordance with the requirements of the license.

114. Based on Commission staff's independent review and evaluation of the project, recommendations from the resource agencies and other stakeholders, and the no-action alternative, as documented in the EA, the proposed Keowee-Toxaway Project, as licensed herein, is best adapted to a comprehensive plan for improving or developing the upper Savannah River Basin.

115. This alternative was selected because: (1) issuance of a new license will serve to maintain a beneficial, dependable, and inexpensive source of electric energy; and (2) the required environmental measures will protect and enhance fish and wildlife resources, water quality, recreational resources, and historic properties.

LICENSE TERM

116. Section 15(e) of the FPA[71] provides that any new license issued shall be for a term that the Commission determines to be in the public interest, but not less than 30 years or more than 50 years. The Commission's general policy is to establish 30-year terms for projects with little or no redevelopment, new construction, new capacity, or environmental mitigation and enhancement measures; 40-year terms for projects with a moderate amount of such activities; and 50-year terms for projects with extensive measures.[72] This license authorizes no new construction or new capacity, and only a minor amount of new environmental mitigation measures. Consequently, a 30-year license term for the Keowee-Toxaway Project is appropriate.

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[71] 16 U.S.C. § 808(e) (2012).

[72] *See Consumers Power Co.,* 68 FERC ¶ 61,077, at 61,383-84 (1994).

117. Because the term of the current license does not expire until August 31, 2016, this license order is not effective until September 1, 2016.[73]

The Director orders:

(A) This license is issued to Duke Energy Carolinas LLC (licensee), for a period of 30 years, effective September 1, 2016, to operate and maintain the Keowee-Toxaway Hydroelectric Project. This license is subject to the terms and conditions of the Federal Power Act (FPA), which is incorporated by reference as part of this license, and subject to the regulations the Commission issues under the provisions of the FPA.

(B) The Project consists of:

(1) All lands, to the extent of the licensee's interests in these lands, described in the project description and the project boundary discussion of this order.

(2) Projects works which include:

Jocassee Development consisting of: (a) a 7,980 acre reservoir (Lake Jocassee) at a full pond elevation of 1,110 feet above mean sea level (AMSL); (b) the 385-foot-high, 1,800-foot-long Jocassee Dam which includes two cylindrical concrete/steel intake structures with two power tunnels connecting the intakes of the powerhouse; (c) two earthfill saddle dikes; (d) a powerhouse containing four reversible pump-turbine units with a total installed capacity of 710.1 MW; (e) a generator step-up transformer feeding a 230-kilovolt (kV) transmission system; (f) a 200-foot-long tailrace emptying into Lake Keowee; and (g) appurtenant facilities.

Keowee Development consisting of: (a) a 17,660-acre reservoir (Lake Keowee) at a full pond elevation of 800 feet AMSL; (b) the 165-foot-high, 3,500-foot-long Keowee Dam which includes (i) a cylindrical concrete/steel intake structure with a power tunnel connected to the powerhouse, and (ii) a 176-foot-wide concrete gated spillway, including an entrance channel and four 38-foot-wide by 35-foot-high Tainter gates; (c) the 165-foot-high, 1,800-foot-long Little River Dam; (d) four earthfill saddle dikes, Saddle Dike A, B, C and D; (e) the Oconee Nuclear Station intake dike; (f) a concrete/steel powerhouse with two Francis turbine/generator units with a total authorized installed capacity of 157.5 MW; (g) a generator step-up transformer, which feeds a 230-kV transmission system; and (h) appurtenant facilities.

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[73] For this reason, the various deadlines in the license articles are measured from the September 1, 2016 effective date of this license, rather than from the order issuance date.

The project works generally described above are more specifically shown and described by those approved portions of Exhibits A and F shown below:

Exhibit A: Project Description, filed on August 27, 2014.

Exhibit F: The following Exhibit F drawings, filed on August 27, 2014:

KEOWEE DEVELOPMENT

Exhibit No.	FERC No.	Title
F-1	1001	Keowee Dam Area Site Plan
F-2	1002	Little River Dam Area Site Plan
F-3	1003	Sections and Details, Keowee Dam
F-4	1004	Sections and Details, Little River Dam
F-5	1005	Sections and Details, Power House and Penstocks

JOCASSEE DEVELOPMENT

Exhibit No.	FERC No.	Title
F-6	1006	North Carolina/ South Carolina, Plans for Jocassee Dam and Powerhouse Area
F-7	1007	North Carolina/ South Carolina, Sections and Details, Jocassee Dam
F-8	1008	North Carolina/ South Carolina, Sections and Details, Powerhouse and Penstocks

(3) All of the structures, fixtures, equipment or facilities used to operate or maintain the project, all portable property that may be employed in connection with the project, and all riparian or other rights that are necessary or appropriate in the operation or maintenance of the project.

(C) Exhibits A and F described above are approved and made part of this license. The Exhibit G drawings filed as part of the application for license do not conform to the Commission's regulations and are not approved.

(D) This license is subject to the conditions submitted by the South Carolina Department of Health and Environmental Control under section 401(a)(1) of the Clean Water Act, 33 U.S.C. § 1341(a)(1)(2012), as those conditions are set forth in Appendix A to this order.

(E) This license is also subject to the articles set forth in Form L-10 (Oct. 1975), entitled "Terms and Conditions of License for Constructed Major Project Affecting the Interests of Interstate or Foreign Commerce," (*see* 54 F.P.C. 1792 et seq.), as reproduced at the end of this order, and the following additional articles:

Article 201. *Administrative Annual Charges*. The licensee must pay the United States annual charges, effective September 1, 2016, and as determined in accordance with the provisions of the Commission's regulations in effect from time to time, for the purposes of reimbursing the United States for the cost of administration of Part I of the Federal Power Act. The authorized installed capacity for that purpose is 867.6 megawatts.

Article 202. *Approved Exhibit F Drawings*. Within 45 days of the effective date of the license, as directed below, the licensee must file the approved exhibit F drawings (F-1001 through F-1008.) in electronic file format on compact disks with the Secretary of the Commission, ATTN: OEP/DHAC.

Digital images of the approved exhibit F drawings must be prepared in electronic format. Prior to preparing each digital image, the FERC Project-Drawing Number (i.e., P-2503-1001 through P-2503-1008) must be shown in the margin below the title block of the approved drawing. Exhibit F drawings must be segregated from other project exhibits, and identified as **Critical Energy Infrastructure Information (CEII) material under 18 C.F.R. §388.113(c)**. Each drawing must be a separate electronic file, and the file name must include: FERC Project-Drawing Number, FERC Exhibit, Drawing Title, date of this license, and file extension in the following format [P-2503-1, F-1001, Keowee Dam Area Site Plan, MM-DD-YYYY.TIF]. All digital images of the exhibit drawings must meet the following format specification:

IMAGERY – black & white raster file
FILE TYPE – Tagged Image File Format, (TIFF) CCITT Group 4
(also known as T.6 coding scheme)
RESOLUTION – 300 dots per inch (dpi) desired, (200 dpi min)
DRAWING SIZE FORMAT – 22" x 34" (minimum), 24" x 36" (maximum)
FILE SIZE – less than 1 megabyte desired

Article 203. *Revised Exhibit G Drawings*. Within 90 days of the effective date of the license, the licensee must file, for commission approval, revised Exhibit G drawings enclosing within the project boundary all principal project works necessary for operation and maintenance of the project, including the recreation amenities at World of Energy Picnic Area. The Exhibit G drawings must comply with sections 4.39 and 4.41 of the Commission's regulations.

Article 204. *Amortization Reserve*. Pursuant to section 10(d) of the Federal Power Act, a specified reasonable rate of return upon the net investment in the project must be used for determining surplus earnings of the project for the establishment and maintenance of amortization reserves. The licensee must set aside in a project amortization reserve account at the end of each fiscal year one half of the project surplus earnings, if any, in excess of the specified rate of return per annum on the net investment. To the extent that there is a deficiency of project earnings below the specified rate of return per annum for any fiscal year, the licensee must deduct the amount of that deficiency from the amount of any surplus earnings subsequently accumulated, until absorbed. The licensee must set aside one-half of the remaining surplus earnings, if any, cumulatively computed, in the project amortization reserve account. The licensee must maintain the amounts established in the project amortization reserve account until further order of the Commission.

The specified reasonable rate of return used in computing amortization reserves must be calculated annually based on current capital ratios developed from an average of 13 monthly balances of amounts properly included in the licensee's long-term debt and proprietary capital accounts as listed in the Commission's Uniform System of Accounts. The cost rate for such ratios must be the weighted average cost of long-term debt and preferred stock for the year, and the cost of common equity must be the interest rate on 10-year government bonds (reported as the Treasury Department's 10-year constant maturity series) computed on the monthly average for the year in question plus four percentage points (400 basis points).

Article 205. *Headwater Benefits*. If the licensee's project was directly benefited by the construction work of another licensee, a permittee, or the United States on a storage reservoir or other headwater improvement during the term of the original license (including extensions of that term by annual licenses), and if those headwater benefits were not previously assessed and reimbursed to the owner of the headwater improvement, the licensee must reimburse the owner of the headwater improvement for those benefits, at such time as they are assessed, in the same manner as for benefits received during the term of this new license. The benefits will be assessed in accordance with Part 11, Subpart B, of the Commission's regulations.

Article 301. *Project Modification Resulting from Environmental Requirements*. If environmental requirements under this license require modification that may affect the project works or operations, the licensee must consult with the Commission's Division of Dam Safety and Inspections–Atlanta Regional Engineer. Consultation must allow sufficient review time for the Commission to ensure that the proposed work does not adversely affect the project works, dam safety, or project operation.

Article 401. *Use of Jocassee Reservoir*. The Jocassee Reservoir must be available to the Bad Creek Pumped Storage Project, Project No. 2740, as a lower pool for pumped-storage operations.

Article 402. *Reservoir Elevations*. Upon the effective date of this license, the licensee must operate the Keowee-Toxaway Project within the Maximum Elevation and Normal Minimum Elevation limits indicated in the table below. The Minimum Elevation must be implemented in accordance with the Low Inflow Protocol (LIP), required by Appendix A of this order, or the Maintenance and Emergency Protocol (MEP), required in Article 403.

Reservoir	**Maximum Elevation**[a] (ft. local datum/ ft. above mean sea level (AMSL))	**Normal Minimum Elevation** (ft. local datum/ ft. AMSL)	**Minimum Elevation**[b] (ft. local datum/ ft. AMSL)
Lake Jocassee	100.00/1110.0	86.0/1096.0	70.0/1080.0
Lake Keowee	100.00/800.0	96.0/796.0	90.0/790.0[c]

[a] Also referred to as Normal Maximum Elevation or Full Pond Elevation. This is the elevation of the reservoir corresponding to the point at which water would first begin to spill from the reservoir dam, which is the lowest point along the top of the flood gates.

[b] Also referred to as Critical Reservoir Elevation. This is the elevation below which any large water intake used for public water supply, industrial water supply, or any regional power plant water supply located on the reservoir may not operate at its licensed capacity.

[c] The minimum elevation of 90.0/790.0 ft AMSL for Lake Keowee becomes effective December 1, 2019, to allow time for the Oconee Nuclear Station to be modified to support operation at lower elevations at Lake Keowee. Until that time, the minimum elevation must be 94.6/794.6 ft AMSL.

The Normal Minimum Elevations outlined in the table above may be temporarily modified if required because of emergencies (operating or otherwise) beyond the control of the licensee, for short periods during annual inspections and repairs, or by operating emergencies or maintenance needs as defined in the LIP or the MEP. The licensee must notify the Commission as soon as possible, but no later than 10 days after each event, and provide the reason for the change in reservoir elevations.

Article 403. *Low Inflow Protocol*. Upon the effective date of this license, the licensee must implement, "The Low Inflow Protocol" (LIP) as required by Appendix A of this order and described in Appendix D of the Relicensing Agreement, filed on August 27, 2014, and attached to this license as Appendix B.

The licensee must notify the Commission as soon as possible, but no later than 10 days after implementing Stage 1 of the LIP, or after implementing each subsequent change in stage. Temporary modifications to the LIP must be made in accordance with the procedures in the LIP. For all such temporary modifications, or other conditions beyond the control of the licensee, the licensee must notify the Commission as soon as possible, but no later than 10 days after each such event, and provide the reason for the modification to the LIP.

The approved LIP must not be amended without prior Commission approval. The Commission reserves the right to make changes to the Low Inflow Protocol. Upon Commission approval, the licensee must implement any changes required by the Commission.

Article 404. *Maintenance and Emergency Protocol.* Upon the effective date of this license, the licensee must implement, "The Maintenance and Emergency Protocol" (MEP) included as Appendix E of the Relicensing Agreement, filed on August 27, 2014, and attached to this order as Appendix C.

The licensee must notify the Commission as soon as possible, but no later than 10 days after implementing any change in project operation required by the MEP. Temporary modifications to the MEP must be made in accordance with the procedures in the MEP. For all such temporary modifications, or other conditions beyond the control of the licensee, the licensee must notify the Commission as soon as possible, but no later than 10 days after each such event, and provide the reason for the modification to the MEP.

The approved MEP must not be amended without prior Commission Approval. The Commission reserves the right to require changes to the MEP, and upon Commission approval, the licensee must implement any changes required by the Commission.

Article 405. *Reservation of Authority to Prescribe Fishways*. Authority is reserved to the Commission to require the licensee to construct, operate, and maintain, or to provide for the construction, operation, and maintenance of such fishways as may be prescribed by the Secretary of the Interior pursuant to section 18 of the Federal Power Act.

Article 406. *Recreation Management Plan*. Within 90 days of the effective date of this license, the licensee must file with the Commission for approval, a revision to the Recreation Management Plan (RMP), filed on August 27, 2014.

The revised plan must include provisions to continue to operate and maintain the existing recreation facilities at each of the following recreation sites for the term of the license: (1) at the Jocassee Development: Devils Fork State Park, Double Springs Campground, Bootleg Access Area, Grindstone Access Area, and Handpole Ridge Access Area; and (2) at the Keowee Development: Cane Creek Access Area, Crow Creek Access Area, Fall Creek Access Area, High Falls County Park, Keowee Town Access Area, Mile Creek County Park, South Cove County Park, Stamp Creek Access Area, Warpath Access Area, and World of Energy Picnic Area. The licensee must also reserve the existing Bootleg Access Area, Grindstone Access Area, and Handpole Ridge Access Area, as well as the new High Falls II Access Area and Mosquito Point Access Area for future public recreation.

The licensee must modify the RMP to include: (1) provisions to construct restrooms with lighting, expanded and lighted vehicle-with-trailer parking, courtesy dock, picnic area/shelter, single-vehicle parking, and bank fishing trail at Crow Creek Access Area; (2) provisions to construct 10 primitive campsites, 5 bank fishing stations, and 10 camping cabins at Mile Creek County Park; (3) a provision to monitor the capacity and condition of Warpath Access Area annually during the summer recreation season and develop (a) plan(s) to address capacity issues, if non-peak weekend use exceeds 90 percent of capacity, and (b) plan(s) to mitigate for overuse, if use exceeds capacity at any time; (4) a description of the existing facilities, site plans, capital and operation and maintenance costs, and schedule of any recreation facility enhancements proposed over the term of a license at World of Energy Picnic Area; (5) a provision to stabilize 6,250 feet of shoreline on islands in Lake Keowee; (6) an implementation schedule describing the anticipated year of construction for all recreation enhancement measures specified in the plan; and (7) a provision that all improvements made to project recreation sites as part of the Access Area Improvement Initiative must be identified in the Commission-approved RMP.

The Commission reserves the right to require changes to the plan. Implementation of the plan must not begin until the licensee is notified by the Commission that the plan is approved. Upon Commission approval, the licensee must implement the plan, including any changes required by the Commission.

Article 407. *Shoreline Management Plan*. The Shoreline Management Plan (SMP) filed on August 27, 2014, is approved, with the following modification: the licensee must extend the provision in section 7.2.24 of the Shoreline Management Guidelines accepting applications for an exemption to the Maximum Size Limit for private facilities from the time of license issuance through December 31, 2020.

The licensee may make minor changes (i.e., minor alterations that are more restrictive or necessary to meet license obligations) to the Shoreline Management Guidelines and Lake Use Restrictions to protect significant environmental resources, including newly discovered archaeological or historic sites, Threatened or Endangered Species, and Special Concern Species; and may make minor changes to Shoreline Classification Maps to correct mapping errors. The licensee must file an annual report with the Commission by December 31 each year describing any modifications made to the SMP, including the Shoreline Classification Maps. If no changes are made to the SMP or Shoreline Classification Maps, the licensee must submit a letter to that effect. If changes are made to the Shoreline Classification Maps, the report must include a description, location (latitude and longitude), and reason for each change. The Commission reserves the right to review such changes and may require changes to the SMP at any time during the term of the license.

Additionally, within 45 days of this order, the licensee must file, on CD or diskette, two separate sets of GIS data in a georeferenced electronic file format (such as ArcView shapefiles, GeoMedia files, MapInfo files, or a similar GIS format) with the Secretary of the Commission, ATTN: OEP/DHAC. The data must include a) polygon files of the surface areas of the project's reservoir(s) and tailrace(s), including separate polygons for each, and b) polyline files representing the linear extent of each shoreline management classification, by reservoir/tailrace. The data must match maps shown in the SMP. The attribute table for the polygon files must contain the name, water elevation, and elevation reference datum of each reservoir and tailrace. The attribute table for the polyline files must contain the name of each shoreline management classification and its associated reservoir/tailrace, consistent with the SMP.

All GIS data must be positionally accurate to ±40 feet in order to comply with National Map Accuracy Standards for maps at a 1:24,000 scale. The file name(s) must include: FERC Project Number, data description, date of this order, and file extension in the following format [P-2503, reservoir name polygon/or reservoir name shoreline polyline data, MM-DD-YYYY.SHP]. The filing must be accompanied by a separate text file describing the spatial reference for the georeferenced data: map projection used (i.e., UTM, State Plane, Decimal Degrees), the map datum (i.e., North American 27, North American 83), and the units of measurement (i.e., feet, meters, miles). The text file name must include: FERC Project Number, data description, date of this order, and file extension in the following format [P-2503, project reservoir/or shoreline classification metadata, MM-DD-YYYY.TXT].

Within ten years following the effective date of the license, and every ten years thereafter for the term of the license, the licensee must file with the Commission, for approval, a revised SMP. The revised SMP must include a description of any proposed changes to the provisions and classification maps of the existing approved SMP based on an evaluation of the adequacy of the existing plan. The revised SMP must also include revised polyline data to correspond with the revised shoreline classification maps, including any necessary corrections to minor mapping errors. If changes are made to the

SMP, the filing must include both a clean copy and a red-line copy of the revised SMP so that plan modifications can be easily identified, as well as justification of such changes. In developing the revised SMP, the licensee must, at a minimum, consult with the U.S. Fish and Wildlife Service, South Carolina Department of Natural Resources, and South Carolina Department of Parks, Recreation, and Tourism to review the implementation of the SMP and recommend potential modifications. The revised SMP must include documentation of consultation with the agencies identified above and specific descriptions of how the agencies' comments are accommodated. The licensee must allow a minimum of 30 days for the agencies to comment and to make recommendations prior to filing the revised SMP with the Commission. If the licensee does not adopt a recommendation, the filing must include the licensee's reasons based on project-specific reasons. The Commission reserves the right to require changes to the revised SMP.

Article 408. *Programmatic Agreement and Historic Properties Management Plan*. The licensee must implement the "Programmatic Agreement Among the Federal Energy Regulatory Commission, the North Carolina State Historic Preservation Officer, and the South Carolina State Historic Preservation Officer for Managing Historic Properties that May be Affected by Issuing a New License to Duke Energy Carolinas, LLC for the Continued Operation of the Keowee-Toxaway Hydroelectric Project in Transylvania County, North Carolina and in Pickens and Oconee Counties, South Carolina," executed on May 8, 2015, by the North Carolina State Historic Preservation Officer (SHPO) and on May 19, 2015, by the South Carolina SHPO, and including but not limited to the Historic Properties Management Plan (HPMP), filed on November 5, 2014, for the project. In the event that the Programmatic Agreement is terminated, the licensee must continue to implement the provisions of its approved HPMP. The Commission reserves the authority to require changes to the HPMP at any time during the term of the license.

Article 409. *Use and Occupancy.* (a) In accordance with the provisions of this article, the licensee must have the authority to grant permission for certain types of use and occupancy of project lands and waters and to convey certain interests in project lands and waters for certain types of use and occupancy, without prior Commission approval. The licensee may exercise the authority only if the proposed use and occupancy is consistent with the purposes of protecting and enhancing the scenic, recreational, and other environmental values of the project. For those purposes, the licensee must also have continuing responsibility to supervise and control the use and occupancies for which it grants permission, and to monitor the use of, and ensure compliance with the covenants of the instrument of conveyance for, any interests that it has conveyed, under this article. If a permitted use and occupancy violates any condition of this article or any other condition imposed by the licensee for protection and enhancement of the project's scenic, recreational, or other environmental values, or if a covenant of a conveyance made under the authority of this article is violated, the licensee must take any lawful action necessary to correct the violation. For a permitted use or occupancy, that action includes, if necessary, canceling the permission to use and occupy the project lands and waters and requiring the removal of any non-complying structures and facilities.

(b) The type of use and occupancy of project lands and waters for which the licensee may grant permission without prior Commission approval are: (1) landscape plantings; (2) non-commercial piers, landings, boat docks, or similar structures and facilities that can accommodate no more than 10 water craft at a time and where said facility is intended to serve single-family type dwellings; (3) embankments, bulkheads, retaining walls, or similar structures for erosion control to protect the existing shoreline; and (4) food plots and other wildlife enhancement. To the extent feasible and desirable to protect and enhance the project's scenic, recreational, and other environmental values, the licensee must require multiple use and occupancy of facilities for access to project lands or waters. The licensee must also ensure, to the satisfaction of the Commission's authorized representative, that the use and occupancies for which it grants permission are maintained in good repair and comply with applicable state and local health and safety requirements. Before granting permission for construction of bulkheads or retaining walls, the licensee must: (1) inspect the site of the proposed construction; (2) consider whether the planting of vegetation or the use of riprap would be adequate to control erosion at the site; and (3) determine that the proposed construction is needed and would not change the basic contour of the impoundment shoreline. To implement this paragraph (b), the licensee may, among other things, establish a program for issuing permits for the specified types of use and occupancy of project lands and waters, which may be subject to the payment of a reasonable fee to cover the licensee's costs of administering the permit program. The Commission reserves the right to require the licensee to file a description of its standards, guidelines, and procedures for implementing this paragraph (b) and to require modification of those standards, guidelines, or procedures.

(c) The licensee may convey easements or rights-of-way across, or leases of project lands for: (1) replacement, expansion, realignment, or maintenance of bridges or roads where all necessary state and federal approvals have been obtained; (2) storm drains and water mains; (3) sewers that do not discharge into project waters; (4) minor access roads; (5) telephone, gas, and electric utility distribution lines; (6) non-project overhead electric transmission lines that do not require erection of support structures within the project boundary; (7) submarine, overhead, or underground major telephone distribution cables or major electric distribution lines (69-kV or less); and (8) water intake or pumping facilities that do not extract more than one million gallons per day from a project impoundment. No later than January 31 of each year, the licensee must file with the Commission a report briefly describing for each conveyance made under this paragraph (c) during the prior calendar year, the type of interest conveyed, the location of the lands subject to the conveyance, and the nature of the use for which the interest was conveyed.

(d) The licensee may convey fee title to, easements or rights-of-way across, or leases of project lands for: (1) construction of new bridges or roads for which all necessary state and federal approvals have been obtained; (2) sewer or effluent lines that discharge into project waters, for which all necessary federal and state water quality certification or permits have been obtained; (3) other pipelines that cross project lands or waters but do not discharge into project waters; (4) non-project overhead electric transmission lines that require erection of support structures within the project boundary, for which all necessary federal and state approvals have been obtained; (5) private or public marinas that can accommodate no more than 10 water craft at a time and are located at least one-half mile (measured over project waters) from any other private or public marina; (6) recreational development consistent with an approved report on recreational resources of an Exhibit E; and (7) other uses, if: (i) the amount of land conveyed for a particular use is five acres or less; (ii) all of the land conveyed is located at least 75 feet, measured horizontally, from project waters at normal surface elevation; and (iii) no more than 50 total acres of project lands for each project development are conveyed under this clause (d)(7) in any calendar year. At least 60 days before conveying any interest in project lands under this paragraph (d), the licensee must file a letter with the Commission, stating its intent to convey the interest and briefly describing the type of interest and location of the lands to be conveyed (a marked Exhibit G map may be used), the nature of the proposed use, the identity of any federal or state agency official consulted, and any federal or state approvals required for the proposed use. Unless the Commission's authorized representative, within 45 days from the filing date, requires the licensee to file an application for prior approval, the licensee may convey the intended interest at the end of that period.

(e) The following additional conditions apply to any intended conveyance under paragraph (c) or (d) of this article:

(1) Before conveying the interest, the licensee must consult with federal and state fish and wildlife or recreation agencies, as appropriate, and the State Historic Preservation Officer.

(2) Before conveying the interest, the licensee must determine that the proposed use of the lands to be conveyed is not inconsistent with any approved report on recreational resources of an Exhibit E; or, if the project does not have an approved report on recreational resources, that the lands to be conveyed do not have recreational value.

(3) The instrument of conveyance must include the following covenants running with the land: (i) the use of the lands conveyed must not endanger health, create a nuisance, or otherwise be incompatible with overall project recreational use; (ii) the grantee must take all reasonable precautions to ensure that the construction, operation, and maintenance of structures or facilities on the conveyed lands will occur in a manner that will protect the scenic, recreational, and environmental values of the project; and (iii) the grantee must not unduly restrict public access to project lands and waters.

(4) The Commission reserves the right to require the licensee to take reasonable remedial action to correct any violation of the terms and conditions of this article, for the protection and enhancement of the project's scenic, recreational, and other environmental values.

(f) The conveyance of an interest in project lands under this article does not in itself change the project boundaries. The project boundaries may be changed to exclude land conveyed under this article only upon approval of revised Exhibit G drawings (project boundary maps) reflecting exclusion of that land. Lands conveyed under this article will be excluded from the project only upon a determination that the lands are not necessary for project purposes, such as operation and maintenance, flowage, recreation, public access, protection of environmental resources, and shoreline control, including shoreline aesthetic values. Absent extraordinary circumstances, proposals to exclude lands conveyed under this article from the project must be consolidated for consideration when revised Exhibit G drawings would be filed for approval for other purposes.

(g) The authority granted to the licensee under this article must not apply to any part of the public lands and reservations of the United States included within the project boundary.

(F) The licensee must serve copies of any Commission filing required by this order on any entity specified in the order to be consulted on matters relating to that filing. Proof of service on these entities must accompany the filing with the Commission.

(G) This order constitutes final agency action. Any party may file a request for rehearing of this order within 30 days from the date of its issuance, as provided in section 313(a) of the FPA, 16 U.S.C. § 825*l* (2012), and section 385.713 of the Commission's regulations, 18 C.F.R. § 385.713 (2015). The filing of a request for rehearing does not operate as a stay of the effective date of this license, or of any other date specified in this order. The licensee's failure to file a request for rehearing shall constitute acceptance of this order.

Ann F. Miles
Director
Office of Energy Projects

Form L-10
(October, 1975)

FEDERAL ENERGY REGULATORY COMMISSION

TERMS AND CONDITIONS OF LICENSE FOR CONSTRUCTED MAJOR PROJECT AFFECTING THE INTERESTS OF INTERSTATE OR FOREIGN COMMERCE

Article 1. The entire project, as described in this order of the Commission, shall be subject to all of the provisions, terms, and conditions of the license.

Article 2. No substantial change shall be made in the maps, plans, specifications, and statements described and designated as exhibits and approved by the Commission in its order as a part of the license until such change shall have been approved by the Commission: Provided, however, That if the Licensee or the Commission deems it necessary or desirable that said approved exhibits, or any of them, be changed, there shall be submitted to the Commission for approval a revised, or additional exhibit or exhibits covering the proposed changes which, upon approval by the Commission, shall become a part of the license and shall supersede, in whole or in part, such exhibit or exhibits theretofore made a part of the license as may be specified by the Commission.

Article 3. The project area and project works shall be in substantial conformity with the approved exhibits referred to in Article 2 herein or as changed in accordance with the provisions of said article. Except when emergency shall require for the protection of navigation, life, health, or property, there shall not be made without prior approval of the Commission any substantial alteration or addition not in conformity with the approved plans to any dam or other project works under the license or any substantial use of project lands and waters not authorized herein; and any emergency alteration, addition, or use so made shall thereafter be subject to such modification and change as the Commission may direct. Minor changes in project works, or in uses of project lands and waters, or divergence from such approved exhibits may be made if such changes will not result in a decrease in efficiency, in a material increase in cost, in an adverse environmental impact, or in impairment of the general scheme of development; but any of such minor changes made without the prior approval of the Commission, which in its judgment have produced or will produce any of such results, shall be subject to such alteration as the Commission may direct.

Article 4. The project, including its operation and maintenance and any work incidental to additions or alterations authorized by the Commission, whether or not conducted upon lands of the United States, shall be subject to the inspection and supervision of the Regional Engineer, Federal Energy Regulatory Commission, in the region wherein the project is located, or of such other officer or agent as the Commission may designate, who shall be the authorized representative of the Commission for such purposes. The Licensee shall cooperate fully with said representative and shall furnish him such information as he may require concerning the operation and maintenance of the project, and any such alterations thereto, and shall notify him of the date upon which work with respect to any alteration will begin, as far in advance thereof as said representative may reasonably specify, and shall notify him promptly in writing of any suspension of work for a period of more than one week, and of its resumption and completion. The Licensee shall submit to said representative a detailed program of inspection by the Licensee that will provide for an adequate and qualified inspection force for construction of any such alterations to the project. Construction of said alterations or any feature thereof shall not be initiated until the program of inspection for the alterations or any feature thereof has been approved by said representative. The Licensee shall allow said representative and other officers or employees of the United States, showing proper credentials, free and unrestricted access to, through, and across the project lands and project works in the performance of their official duties. The Licensee shall comply with such rules and regulations of general or special applicability as the Commission may prescribe from time to time for the protection of life, health, or property.

Article 5. The Licensee, within five years from the date of issuance of the license, shall acquire title in fee or the right to use in perpetuity all lands, other than lands of the United States, necessary or appropriate for the construction maintenance, and operation of the project. The Licensee or its successors and assigns shall, during the period of the license, retain the possession of all project property covered by the license as issued or as later amended, including the project area, the project works, and all franchises, easements, water rights, and rights or occupancy and use; and none of such properties shall be voluntarily sold, leased, transferred, abandoned, or otherwise disposed of without the prior written approval of the Commission, except that the Licensee may lease or otherwise dispose of interests in project lands or property without specific written approval of the Commission pursuant to the then current regulations of the Commission. The provisions of this article are not intended to prevent the abandonment or the retirement from service of structures, equipment, or other project works in connection with replacements thereof when they become obsolete, inadequate, or inefficient for further service due to wear and tear; and mortgage or trust deeds or judicial sales made thereunder, or tax sales, shall not be deemed voluntary transfers within the meaning of this article.

Article 6. In the event the project is taken over by the United States upon the termination of the license as provided in Section 14 of the Federal Power Act, or is transferred to a new licensee or to a nonpower licensee under the provisions of Section 15 of said Act, the Licensee, its successors and assigns shall be responsible for, and shall make good any defect of title to, or of right of occupancy and use in, any of such project property that is necessary or appropriate or valuable and serviceable in the maintenance and operation of the project, and shall pay and discharge, or shall assume responsibility for payment and discharge of, all liens or encumbrances upon the project or project property created by the Licensee or created or incurred after the issuance of the license: Provided, That the provisions of this article are not intended to require the Licensee, for the purpose of transferring the project to the United States or to a new licensee, to acquire any different title to, or right of occupancy and use in, any of such project property than was necessary to acquire for its own purposes as the Licensee.

Article 7. The actual legitimate original cost of the project, and of any addition thereto or betterment thereof, shall be determined by the Commission in accordance with the Federal Power Act and the Commission's Rules and Regulations thereunder.

Article 8. The Licensee shall install and thereafter maintain gages and stream-gaging stations for the purpose of determining the stage and flow of the stream or streams on which the project is located, the amount of water held in and withdrawn from storage, and the effective head on the turbines; shall provide for the required reading of such gages and for the adequate rating of such stations; and shall install and maintain standard meters adequate for the determination of the amount of electric energy generated by the project works. The number, character, and location of gages, meters, or other measuring devices, and the method of operation thereof, shall at all times be satisfactory to the Commission or its authorized representative. The Commission reserves the right, after notice and opportunity for hearing, to require such alterations in the number, character, and location of gages, meters, or other measuring devices, and the method of operation thereof, as are necessary to secure adequate determinations. The installation of gages, the rating of said stream or streams, and the determination of the flow thereof, shall be under the supervision of, or in cooperation with, the District Engineer of the United States Geological Survey having charge of stream-gaging operations in the region of the project, and the Licensee shall advance to the United States Geological Survey the amount of funds estimated to be necessary for such supervision, or cooperation for such periods as may mutually agreed upon. The Licensee shall keep accurate and sufficient records of the foregoing determinations to the satisfaction of the Commission, and shall make return of such records annually at such time and in such form as the Commission may prescribe.

Article 9. The Licensee shall, after notice and opportunity for hearing, install additional capacity or make other changes in the project as directed by the Commission, to the extent that it is economically sound and in the public interest to do so.

Article 10. The Licensee shall, after notice and opportunity for hearing, coordinate the operation of the project, electrically and hydraulically, with such other projects or power systems and in such manner as the Commission may direct in the interest of power and other beneficial public uses of water resources, and on such conditions concerning the equitable sharing of benefits by the Licensee as the

Commission may order.

Article 11. Whenever the Licensee is directly benefited by the construction work of another licensee, a permittee, or the United States on a storage reservoir or other headwater improvement, the Licensee shall reimburse the owner of the headwater improvement for such part of the annual charges for interest, maintenance, and depreciation thereof as the Commission shall determine to be equitable, and shall pay to the United States the cost of making such determination as fixed by the Commission. For benefits provided by a storage reservoir or other headwater improvement of the United States, the Licensee shall pay to the Commission the amounts for which it is billed from time to time for such headwater benefits and for the cost of making the determinations pursuant to the then current regulations of the Commission under the Federal Power Act.

Article 12. The operations of the Licensee, so far as they affect the use, storage and discharge from storage of waters affected by the license, shall at all times be controlled by such reasonable rules and regulations as the Commission may prescribe for the protection of life, health, and property, and in the interest of the fullest practicable conservation and utilization of such waters for power purposes and for other beneficial public uses, including recreational purposes, and the Licensee shall release water from the project reservoir at such rate in cubic feet per second, or such volume in acre-feet per specified period of time, as the Commission may prescribe for the purposes hereinbefore mentioned.

Article 13. On the application of any person, association, corporation, Federal agency, State or municipality, the Licensee shall permit such reasonable use of its reservoir or other project properties, including works, lands and water rights, or parts thereof, as may be ordered by the Commission, after notice and opportunity for hearing, in the interests of comprehensive development of the waterway or waterways involved and the conservation and utilization of the water resources of the region for water supply or for the purposes of steam-electric, irrigation, industrial, municipal or similar uses. The Licensee shall receive reasonable compensation for use of its reservoir or other project properties or parts thereof for such purposes, to include at least full reimbursement for any damages or expenses which the joint use causes the Licensee to incur. Any such compensation shall be fixed by the Commission either by approval of an agreement between the Licensee and the party or parties benefiting or after notice and opportunity for hearing. Applications shall contain information in sufficient detail to afford a full understanding of the proposed use, including satisfactory evidence that the applicant possesses necessary water rights pursuant to applicable State law, or a showing of cause why such evidence cannot concurrently be submitted, and a statement as to the relationship of the proposed use to any State or municipal plans or orders which may have been adopted with respect to the use of such waters.

Article 14. In the construction or maintenance of the project works, the Licensee shall place and maintain suitable structures and devices to reduce to a reasonable degree the liability of contact between its transmission lines and telegraph, telephone and other signal wires or power transmission lines constructed prior to its transmission lines and not owned by the Licensee, and shall also place and maintain suitable structures and devices to reduce to a reasonable degree the liability of any structures or wires falling or obstructing traffic or endangering life. None of the provisions of this article are intended to relieve the Licensee from any responsibility or requirement which may be imposed by any other lawful authority for avoiding or eliminating inductive interference.

Article 15. The Licensee shall, for the conservation and development of fish and wildlife resources, construct, maintain, and operate, or arrange for the construction, maintenance, and operation of such reasonable facilities, and comply with such reasonable modifications of the project structures and operation, as may be ordered by the Commission upon its own motion or upon the recommendation of the Secretary of the Interior or the fish and wildlife agency or agencies of any State in which the project or a part thereof is located, after notice and opportunity for hearing.

Article 16. Whenever the United States shall desire, in connection with the project, to construct fish and wildlife facilities or to improve the existing fish and wildlife facilities at its own expense, the Licensee shall permit the United States or its designated agency to use, free of cost, such of the Licensee's lands and interests in lands, reservoirs, waterways and project works as may be reasonably required to complete such facilities or such improvements thereof. In addition, after notice and opportunity for hearing, the Licensee shall modify the project operation as may be reasonably prescribed by the Commission in order to permit the maintenance and operation of the fish and wildlife facilities constructed or improved by the United States under the provisions of this article. This article shall not be interpreted to place any obligation on the United States to construct or improve fish and wildlife facilities or to relieve the Licensee of any obligation under this license.

Article 17. The Licensee shall construct, maintain, and operate, or shall arrange for the construction, maintenance, and operation of such reasonable recreational facilities, including modifications thereto, such as access roads, wharves, launching ramps, beaches, picnic and camping areas, sanitary facilities, and utilities, giving consideration to the needs of the physically handicapped, and shall comply with such reasonable modifications of the project, as may be prescribed hereafter by the Commission during the term of this license upon its own motion or upon the recommendation of the Secretary of the Interior or other interested Federal or State agencies, after notice and opportunity for hearing.

Article 18. So far as is consistent with proper operation of the project, the Licensee shall allow the public free access, to a reasonable extent, to project waters and adjacent project lands owned by the Licensee for the purpose of full public utilization of such lands and waters for navigation and for outdoor recreational purposes, including fishing and hunting: Provided, That the Licensee may reserve from public access such portions of the project waters, adjacent lands, and project facilities as may be necessary for the protection of life, health, and property.

Article 19. In the construction, maintenance, or operation of the project, the Licensee shall be responsible for, and shall take reasonable measures to prevent, soil erosion on lands adjacent to streams or other waters, stream sedimentation, and any form of water or air pollution. The Commission, upon request or upon its own motion, may order the Licensee to take such measures as the Commission finds to be necessary for these purposes, after notice and opportunity for hearing.

Article 20. The Licensee shall clear and keep clear to an adequate width lands along open conduits and shall dispose of all temporary structures, unused timber, brush, refuse, or other material unnecessary for the purposes of the project which results from the clearing of lands or from the maintenance or alteration of the project works. In addition, all trees along the periphery of project reservoirs which may die during operations of the project shall be removed. All clearing of the lands and disposal of the unnecessary material shall be done with due diligence and to the satisfaction of the authorized representative of the Commission and in accordance with appropriate Federal, State, and local statutes and regulations.

Article 21. If the Licensee shall cause or suffer essential project property to be removed or destroyed or to become unfit for use, without adequate replacement, or shall abandon or discontinue good faith operation of the project or refuse or neglect to comply with the terms of the license and the lawful orders of the Commission mailed to the record address of the Licensee or its agent, the Commission will deem it to be the intent of the Licensee to surrender the license. The Commission, after notice and opportunity for hearing, may require the Licensee to remove any or all structures, equipment and power lines within the project boundary and to take any such other action necessary to restore the project waters, lands, and facilities remaining within the project boundary to a condition satisfactory to the United States agency having jurisdiction over its lands or the Commission's authorized representative, as appropriate, or to provide for the continued operation and maintenance of nonpower facilities and fulfill such other obligations under the license as the Commission may prescribe. In addition, the Commission in its discretion, after notice and opportunity for hearing, may also agree to the surrender of the license when the Commission, for the reasons recited herein, deems it to be the intent of the Licensee to surrender the license.

Article 22. The right of the Licensee and of its successors and assigns to use or occupy waters over which the United States has jurisdiction, or lands of the United States under the license, for the purpose of maintaining the project works or otherwise, shall absolutely cease at the end of the license period, unless the Licensee has obtained a new license pursuant to the then existing laws and regulations, or an annual license under the terms and conditions of this license.

Article 23. The terms and conditions expressly set forth in the license shall not be construed as impairing any terms and conditions of the Federal Power Act which are not expressly set forth herein.

APPENDIX A

Water Quality Certificate Conditions for the Keowee-Toxaway Project Issued by the South Carolina Department of Health and Environmental Control on October 29, 2015

[Commission staff has added language for clarity and ease of administration. The added text is indicated by brackets.]

Conditions of Certification:

1. Duke Energy (applicant) shall operate the Keowee-Toxaway Hydroelectric Project in accordance with the portions of the "Relicensing Agreement" [dated August 27, 2014], entered into by the applicant and members of the relicensing stakeholder team, related to the Low Inflow Protocol and Water Quality Monitoring. Specifically, the applicant shall operate the Project in accordance with Section A-2.0 Low Inflow Protocol Article and Section A-7.0 Water Quality Monitoring Article in the Relicensing Agreement.

   [For ease of administration, the text of the two Articles follows:

A-2.0 LOW INFLOW PROTOCOL ARTICLE

Article – Low Inflow for the Keowee-Toxaway Hydroelectric Project

(A) The Low Inflow Protocol (LIP) for the Keowee-Toxaway Hydroelectric Project filed with the license application as Appendix D of the Relicensing Agreement is approved and incorporated into this license and the Licensee shall implement the LIP.

(B) The Licensee may modify the LIP in accordance with the procedures in the LIP. The Licensee may also make temporary modifications to the LIP to account for any changed physical conditions at the Keowee and Jocassee Developments. The Licensee shall notify the Commission of any such modifications in accordance with the LIP. Any modifications may be subject to Commission approval.

A-7.0 WATER QUALITY MONITORING ARTICLE

Article – Water Quality Monitoring

(A) During the first full month of August occurring at least 60 days following issuance of this license and during every subsequent August for the term of this license, the Licensee shall continuously monitor dissolved oxygen concentrations in both the Keowee Hydro Station and Jocassee Pumped Storage Station tailwaters to demonstrate compliance with South Carolina's water quality certification.

(B) The Licensee shall submit the results obtained from this annual monitoring to the Commission and the South Carolina Department of Health and Environmental Control each year by November 30.]

2. The applicant must take all necessary measures during Keowee-Toxaway Hydroelectric Project operation and maintenance to prevent fuel, oil, tar, trash, debris, and other pollutants from entering the adjacent waters or wetlands.

3. Any "large water intake" owner or "major water withdrawer" applicant to Duke Energy Carolinas, LLC for a large water intake or major water withdrawal from the project must comply with the Surface Water Withdrawal, Permitting, Use And Reporting Act, S.C. Code Ann. §§ 49-4-10 et seq. A "large water intake" means any water intake (e.g., public water supply, industrial, agricultural, power plant, irrigation, etc.) having a maximum instantaneous capacity greater than or equal to one million gallons per day, and a "major water withdrawer" means a person withdrawing surface water in excess of three million gallons during any one month from a single intake or multiple intakes under common ownership within a one mile radius from any one existing or proposed intake.

The Department reserves the right to impose additional conditions on this Certification to respond to unforeseen, specific problems and to take any enforcement necessary to ensure compliance with State water quality standards.

APPENDIX B

Low Inflow Protocol

[Included in Appendix D of the Relicensing Agreement, filed on August 27, 2014]

LOW INFLOW PROTOCOL (LIP) FOR THE KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

Purpose

To establish a joint management plan that Duke Energy Carolinas, LLC (Licensee); Seneca Light & Water (Seneca), Greenville Water (GW), any public water suppliers that add Large Water Intakes withdrawing water from Project Reservoirs (Jocassee and Keowee); and any public water suppliers with Large Water Intakes on the U.S. Army Corps of Engineers' (USACE) Reservoirs (Hartwell, Russell and Thurmond) that choose to participate, will follow in response to drought conditions.

Key Facts and Assumptions

1. Importance of Human Health and Safety and the Integrity of the Public Water Supply and Electric Systems – Nothing in this LIP will limit the Licensee's ability to take any and all lawful actions necessary at the Keowee-Toxaway Hydroelectric Project ("Project") to protect human health and safety, to protect its equipment from damage, to ensure the stability of the regional electric grid, to protect the equipment of the Large Water Intake owners from damage, and to ensure the stability of public water supply systems; provided that nothing in the Relicensing Agreement (RA) or LIP obligates the Licensee to take any actions to protect the equipment of Large Water Intake owners from damage or to ensure the stability of public water supply systems. It is recognized that the Licensee may provide this protection without prior consultation or notification.
2. This LIP is intended to support management of the Licensee's Reservoirs (Bad Creek, Jocassee and Keowee) in the Upper Savannah River Basin for the Licensee's operations, while meeting the water resource needs of the public.
3. As of the date of this LIP, only five entities have Large Water Intakes withdrawing water from the Project. GW and Seneca are public water suppliers. The Licensee's Large Water Intake at Oconee Nuclear Station (ONS) is used for thermal power plant cooling. The Reserve at Lake Keowee and The Cliffs Club at Keowee Vineyards, LLC each use Large Water Intakes for irrigation. The Reserve at Lake Keowee and The Cliffs Club at Keowee Vineyards, LLC have easements with clauses permitting the Licensee to require water conservation measures during droughts.
4. Any public water supplier owning a Large Water Intake that intends to locate a new intake, expand an existing intake, or rebuild an existing intake on Lake Keowee will

be required to abide by the applicable portions of this LIP, except as provided for in existing agreements (e.g., easements, leases, lake use permits or other written agreements) between the Large Water Intake owner and the Licensee.

5. Nothing in this LIP amends or replaces any other contract or agreement to which the Licensee and/or any other Large Water Intake owner is a party.

6. <u>Revising the LIP</u> – During the term of the New License, the Keowee-Toxaway Drought Management Advisory Group (KT-DMAG) will periodically review and recommend updates to the LIP to ensure continuous improvement of the LIP and its implementation. These evaluations and modifications will be considered at least once every ten (10) years during the New License term. Any modifications must be approved by the Licensee and all of the applicable public water suppliers with Large Water Intakes on Project Reservoirs. If such unanimous approval cannot be reached, then the dispute resolution procedures set forth in the RA will apply. Approved modifications will be incorporated through revision of the LIP, and the Licensee will file the revised LIP with the Federal Energy Regulatory Commission (FERC). If any modifications of the LIP require amendment of the New License, the Licensee will: (i) provide notice to all Parties to the RA, pursuant to Section 23.0 of the RA, advising them of the New License amendment and the Licensee's intent to file it with the FERC; (ii) submit a modification request to the South Carolina Department of Health and Environmental Control (SCDHEC) for formal review and approval if required; and (iii) file a license amendment request for FERC approval if required. The filing of a revised LIP by the Licensee will not constitute or require modification of the RA, and any Party to the RA may be involved in the FERC's or SCDHEC's public processes for assessing the revised LIP, but may not oppose any part of a revised LIP that is consistent with the LIP included in the RA.

7. <u>Transitioning to a Lower Critical Reservoir Elevation on Lake Keowee</u> – The Licensee will operate in accordance with the provisions of the LIP, except Lake Keowee's Critical Reservoir Elevation will remain at or above 94.6 ft local datum / 794.6 ft above Mean Sea Level (AMSL) until December 1, 2019, to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. The Licensee may also, in its sole discretion, decide to maintain Lake Keowee's Critical Reservoir Elevation at or above 94.6 ft local datum / 794.6 ft AMSL until both of the following are complete:

   a. A New License that is consistent with the RA has been issued, the end of all appeals, and all rehearing and administrative challenge periods have closed; and

   b. The Licensee, the USACE, and the Southeastern Power Administration (SEPA) have signed a New Operating Agreement (NOA) that is not inconsistent with the RA.

8. The following table provides storage volumes at various lake elevations in the Licensee's Reservoirs. Data for the Bad Creek Reservoir are from original licensing

data. Data for Lakes Jocassee and Keowee are from a 2010 bathymetric study performed by the Licensee. These data are for planning purposes and not of physical survey quality.

Reservoir	Elevations (ft local datum / ft AMSL)		Storage Increment (ac-ft)	Storage Increment (%)
	Elevation From	Elevation To		
Bad Creek	100.0 / 2310	-60.0 / 2150	30,229	
		Total Bad Creek	30,229	7
Jocassee	100.0 / 1110	86.0 / 1096	108,738	
	86.0 / 1096	82.0 / 1092	30,000	
	82.0 / 1092	77.0 / 1087	36,687	
	77.0 / 1087	73.0 / 1083	28,730	
	73.0 / 1083	70.0 / 1080	21,233	
		Total Jocassee	225,387	54
Keowee	100.0 / 800.0	96.0 / 796.0	67,636	
	96.0 / 796.0	95.0 / 795.0	16,249	
	95.0 / 795.0	94.6 / 794.6	6,434	
	94.6 / 794.6	93.0 /793.0	25,368	
	93.0 / 793.0	92.0 / 792.0	15,565	
	92.0 / 792.0	91.5 / 791.5	7,700	
	91.5 / 791.5	90.0 / 790.0	22,775	
		Total Keowee	161,727	39
Total for Licensee's Reservoirs			417,343	100

Definitions

1. <u>Critical Reservoir Elevation</u> – Unless otherwise defined herein, the Critical Reservoir Elevation is the level of water in a reservoir (measured by reference to local datum or in ft AMSL) below which any Large Water Intake used for public water supply, industrial water supply, or any regional power plant water supply located on the reservoir will not operate at its Licensee-approved capacity. The Critical Reservoir Elevations are:

Reservoir	Critical Reservoir Elevation (ft local datum / ft AMSL)	Type of Limit
Lake Keowee	90.0[1] / 790.0[1]	Power Production
Lake Jocassee	70.0 / 1080.0	Power Production
Bad Creek	-60.0 / 2150.0	Power Production

Note 1 – This new Critical Reservoir Elevation will become effective December 1, 2019, to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. See Item 7 under Key Facts and Assumptions for guidance prior to converting to this new Critical Reservoir Elevation.

2. Total Usable Storage – For the Licensee's Reservoirs (Keowee, Jocassee, and Bad Creek), Total Usable Storage is the sum of the volume of water contained between each reservoir's Critical Reservoir Elevation and its Full Pond Elevation, expressed in acre-feet (ac-ft). For the USACE Reservoirs in the Upper Savannah River Basin (Hartwell, Richard B. Russell, and J. Strom Thurmond), Total Usable Storage is the sum of the volume of water contained between each reservoir's bottom-of-power-pool elevation (top of inactive pool) and the guide curve elevation denoting the top of conservation storage for any particular time of year, expressed in ac-ft.

3. Remaining Usable Storage – The sum of the volume of water contained between each reservoir's Critical Reservoir Elevation and the actual reservoir elevation at any given point in time, expressed in ac-ft, for the Licensee's Reservoirs. The Remaining Usable Storage calculation for the Licensee's Reservoirs is based on a maximum drawdown elevation of 90 ft local datum / 790 ft AMSL for Lake Keowee, a maximum drawdown elevation of 70 ft local datum / 1080 ft AMSL for Lake Jocassee, and a maximum drawdown elevation of -60 ft local datum / 2150 ft AMSL for the Bad Creek Reservoir. For the USACE Reservoirs in the Upper Savannah River Basin (Hartwell, Richard B. Russell, and J. Strom Thurmond), Remaining Usable Storage is the sum of the volume of water contained between each reservoir's bottom-of-power-pool elevation (top of inactive pool) and the actual elevation, expressed in ac-ft.

4. Storage Index – The ratio, expressed in percent, of Remaining Usable Storage to Total Usable Storage at any given point in time.

5. Large Water Intake – Any water intake (e.g., public water supply, industrial, agricultural, power plant, irrigation, etc.) having a maximum instantaneous capacity greater than or equal to one million gallons per day (MGD).

6. Keeowee-Toxaway Drought Management Advisory Group (KT-DMAG) – The KT-DMAG is a voluntary advisory group to be formed and tasked with working with the Licensee when the LIP is initiated. This KT-DMAG will also meet as necessary to foster a basin-wide response to a Low Inflow Condition (see Specific Actions at Each LIP Stage). The KT-DMAG will consist of a representative from each of the following organizations that decides to form or join the KT-DMAG. By agreeing to form or join the KT-DMAG, each Member agrees to comply with all applicable requirements of this LIP. Each KT-DMAG Member may have a primary representative and an alternate representative, who may act in the absence of the primary representative.

    a. SC Department of Natural Resources (SCDNR);
    b. SCDHEC;
    c. US Geological Survey (USGS);
    d. USACE;
    e. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on the Project Reservoirs;
    f. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on any tributary stream within the Keowee-Toxaway River Basin that ultimately drains to Lake Keowee and that agrees to coordinate its drought planning and management under the KT-DMAG;
    g. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on the USACE Reservoirs that agrees to coordinate its drought planning and management under the KT-DMAG; and
    h. Licensee (KT-DMAG Coordinator).

Members of the KT-DMAG will adopt a Charter to guide the operation of the KT-DMAG, as set forth in part below, and said Charter will require KT-DMAG Members to comply with the applicable requirements of this LIP. The KT-DMAG will meet at least annually (typically during the month of June), beginning in 2014 and continuing throughout the term of the New License, regardless of the Low Inflow Condition status, to review prior year activities, discuss data input from public water suppliers that are Large Water Intake owners, and discuss other issues relevant to the LIP. The Licensee will lead the formation of the KT-DMAG, will call meetings and set agendas, and will maintain an active roster of the KT-DMAG and update the roster as needed. The Licensee will prepare meeting summaries of all KT-DMAG meetings, make these meeting summaries available to the public by posting on its website, and notify Parties to the RA without specific responsibilities under the LIP of the availability of information on the current LIP status and possible actions.

Basic Responsibilities

Licensee's Responsibilities

The Licensee accepts the following basic responsibilities in furtherance of this LIP.

1. Monitor the following drought triggers and relevant data at least monthly or as specified for each LIP Stage.
    - Remaining Usable Storage in the Licensee's Reservoirs
    - Composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC (USGS Gage # 02186000); Chattooga River near Clayton, GA (USGS Gage # 02177000); French Broad River near Rosman, NC (USGS Gage # 03439000))
    - U.S. Drought Monitor for the Upper Savannah River Basin (i.e., from Thurmond Dam upstream)
    - Composite average of the Licensee's rainfall gauge readings at the Jocassee Pumped Storage Station, Keowee Hydro Station, and the Bad Creek Project
    - Oconee County USGS groundwater gage (USGS Gage # 345051083041800 OC-233) (Note: Data from other groundwater gages can be added in the future if beneficial.)
    - Remaining Usable Storage in the USACE Reservoirs downstream
    - USACE Savannah River Basin drought status
2. Coordinate KT-DMAG meetings including those noted for the particular drought stage. Provide to the KT-DMAG trigger updates, composite rainfall gauge readings, and operational and meteorological projections. Meetings can be in person, telephonic or by use of other appropriate communications. In consultation with KT-DMAG members, select and publicly communicate the LIP Stage based on the triggers established in this LIP.
3. Provide to the KT-DMAG the estimated water consumption rate by ONS (average for the current month and projections for the next month) and the estimated natural evaporation rate by reservoir from the Licensee's Reservoirs for the current month and projections for the next month.
4. Quantify total weekly flow releases (hydro generation, flood gate releases, hydro unit leakage, and dam seepage) made from the Keowee Development for the previous four weeks and provide to the KT-DMAG.
5. Coordinate with the USACE to make flow releases from Lake Keowee in accordance with the NOA between the Licensee, USACE, and SEPA regarding flow releases from the Keowee Development into the USACE's Hartwell Project and this LIP.
6. Depending on the LIP Stage, request voluntary or require mandatory water use restrictions for withdrawing water from the Licensee's Reservoirs to irrigate lakeside properties.
7. When operating in the LIP near Stage Minimum Elevations, except for flow releases required for ONS operations or situations covered by the Maintenance and

Emergency Protocol (MEP), the Licensee will not make an intentional flow release from Keowee Dam if that flow release would reduce the level of Lake Jocassee or Lake Keowee below its Stage Minimum Elevation as specified for the applicable LIP stage.

8. When operating in the LIP, the Licensee will limit weekly flow releases from the Keowee Dam to no more than the maximum weekly flow release for the applicable LIP Stage except for flow releases required for ONS operations or situations covered in the MEP. The weekly flow release amount includes the sum of all water released downstream from the Keowee Dam (i.e., hydro unit generation plus hydro unit leakage plus dam seepage plus any flood gate releases).

9. Stage Minimum Elevations are defined for each Stage of the LIP. When a subsequent Stage of the LIP is reached, the Licensee agrees both Project Reservoirs must be within 0.25 ft of the Stage Minimum Elevation of the previous Stage of the LIP before each reservoir can be lowered to the next Stage Minimum Elevation.

Responsibilities of Large Water Intake Owners that are Public Water Suppliers

Large Water Intake owners that are public water suppliers withdrawing water from the Licensee's Reservoirs agree to the following basic responsibilities in furtherance of this LIP.

1. Provide to the Licensee current month and projections for next month's water use from the Licensee's Reservoirs and from any alternative water supply sources.
2. Provide to the Licensee an overview of system conditions related to water use from the Licensee's Reservoirs (i.e., leaks, status of alternative water sources, new or potential large water users, etc.).
3. Request or require water use restrictions from water customers and/or make greater use of alternative water sources for the purpose of reducing water withdrawals from the Licensee's Reservoirs below what those withdrawals would have been otherwise, consistent with best practices and operating principles for those Large Water Intake owners' systems in accordance with the specific actions listed in this document at each LIP stage.

LIP Stage Triggers

For the purposes of this LIP, the following triggers will define the LIP Stage.

Stage 0 (Low Inflow Watch) Drought Trigger Levels

1. Storage Index in USACE Reservoirs and Storage Index in the Licensee's Reservoirs are both less than 90% (using the Critical Reservoir Elevations defined above); and
2. One of the following triggers:

a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 0; or

b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 85% of long-term average for the previous four months.

<u>Stage 1 Drought Trigger Levels</u>

1. USACE implements Level 1 of its existing Drought Contingency Plan (DCP); and
2. One of the following triggers:

   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 1; or

   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 75% of long-term average for the previous four months.

<u>Stage 2 Drought Trigger Levels</u>

1. USACE implements Level 2 of its existing DCP; and
2. One of the following triggers:

   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 2; or

   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 65% of long-term average for the previous four months.

<u>Stage 3 Drought Trigger Levels</u>

1. USACE implements Level 3 of its existing DCP; and
2. One of the following triggers:

   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 3; or

   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and

French Broad River near Rosman, NC) is less than 55% of long-term average for the previous four months.

Stage 4 Drought Trigger Levels

1. Storage Index in the Licensee's Reservoirs is less than 25%; and
2. One of the following triggers:
   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is equal to 4; or
   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 40% of long-term average for the previous four months.

Specific Actions at Each LIP Stage

Stage 0

The Licensee will:

1. Notify the KT-DMAG members and the South Carolina Department of Parks, Recreation and Tourism (SCDPRT) that LIP Stage 0 has been reached;
2. Initiate drought meetings (typically monthly) among the KT-DMAG members and any other interested water system managers;
3. Provide detailed updates to the KT-DMAG on drought triggers and other relevant data, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous four weeks;
5. Provide flow releases from Keowee Dam in accordance with the following limitations:
   a. When the Storage Index for the Licensee's Reservoirs is below 90% but greater than or equal to 85%, limit the total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 25,000 ac-ft (1800 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Normal Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP;
   b. When the Storage Index for the Licensee's Reservoirs is below 85% but greater than or equal to 80%, limit the total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 20,000 ac-ft (1440 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Normal

Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and

6. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will provide detailed updates to the Licensee on relevant data as noted in the Basic Responsibilities section.

Stage 1

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 1 has been reached;
2. Coordinate drought meetings (typically monthly) among the KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous four weeks;
5. Request those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties voluntarily limit their withdrawals to no more than two days per week, with the days to be specified by the Licensee;
6. Reduce the Minimum Elevation for Lake Keowee to 95.0 ft local datum / 795.0 ft AMSL (Stage 1 Minimum Elevation);
7. Reduce the Minimum Elevation for Lake Jocassee to 82.0 ft local datum / 1092.0 ft AMSL (Stage 1 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 18,750 ac-ft (1350 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 1 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 3-5% (or more) from the withdrawal amounts otherwise expected; and

3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Stage 2

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 2 has been reached;
2. Coordinate drought meetings (typically bi-weekly) among the KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to limit their withdrawals to no more than two days per week, with the days to be specified by the Licensee;
6. Reduce the Minimum Elevation for Lake Keowee to 93 ft local datum / 793.0 ft AMSL (Stage 2 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 77.0 ft local datum / 1087.0 ft AMSL (Stage 2 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 15,000 ac-ft (1080 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 2 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 5-10% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Stage 3

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 3 has been reached;
2. Coordinate drought meetings (typically bi-weekly) among the KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to limit their withdrawals to no more than one day per week, with the day to be specified by the Licensee;
6. Reduce the Minimum Elevation for Lake Keowee to 92.0 ft local datum / 792.0 ft AMSL (Stage 3 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 73.0 ft local datum / 1083.0 ft AMSL (Stage 3 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 10,000 ac-ft (720 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 3 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with increased emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 10-20% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Stage 4

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 4 has been reached;
2. Coordinate bi-weekly (or more frequently if needed) drought meetings among KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to cease all such withdrawals;
6. Reduce the Minimum Elevation for Lake Keowee to 90.0 ft local datum / 790.0 ft AMSL (Stage 4 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 70.0 ft local datum / 1080.0 ft AMSL (Stage 4 Minimum Elevation);
8. Limit flow releases from Keowee Dam to the following:
    a. When the Storage Index for the Licensee's Reservoirs is below 25% but greater than 12%, except for flow releases required by the FERC, for ONS operations, or situations covered by the MEP, limit the total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 7,500 ac-ft (540 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee below its Stage 4 Minimum Elevation and to maintain the level of Lake Keowee at or above 91.5 ft local datum / 791.5 ft AMSL or its Critical Reservoir Elevation, whichever is higher;
    b. When the Storage Index for the Licensee's Reservoirs is at or below 12%, cease making hydro unit and floodgate flow releases, except for flow releases required by the FERC, for ONS operations, or situations covered by the MEP.
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with increased emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee by 20-30% (or more) from the withdrawal amounts otherwise expected; and

3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Recovery from LIP Stages

Recovery under this LIP as conditions improve will be accomplished by reversing the staged approach outlined above, except the only trigger to recover from a stage is for either the storage index for the Licensee's Reservoirs or the USACE drought trigger to be exceeded for the current stage as described below. The following table provides the storage levels required for recovery from a higher numbered "Stage Y" to a lower numbered "Stage X":

Recovery from Stage Y to Stage X	Required Storage
From Stage 4 to Stage 3	Storage Index for the Licensee's Reservoirs is greater than or equal to 25%
From Stage 3 to Stage 2	Storage for the USACE Reservoirs recovers to amount for initial implementation[1] of Level 2 of its DCP
From Stage 2 to Stage 1	Storage for the USACE Reservoirs recovers to amount for initial implementation[1] of Level 1 of its DCP
From Stage 1 to Stage 0	Storage for the USACE Reservoirs returns to amount required for Normal operations[1]
From Stage 0 to Normal	Storage Index for the Licensee's Reservoirs is greater than or equal to 90%

Note 1 – These are USACE storage amounts that indicate when the USACE increases its drought level (Normal to 1, 1 to 2 or 2 to 3) which is not the same storage amount that indicates when USACE decreases its drought level (3 to 2, 2 to 1 or 1 to Normal). The USACE requires greater storage amounts when recovering from drought (decreasing drought levels).

APPENDIX C

Maintenance and Emergency Protocol

[Included in Appendix E of the Relicensing Agreement, filed on August 27, 2014]

MAINTENANCE AND EMERGENCY PROTOCOL (MEP) FOR THE KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

Introduction

Under some emergency, equipment failure, power plant maintenance, and other situations, certain license conditions may be impractical or even impossible to meet and may need to be suspended or modified temporarily to avoid taking unnecessary risks. The objectives of this protocol are to define the most likely situations of this type, identify the potentially impacted license conditions, and outline the general approach the Licensee will take to mitigate the impacts to license conditions and to communicate with the resource agencies and affected parties.

Note: Due to the potential variability of these situations, this protocol is not intended to give an exact step-by-step solution for all situations. It does, however, provide basic expectations for the Licensee's approach to dealing with such situations. Specific details will vary and will be determined on a case-by-case basis as the protocol is implemented.

The Licensee will review the requirements of this protocol each time it is used and may revise the MEP from time to time as noted below.

Key Facts and Definitions

1. Human Health and Safety and the Integrity of the Public Water Supply and Electric Systems – Nothing in this protocol will limit the Licensee's ability to take any and all lawful actions necessary at the Keowee-Toxaway Hydroelectric Project (Project) to protect human health and safety, to protect its equipment from damage, to ensure the stability of the regional electric grid, to protect the equipment of the Large Water Intake owners from damage, and to ensure the stability of public water supply systems; provided that nothing in the Relicensing Agreement ("RA") or MEP obligates the Licensee to take any actions to protect the equipment of Large Water Intake owners from damage or to ensure the stability of public water supply systems. It is recognized the Licensee may provide this protection without prior consultation or notification.
2. Normal Full Pond Elevation – Also referred to simply as "full pond," this is the level of a reservoir corresponding to the point at which water would first begin to spill from the reservoir's dam(s) if the Licensee took no action. This level corresponds to the lowest point along the top of the floodgates for Project Reservoirs (i.e., Lake

Jocassee and Lake Keowee). To avoid confusion among the many reservoirs the Licensee operates, it has adopted the practice of referring to the Full Pond Elevation for all of its reservoirs as equal to 100.0 ft relative to local datum. The Full Pond Elevations for the Project Reservoirs are:

	Full Pond Elevation	
Reservoir	**Local Datum (ft)**	**Above Mean Sea Level (ft AMSL)**
Lake Jocassee	100.0	1110.0
Lake Keowee	100.0	800.0

3. Normal Minimum Elevation – The level of a reservoir (measured in ft AMSL, or feet relative to the full pond contour with 100.0 ft corresponding to full pond) that defines the bottom of the reservoir's Normal Operating Range for a given day of the year. If inflows and outflows to the reservoir are kept within some reasonable range of the average or expected amounts, hydroelectric project equipment is operating properly, and neither the Low Inflow Protocol (LIP) nor MEP has been implemented, reservoir level excursions below the Normal Minimum Elevation should not occur.

4. Normal Maximum Elevation – The level of a reservoir (measured in ft AMSL, or feet relative to the full pond contour with 100.0 ft corresponding to full pond) that defines the top of the reservoir's Normal Operating Range for a given day of the year. If inflows and outflows to the reservoir are kept within some reasonable range of the average or expected amounts, hydroelectric project equipment is operating properly, and neither the LIP nor MEP has been implemented, reservoir level excursions above the Normal Maximum Elevation should not occur.

5. Normal Operating Range – The band of reservoir levels within which the Licensee normally attempts to maintain a given reservoir on a given day. Each Project Reservoir has its own specific Normal Operating Range bounded by a Normal Maximum Elevation and a Normal Minimum Elevation. If inflows and outflows to the reservoir are kept within some reasonable range of the average or expected amounts, hydroelectric project equipment is operating properly and neither the LIP nor MEP has been implemented, reservoir level excursions outside of the Normal Operating Range should not occur. The New License for the Project includes the Normal Operating Ranges for the Project Reservoirs (i.e., Normal Minimum, Normal Maximum) as listed in the proposed Reservoir Elevations License Article and as follows.

Reservoir	Normal Maximum Elevation (ft local datum / ft AMSL)	Normal Minimum Elevation (ft local datum / ft AMSL)
Lake Jocassee	100.0 / 1110.0	86.0 / 1096.0
Lake Keowee	100.0 / 800.0	96.0 / 796.0

6. Returning to Normal – Some of the situations noted in this MEP can impact the Licensee's ability to operate the Project in the most efficient and safest manner for power production. The Licensee will therefore endeavor in good faith to repair existing Project equipment and facilities and return them to service within a reasonable period of time, commensurate with the severity of the equipment / facility repair requirements. If the Licensee decides that repair is not cost-effective or that hydro station or dam retirement is necessary, the Licensee will notify the Parties to the RA, pursuant to Section 23.0 of the RA and consult with them as well as with the Federal Energy Regulatory Commission (FERC) to determine any necessary modifications of the New License and / or the RA.

7. Incidental Maintenance – This is a maintenance activity at the Project works that is very brief in nature or that requires minimal if any deviation from normal license conditions and that does not require deviation from any license conditions related to prescribed flow releases from Project structures, or the Normal Operating Ranges for reservoir levels, or that is less than 72 hours in duration and will not require any excursions below any applicable Critical Reservoir Elevations. Except for the notification steps identified in the tables below for communication with resource agencies and affected parties for conditions that impact prescribed flow releases, Incidental Maintenance is exempt from the requirements of this protocol.

8. Notification Guidance

   a. Scheduled Maintenance that Affects License Conditions – Typically, scheduled maintenance is planned in advance. Once a likely maintenance schedule has been established, the Licensee will endeavor in good faith to provide as much advance notice as possible to the affected parties identified in this protocol.

   b. Unscheduled Maintenance and Emergencies that Affect License Conditions – It is not possible for the Licensee to assure any level of advance notice. For these situations, the Licensee will endeavor in good faith to inform the affected parties identified in this protocol within some reasonable amount of time after the situation has been identified.

9. Relationship Between this MEP and the LIP – The LIP provides for reductions in Project water use and modification of the Normal Operating Ranges for reservoir levels when water demands on Project Reservoirs substantially exceed net inflow. Lowered reservoir levels caused by situations addressed under this MEP will not

invoke implementation of the LIP. Also, if the LIP has already been implemented at the time this MEP is initiated, the Licensee will typically suspend its implementation of the LIP requirements until the MEP situation has been eliminated. The Licensee may however choose to continue with the LIP.

10. Peak Recreation Period – The period when recreation use on Project Reservoirs is generally at the highest levels (i.e., April 1 through September 30).

11. Critical Reservoir Elevation – Unless otherwise defined herein, the Critical Reservoir Elevation is the level of water in a reservoir (measured by reference to local datum or in ft AMSL) below which any Large Water Intake used for public water supply, industrial water supply, or any regional power plant water supply located on the reservoir will not operate at its Licensee-approved capacity. The Critical Reservoir Elevations are as follows.

Reservoir	Critical Reservoir Elevation (ft local datum / ft AMSL)	Type of Limit
Lake Jocassee	70.0 / 1080.0	Power Production
Lake Keowee	90.0[1] / 790.0[1]	Power Production

Note 1 - This new Critical Reservoir Elevation of 90.0 / 790.0 will become effective December 1, 2019 to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. See Item 12 below for guidance prior to converting to this new Critical Reservoir Elevation.

12. Transitioning to a Lower Critical Reservoir Elevation on Lake Keowee – The Licensee will operate in accordance with the provisions of the MEP, except Lake Keowee's Critical Reservoir Elevation will remain at or above 94.6 ft local datum / 794.6 ft AMSL until December 1, 2019, to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. The Licensee may also, in its sole discretion, decide to maintain Lake Keowee's Critical Reservoir Elevation at or above 94.6 ft local datum / 794.6 ft AMSL until both of the following are complete:

a. A New License that is consistent with the RA has been issued, the end of all appeals, and all rehearing and administrative challenge periods have closed; and

b. The Licensee, the United States Army Corps of Engineers, and the Southeastern Power Administration have signed a New Operating Agreement (NOA) that is not inconsistent with the RA.

13. Abbreviations for Organizational Contacts – Greenville Water (GW); North Carolina State Historic Preservation Office (NCSHPO); Seneca Light and Water (Seneca); South Carolina Department of Natural Resources (SCDNR); South Carolina Department of Health and Environmental Control (SCDHEC); South Carolina State Historic Preservation Office (SCSHPO); United States Fish and Wildlife Service

(USFWS); the Eastern Band of Cherokee Indians (EBCI); US Army Corps of Engineers - Savannah District (USACE); South Carolina Department of Parks, Recreation and Tourism (SCDPRT); Friends of Lake Keowee Society (FOLKS), Advocates for Quality Development (AQD), and Mountain Lakes Community Association (MLCA).

14. Voltage and Capacity Emergencies – The electric transmission system serving the Project area is part of the Licensee's main transmission system. The Licensee's system is connected to other large transmission systems located in the southeast. If the Licensee's system reliability is at risk due to Voltage and Capacity Emergencies, the ability to provide secure and continuous electric service to the Licensee's electric customers becomes compromised. The Licensee continuously monitors the electric transmission system. Therefore, for the purposes of this protocol, a Voltage or Capacity Emergency shall exist when declared by the Licensee.

15. Large Water Intake – Any water intake (e.g., public water supply, industrial, agricultural, power plant, irrigation, etc.) having a maximum instantaneous capacity greater than or equal to one million gallons per day (MGD).

16. Preparation for High Inflow Events – With modern forecasting, it is possible to forecast many high inflow events days in advance and to increase hydro generation hours to lower reservoir levels to reduce the potential for spilling and high water. This type of advance action is typically taken from one to five days or more before the expected arrival of the storm. The Normal Operating Ranges of reservoir levels may not allow for this type of reservoir level reduction under anticipated heavy inflow circumstances, and therefore, allowances are made in this MEP to lower reservoir levels below the Normal Minimum Elevations if needed in preparation for such events.

17. Revising the MEP – The Licensee will review the requirements of this MEP each time it is used and will consult with the organizations listed in Item 13 above if the Licensee determines modifications are warranted. If the MEP is modified, the Licensee will inform the Parties to the RA. If any modifications of the MEP require amendment of the New License, the Licensee will: (i) provide notice to all Parties to the RA, pursuant to Section 23.0 of the RA, advising them of the proposed New License amendment and the Licensee's intent to file it with the FERC; (ii) request the SCDHEC formally review and approve modification of the 401 WQC if required; and (iii) file a license amendment request for FERC approval if required. The filing of a revised MEP by the Licensee will not by itself constitute or require modification of the RA, and any Party to the RA may be involved in the FERC's or SCDHEC's public processes for assessing the revised MEP, but may not oppose any part of a revised MEP that is consistent with the MEP included in the RA.

Guidance for Responding to MEP Conditions

This section provides guidance for responding to the most likely MEP conditions (see Table 1 below) when this protocol will be enacted. Required flow releases and normal reservoir operating ranges are the license requirements most likely to be affected by MEP conditions.

Table 1: Conditions and Potential Impacts to License Requirements

Condition	Condition Name	Indications
MEP1	Hydro Unit Maintenance	Maintenance will require hydro unit shutdown
MEP2	Dam Safety Emergency	Condition A or B per the Emergency Action Plan (EAP) (i.e., dam failure has occurred, is imminent or a potentially hazardous situation exists) or some other dam safety concern is identified
MEP3	Voltage or Capacity Emergency	Voltage or capacity conditions on the electric grid in the Licensee's system or the larger regional electric grid cause the Licensee's system reliability and safety to be at risk and a voltage or capacity emergency is declared by the Licensee
MEP4	Reservoir Drawdown Below Normal Minimum Elevation due to maintenance, emergency or other reasons (not due to low or high inflow)	The reservoir level is below Normal Minimum Elevation
MEP5	Expected or existing high inflow event	The water level at a reservoir is or is projected to be significantly above or below the Normal Operating Range

Communication with Resource Agencies and Affected Parties

The Licensee will implement the appropriate communications based on the potential license requirements affected by the MEP condition. Communications include the following:

- Notification – The Licensee notifies the organization of the MEP event and the Licensee's planned actions; and

- Consultation – The Licensee notifies the organization of the MEP event and the Licensee's planned actions. The Licensee also requests input from the consulting organizations about options and alternatives to lessen the environmental, cultural, and human impacts of the MEP condition.

Generally, for unplanned and unscheduled MEP conditions, notifications occur as conditions unfold and will be followed by consultation.

Condition MEP1.1 – Scheduled Hydro Unit Maintenance

Mitigating Actions

1. Scheduling – To the extent practical, the Licensee will avoid scheduling hydro unit maintenance requiring drawdowns of the Project Reservoirs below the Normal Minimum Elevation during the period April 1 to May 15 to protect black bass spawning and to avoid hindering the Licensee's ability to provide recreation access during the Peak Recreation Period as defined above.
2. Drawing Down the Affected Reservoir –To minimize the impacts to its electric customers, the Licensee may choose to draw down a reservoir using its hydro units to minimize spillage from the dam during maintenance operations. The Licensee may draw down reservoir levels below the Normal Minimum Elevations, but not to levels below the applicable Critical Reservoir Elevations, unless such deeper drawdown is essential for access or safety.

Communication with Resource Agencies and Affected Parties

Condition MEP1.1 – Scheduled Hydro Unit Maintenance		
Notification	**Consultation**	**Comments**
FERC	AQD FOLKS Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	If the maintenance will affect any Normal Operating Range for Project Reservoir levels, provide notification and initiate consultation when maintenance schedules are determined, but at least 30 days prior to beginning any reservoir drawdown or the hydro unit maintenance.
	NCSHPO[1] SCSHPO EBCI	Consult no less than 30 days prior to the planned activity if required by the Historic Properties Management Plan.
AQD FOLKS MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.

Condition MEP1.1 – Scheduled Hydro Unit Maintenance		
Notification	**Consultation**	**Comments**
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free phone system plus implement other appropriate measures to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance

Condition MEP1.2 – Unscheduled Hydro Unit Maintenance

Mitigating Actions

1. Drawing Down the Affected Reservoir –To minimize the impacts to its electric customers, the Licensee may choose to draw down a reservoir using its hydro units to minimize spillage from the dam during maintenance operations. The Licensee may draw down reservoir levels below the Normal Minimum Elevations, but not to levels below the applicable Critical Reservoir Elevations, unless such deeper drawdown is essential for access or safety.

Communication with Resource Agencies and Affected Parties

Condition MEP1.2 – Unscheduled Hydro Unit Maintenance		
Notification	**Consultation**	**Comments**
FERC AQD FOLKS Large Water Intake owners MLCA SCDHEC SCDNR SCDPRT USACE USFWS	AQD FOLKS Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	If the maintenance will affect any Normal Operating Range for Project Reservoir levels, perform notification promptly after the unscheduled maintenance begins, but no longer than 10 days afterwards. Initiate consultation within 10 days.
NCSHPO[1] SCSHPO EBCI	NCSHPO[1] SCSHPO EBCI	Consult if required by the Historic Properties Management Plan.
AQD FOLKS MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.

Condition MEP1.2 – Unscheduled Hydro Unit Maintenance		
Notification	**Consultation**	**Comments**
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free phone system and implement other appropriate measures to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance

Condition MEP2 – Dam Safety Emergency

Mitigating Actions

1. Safety Must Come First – If a Condition A or B is declared per the Licensee's EAP, or if other dam safety concerns arise, the Licensee may modify or suspend any license conditions immediately and for as long as necessary to restore the dam to a safe condition.

Communication with Resource Agencies and Affected Parties

Condition MEP2 – Dam Safety Emergency	
Timing of Communication	**Comments**
During EAP Condition A or B	Conducted strictly in accordance with the Licensee's EAP. In cases where dam safety concerns arise that are not a Condition A or B per the Licensee's EAP, consultation with resource agencies and affected parties will occur as soon as practical after the dam safety concern arises.
Once Dam Safety Conditions Have Stabilized	When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free telephone system to inform the general public.
Access Area Closure Notification	The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.

Condition MEP3 – Voltage and Capacity Emergencies

Mitigating Actions

1. Suspension of the Normal Operating Ranges for Reservoir Levels – If a voltage or capacity emergency (as defined above) occurs, the Licensee may modify or suspend reservoir level operating limitations immediately and for as long as necessary, if doing so would allow additional hydro station operation needed to restore the electric grid to a stable condition. Reservoir levels will not be reduced below the applicable Critical Reservoir Elevations.

Communication with Resource Agencies and Affected Parties

Condition MEP3 – Voltage and Capacity Emergencies		
Notification	**Consultation**	**Comments**
FERC SCDNR SCDHEC SCDPRT USFWS USACE Large Water Intake owners	Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Perform notification as soon as practical, but no longer than 10 days following the deviation from a license condition for Voltage or Capacity Emergency reasons. Initiate consultation as soon as practical.
NCSHPO[1] SCSHPO EBCI	NCSHPO[1] SCSHPO EBCI	Consult if required by the Historic Properties Management Plan.
AQD FOLKS MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free telephone system plus implement other appropriate measure to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance

Condition MEP4.1 – Reservoir Drawdown (Planned)

Mitigating Actions

1. Scheduling – To the extent practical, the Licensee will avoid scheduling drawdowns of the Project Reservoirs below the Normal Minimum Elevations during the period from April 1 to May 15 to protect black bass spawning and to avoid hindering the Licensee's ability to provide recreation access during the Peak Recreation Period as defined above.

2. Avoid Falling Below Critical Reservoir Elevations – To the extent practical, the Licensee will avoid falling below the applicable Critical Reservoir Elevations as noted above.

Communication with Resource Agencies and Affected Parties

Condition MEP4.1 – Reservoir Drawdown (Planned)		
Notification	**Consultation**	**Comments**
FERC AQD FOLKS Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Provide notification and consult when approximate drawdown dates are determined, but at least 30 days prior to beginning drawdown.
	NCSHPO[1] SCSHPO EBCI	Consult no less than 30 days prior to the planned activity if required by the Historic Properties Management Plan.
MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.

Condition MEP4.1 – Reservoir Drawdown (Planned)		
Notification	**Consultation**	**Comments**
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free telephone system implement other appropriate measures to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance

Condition MEP4.2 – Reservoir Drawdown (Unplanned)

Mitigating Actions

1. Avoid Falling Below Critical Reservoir Elevations – To the extent practical, the Licensee will avoid falling below the applicable Critical Reservoir Elevations as noted above.

Communication with Resource Agencies and Affected Parties

Condition MEP4.2 – Reservoir Drawdown (Unplanned)		
Notification	**Consultation**	**Comments**
FERC AQD FOLKS Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Large Water Intake owners SCDHEC SCDNR SCDPRT USACE USFWS	Perform notification as soon as practical, but no longer than 10 days after the drawdown begins. Begin consultation within 10 days after the drawdown begins.
NCSHPO[1] SCSHPO EBCI	NCSHPO[1] SCSHPO EBCI	Consult if required by the Historic Properties Management Plan.
MLCA Project Access Area Lessees[2]		The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low reservoir levels) in accordance with the Recreation Management Plan.
General Public		When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free telephone system and to implement other appropriate measures to inform the general public.

Note 1 - If Lake Jocassee is the reservoir being drawn down
Note 2 - If affected by the maintenance drawdown

Condition MEP5 – Expected or Existing High Inflow Event

<u>Mitigating Actions</u>

1. As outlined in the Key Facts and Definitions section of this protocol, in preparation for high inflow events and to minimize the potential for unplanned spillage the Licensee may reduce reservoir levels below the Normal Minimum Elevation, but not below the applicable Critical Reservoir Elevations. Reservoir levels may also rise significantly above Normal Maximum Elevations as a result of high inflow events. The reservoir levels may be below Normal Minimum Elevations or above Normal Maximum Elevations for as long as necessary to minimize the effects of the high inflow event on the Project Reservoirs and downstream reservoirs and to manage reservoir elevations during high inflow events.

Communication with Resource Agencies and Affected Parties

Condition MEP5 – Expected or Existing High Inflow Event	
Notification	**Comments**
FERC SCDHEC SCDNR SCDPRT USACE USFWS	The Licensee will perform notification as soon as practical following or prior to a deviation from license requirements for an existing or expected high inflow event.
AQD FOLKS MLCA Project Access Area Lessees	The Licensee will implement notification procedures for any temporary closures of recreation facility/access areas (e.g., closure due to extended low or high reservoir levels) in accordance with the Recreation Management Plan.
General Public	When the Licensee determines the response to a MEP condition will potentially impact license conditions, the Licensee will add appropriate messages to its public information Web site and its reservoir level toll-free phone system plus implement other appropriate measure to inform the general public.

Appendix E

Appendix E – Visual Resources Study Plan

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APPENDIX E

VISUAL RESOURCES PROPOSED STUDY PLAN

Bad Creek Pumped Storage Project
FERC Project No. 2740

August 2022

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VISUAL RESOURCES PROPOSED STUDY PLAN
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
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ACRONYMS AND ABBREVIATIONS

Bad Creek or Project	Bad Creek Pumped Storage Project Bad
Bad Creek II Complex	Creek II Power Complex
Duke Energy or Licensee	Duke Energy Carolinas, LLC
FERC or Commission	Federal Energy Regulatory Commission
GPS	Global Positioning System
KT Project	Keowee-Toxaway Hydroelectric Project
PM&E	Protection, Mitigation, and Enhancement
SMS	Scenery Management System
USFS	U.S. Forest Service

1 Study Requests and Formal Comments

The Federal Energy Regulatory Commission's (FERC or the Commission) April 22, 2022 Scoping Document 1 identified the following environmental resource issue to be analyzed in the National Environmental Policy Act document for the Bad Creek Pumped Storage Project (Project) relicensing related to scenery and visual resources. The resource issue addresses the effects of continued Project operations under the Existing License as well as potential construction and operation of a second powerhouse during the New License term (Bad Creek II Power Complex [Bad Creek II Complex]):

- Effects of Project construction, operation (including the presence of Project facilities), and maintenance activities on scenery and visual resources.

In Section 7.1.7.3 of the Pre-Application Document (Duke Energy 2022), Duke Energy Carolinas, LLC (Duke Energy or Licensee) proposed to conduct a Visual Resources Study in support of the proposed Bad Creek II Complex. More specifically, the study will include an assessment of baseline conditions and an evaluation of potential visual impacts from construction and operation of the Bad Creek II Complex. No formal study requests related to scenery and visual resources were received during the scoping process; however, numerous stakeholders expressed support for the study proposed by Duke Energy. Requests and comments relevant to visual resources were considered in the development of this PSP and summaries of all comments and responses are included in Appendix A. Copies of all comments are provided in Appendix B.

2 Goals and Objectives

Due to the topographic location of the dams and upper reservoir, the underground location of the powerhouse, the surrounding terrain, and heavily forested nature of the Project area, there are limited public and [non-Duke Energy] private access areas providing views of Project facilities. No adverse additional effects to scenery and visual resources are expected to result from the continued operation of the Project over the New License term, and no practical or necessary protection, mitigation, and enhancement (PM&E) measures have been previously identified or proposed for existing Project structures.

Therefore, this study is focused on visual impacts from the potential construction and operation of the Bad Creek II Complex. These impacts may include land clearing and grading activities; creation of new upland spoil areas; temporary, localized turbidity impacts in the Whitewater River cove (also called Whitewater River arm); construction traffic; temporary construction facilities; and the presence of heavy construction equipment. The scenery will be permanently altered through the addition of new Project structures, though these will be similar in appearance and adjacent to existing Project structures.

Duke Energy will conduct a Visual Resources Study for this relicensing to include and address the following:

- Establish the baseline condition of scenery and visual resources near the existing Project and to provide additional information (e.g., including simulations of the expanded Project) to evaluate expected impacts of construction and operation of the Bad Creek II Complex on these resources and any PM&E measures.

This Visual Resources Study will be carried out to provide additional information to support the pursuit of the New License for the Project; data collected will be used to support Project feasibility and design processes and to assess potential effects of the proposed Project on scenery and visual resources. This study plan briefly describes planned study activities that will be performed to address these issues.

3 Study Area

The study area for the Visual Resources study area is shown on Figure 3-1 and includes the upper reservoir, lower reservoir (Whitewater River arm only), preliminary transmission line alignment, and main (expanded) Project site.

The Project is situated within the Blue Ridge Mountains in the Upstate of South Carolina. The existing landscape and scenic attributes in the vicinity are dominated by rolling hills, forests, stream corridors, steep slopes, waterfalls, rock outcrops, and mountain ridges. The areas surrounding the Project reservoir are primarily undeveloped forested land (managed by the U.S.

Forest Service [USFS]). Although there is some development around Lake Jocassee, the shoreline is also mostly forested with a mixture of pines and hardwoods and there are numerous waterfalls where tributaries flow into the reservoir. Surrounding protected lands include the Sumter National Forest and the Jocassee Gorges and the area overall is aesthetically appealing.

The Project site is located entirely on Duke Energy-owned property, except for a portion of the transmission line corridor that is currently maintained under a property easement. The Project is not generally visible from any state highway nor is it visible from Lake Jocassee (via boat) - it is only visible from the Bad Creek access road. The existing inlet/outlet structure in the Whitewater River cove is the only facility structure visible to the public (via boat).

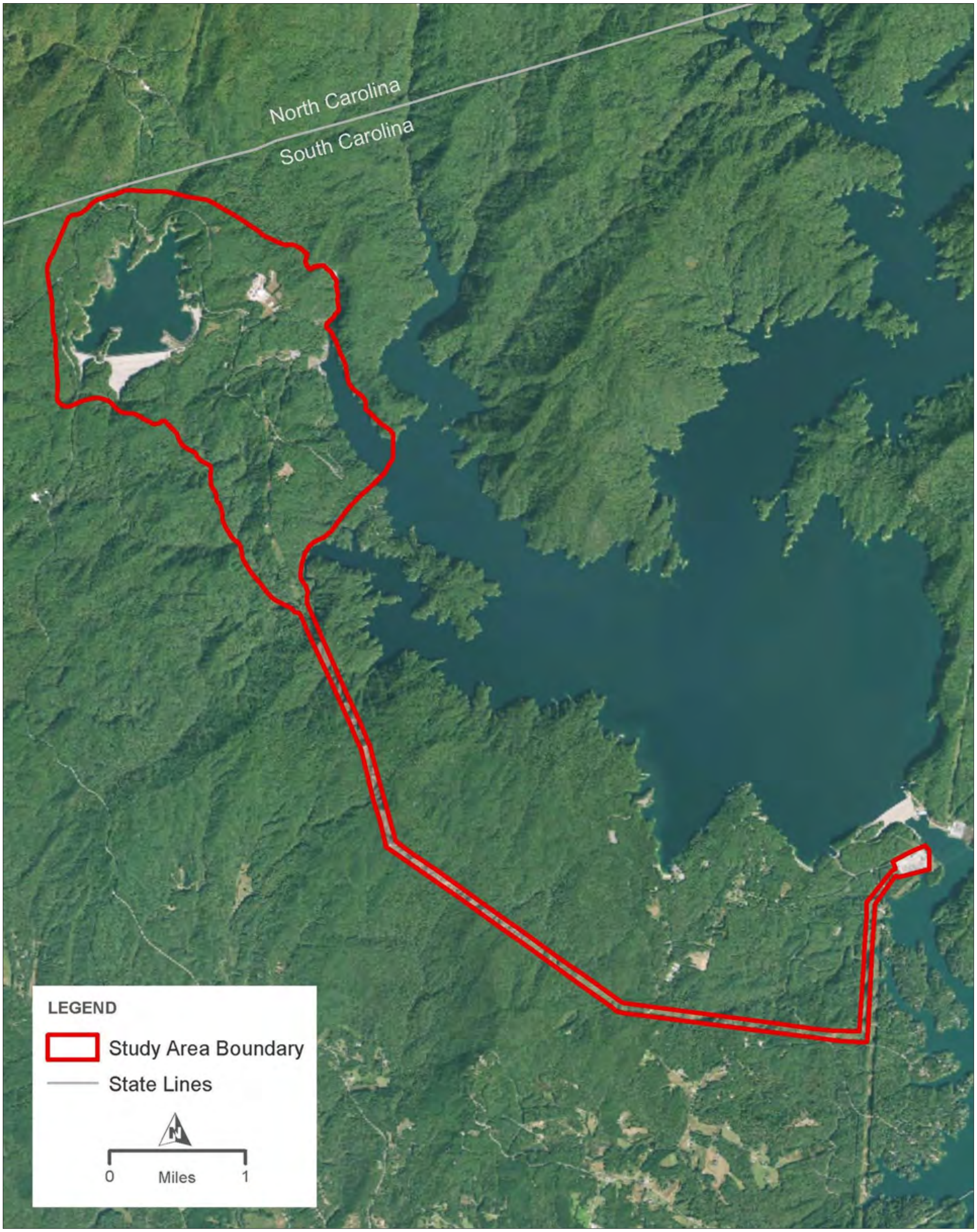

Figure 3-1. Visual Resources Study Area

4 Background and Existing Information

The FERC regulations for license applications require that Exhibit E include a report on aesthetic resources (18 CFR 4.41(f) (8)). The report must describe the scenic and visual resources of the proposed Project area, expected impacts on these resources, and the mitigation, enhancement and protection measures proposed. The report must be prepared following consultation with federal, state, and local agencies having managerial responsibility for any part of the proposed Project lands and abutting lands.

There are numerous opportunities to enjoy nature and scenery in the immediate vicinity of the Project such as hiking, camping, fishing, hunting, scenic and wildlife viewing, and boating (flatwater and whitewater). The scenic conditions within the vicinity of the Project have been a priority for Duke Energy since the 1970's and this commitment continues today. Duke Energy has played a large role in contributing to the protection of large amounts of nearby public recreational and conservation lands to enhance the scenery of the area.

Visual elements associated with the Project include the upper reservoir, the main dam, the west dam, the east dike, the equipment building, access roads, lower reservoir inlet/outlet structure and powerhouse portal area (Whitewater River arm of Lake Jocassee), transformer yard and switchyard (adjacent to equipment building), and transmission line extending from the Bad Creek transformer yard to a grid intertie station at the Jocassee Station.

During a 2013 Recreation Use and Needs Study at the Keowee-Toxaway (KT) Project (Duke Energy 2014), one third of the people surveyed stated nothing detracts from the scenic quality of Lake Jocassee. Almost half of Lake Jocassee respondents listed low-water levels as the main detraction to visual resources, while in a 2007 Recreation Use and Needs Study only 36 percent of respondents listed low-water levels as a detraction. No respondents listed "development" as detracting from scenic and visual qualities of the area (Duke Energy 2014).

As a result of the Original License for the KT Project, the Jocassee Shoreline Management Plan has provisions limiting the ability of adjoining property owners to eliminate shoreline vegetation along Lake Jocassee with the intention to provide a more natural looking shoreline buffer. Additionally, following the relicensing of the KT Project, new normal minimum lake elevations were set higher, a new drought protocol (Low Inflow Protocol) was put in place and a New

Operating Agreement with the U. S. Army Corps of Engineers was put in place; each of which contribute to reducing the frequency and magnitude of exposed Jocassee shorelines, improving the visual appearance for visitors.

As previously stated, visual impacts would result from the construction and operation of the Bad Creek II Complex. Common mitigation techniques can be applied to reduce impacts to visual resources during and after construction including minimization of disturbance (e.g., limit clearing trees and vegetation to the extent possible), lighting control, strategic placement of facility appurtenances, and reduction of visual contrast caused by new rights-of-way, access roads, laydown areas, and staging areas. Duke Energy expects the best management practices and PM&E measures required to address the requirements of the FERC license and Section 404/401 permit will also benefit visual resources. In association with this study and the larger relicensing process, Duke Energy expects to further consult with relicensing stakeholders to determine whether additional PM&E measures are needed for the protection of visual resources.

5 Project Nexus

The natural and aesthetic character of Lake Jocassee, the Foothills Trail, Whitewater Falls, and non-developed, forested areas surrounding the Bad Creek Project contribute to the recreational and cultural value of the Project vicinity, within the Blue Ridge Mountains in the Upstate of South Carolina. The existing Project facilities have been in place since construction of Bad Creek was completed in the early 1990s, and the Project has actively operated since that time.

The construction of the Bad Creek II Complex will include a new underground powerhouse and associated structures as well as the new inlet/outlet structure to Lake Jocassee. Similar to the existing inlet/outlet structure, following completion of construction, the new inlet/outlet structure will be viewable by the public via boat (primarily from the Whitewater River cove). With the construction of the proposed Project expansion, the visual landscape will be altered during and after construction.

6 Methods

Study objectives are to provide information needed to determine the potential direct, indirect, and/or cumulative effects of the proposed Project on scenic and visual resources. The results of this study, in conjunction with existing information, will be used to inform analysis in and recommendations for the New License application regarding potential Project effects on visual scenic and potential PM&E measures to be included in the New License. This study will be carried out through implementation of the tasks outlined below.

6.1 Task 1 – Existing Landscape Description

Duke Energy will review existing available information in the study area to characterize the existing landscape within the proposed expanded Project area and the scenic quality of the landscape. This task will primarily involve review of available baseline information to describe the key scenic characteristics of the existing landscape within the Project area and surrounding lands expected to potentially be within visual range of Project facilities. The objective will be to identify and describe the key elements of the existing landscape, including landforms and terrain (i.e., slope); water features; vegetative cover type, pattern, height, and distribution; soils; geology; and cultural features (i.e., developed uses and structural modifications of the natural landscape). This task will also characterize any management and/or regulation of the scenic resources within the Visual Resources Study area. The landscape description will include the fundamental visual elements of form, line, color, texture, and pattern. Key information sources are expected to be U.S. Geological Survey (USGS) topographic maps and the National Land Cover Database; federal, commonwealth/state and local government planning documents that include information on scenic and visual resource conditions; and photographs and aerial/satellite imagery.

6.2 Task 2 – Seen Area Analysis

A preliminary seen area (viewshed) analysis will be conducted to identify areas within the existing landscape from which any part of the proposed Bad Creek II facilities would potentially be visible. The seen area analysis will be run in ArcGIS using the preliminary expanded Project layout and a U.S. Geological Survey 10-meter digital elevation model dataset. The analysis results will identify locations on the terrain surface with a direct line of sight to the tip elevation of one or more project features (visible/not visible).

The initial seen area analysis will be done on a bare-earth basis, which represents line-of-sight conditions based only on topography; it does not account for factors that might obscure or block visibility from a specific location or at certain times, such as weather conditions, existing structures or vegetation. Because the primary Project area is predominantly forested, the bare-earth seen area analysis results will be a conservative representation of potential visibility.

The initial seen area analysis will address the Project reservoirs and directly associated facilities; a subsequent viewshed analysis covering the new transmission corridor may be conducted if a new corridor is defined for the Bad Creek II Complex. The seen area analysis will be used to identify potential Key Views for the field investigation (Section 6.3) and selection of Key Views for analysis (Section 6.4).

6.3 Task 3 – Field Investigation

This task will be a field investigation of the "visible" areas identified through the seen area analysis task. Specific field instructions and data forms will be prepared in advance of the field effort. Photographs and field records will be carefully logged and organized immediately following the field investigation.

The field work to collect facilities inventory data will entail qualified personnel (two-person crew) operating Global Positioning System (GPS) equipment to take photographs at each potential Key View location. GPS location points will be recorded for each simulation viewpoint, preferably using a GPS unit with sub-meter accuracy, but at least 3-meter accuracy, to ensure repeatability. Multiple site photographs will be collected at each location using a tripod.

Site photographs to be used in assessment will be correlated with x, y, z coordinates and heading angle. For each inventory point, the following information will be collected:

- GPS – accuracy for photo-simulations should be within 3 feet (+or- 1 meter horizontal)
  - GPS model
  - PDOP (position dilution of precision) and post-processing information
- Camera
  - Make, model (suitable for producing photo-simulations)

    - Camera lens information
- Ground truth
    - Confirm Key View based on logical on-site conditions
    - Field notes – time of day, atmospheric condition, heading of camera view

6.4 Task 4 – Key Views Selection

This task will result in selection of a representative subset of the potential Key Views investigated during the field investigation that will be used as Key Views for the visual impact analysis. The objective will be to identify a set of Key Views (up to four) that adequately covers the range of visibility and potential scenic and visual impacts for the Project. Considerations that will be used in selecting specific Key Views include viewing distance, to ensure adequate representation of potential foreground, middleground, and background views of the Project features; viewing direction; and the types of viewer groups (typically including residents, recreational users and motorists) that might experience views of the Project facilities. This task will involve desktop analysis of data developed through the first three study tasks, and supplemental data involving travel routes and potential viewer characteristics. Additionally, Duke Energy will consult with stakeholders (the Recreation Resources Committee) to identify representative and critical Key Views.

6.5 Task 5 – Existing Visual Quality Assessment

This task will involve assessing the existing scenic and visual quality at each Key View identified in the Key Views Selection task. The assessment will be based on consideration of the standard visual elements (form, line, color, texture, and pattern), the apparent naturalness of the landscape as seen from the specific Key View, and the degree of human modification of the landscape.

Scenic and visual quality will be evaluated using concepts from the USFS Scenery Management System (SMS), includes landscape character descriptions and scenic integrity objectives for USFS landscapes that can be used to help assess the compatibility of a proposed project with the surrounding landscape. The evaluation will take into account a wide variety of landscaped characteristics, such as:

- Slope

- Vegetative cover type, pattern, height, and distribution
- Water
- Color, texture, line
- Effects of adjacent scenery
- Cultural modifications

Distance zones are used to describe how viewers see the landscape. The SMS identifies four distance zones:

- immediate foreground (0 to 300 feet);
- foreground (300 feet to 0.5 mile);
- middleground (0.5 mile to 4 miles); and
- background (4 miles to the horizon).

Immediate foreground and foreground views tend to highlight details ranging from individual leaves to individual trees. The middleground "is usually the predominant distance zone at which National Forest landscapes are seen, except for regions of…tall, dense vegetation." In the background, "texture has disappeared and color has flattened, but large patterns of vegetation or rock are still distinguishable" (USDA, 1995).

Scenic classes recognize the idea that all National Forests have "value" as scenery. The classes, which range from 1 (most valuable scenery) to 7 (least valuable scenery) can be used to consistently evaluate the scenic value and relative scenic importance of a particular area. They are used in forest planning to compare values of scenery with other types of resources. The higher the scenic value (i.e., Scenic Classes 1 and 2), the more important it is to maintain.

Scenic Integrity Objectives range from very high to very low and express the desired future aesthetic condition of a forest. Scenic Integrity Objectives descriptions, as defined below, generally express a comparison to existing or preferred conditions (USDA 1995):

- Very High: "landscapes where the valued landscape character 'is' intact with only minute if any deviations."
- High: "landscapes where the valued landscape character 'appears' intact. Deviations may be present but must repeat the form, line, color, texture, and pattern common to the landscape character so completely and at such scale that they are not evident."

- Moderate: "landscapes where the valued landscape character 'appears slightly altered.' Noticeable deviations must remain visually subordinate to the landscape character being viewed."
- Low: "landscapes where the valued landscape character 'appears moderately altered' Deviations begin to dominate the valued landscape character being viewed but they borrow valued attributes such as size, shape, edge effect and pattern of natural openings, vegetative type changes or architectural styles outside the landscape being viewed."
- Very Low: "landscapes where the valued landscape character 'appears heavily altered.' Deviations may strongly dominate the valued landscape character."

6.6 Task 6 – Visual Analysis

This task will involve specific assessment of the expected scenic and visual impact at each Key View, based on changes in landform, change or addition to structures, to determine the potential extent of visual contrast introduced by the proposed Bad Creek II Complex, and the expected viewer response to those changes. Visual simulations of the expected appearance of the expanded Project from a specified set of Key Views will be used to provide the basis for the visual analysis, which includes assessing the effect the expansion of the Project to the landscape would have on the area's landscape character and the landscape's scenic integrity. Contrast will be assessed by considering the differences in form, line, color, texture, scale, and landscape juxtaposition between the existing conditions and conditions after implementation of the Bad Creek II Complex.

These Project elements are then assessed in terms of their level of impact based on setting and viewer characteristics. Considered in terms of the setting, the assessment of impacts is made based on proximity to views—that is, whether the project element is within the foreground, middleground, or background in relation to the viewpoint. The visual impact assessment consists of an overlay of Contrast, Landscape Characteristic, and Views to determine whether the alternative is dominant to the characteristic landscape, subordinate to the characteristic landscape, or somewhere in between. Impact results derived for the individual Key Views will be aggregated and evaluated to provide an overall assessment of the visual impacts of the proposed Project.

6.7 Task 7 – Visual Management Consistency Review

This task will involve review of the consistency of the expanded Project with visual resource protection guidance established in applicable land use plans and regulations, to the extent that such guidance exists. Based on current information regarding land ownership and management, this task will involve review of comprehensive plan direction and zoning requirements adopted by Oconee County and USFS for surrounding areas.

6.8 Task 8 – Mitigation Assessment

This task will involve identification and assessment of potential mitigation measures that would address the scenic and visual impacts of the Bad Creek II Complex identified during the visual impact assessment. Measures that could reduce the contrast created by the Project facilities, and thereby reduce the level of scenic and visual impact, will be identified. Potential measures will be evaluated in terms of their physical feasibility, approximate cost, and effectiveness in reducing contrast and visual impact.

6.9 Task 9 – Conceptual Design of Bad Creek II Complex

This task will assess, to the extent possible, visual resource conditions relative to site layouts, conceptual designs, proposed construction processes, and lighting. Three-dimensional renderings will be produced.

6.10 Analysis and Reporting

Results of this study will be included in the Initial and Updated Study Reports. Duke Energy anticipates that the Visual Resources Study report will include Project information and background, a depiction and description of the study area, methodology, results, and analysis and discussion. The report will also include relevant stakeholder correspondence and/or consultation, as well as literature cited.

7 Schedule and Level of Effort

The preliminary schedule for this study is outlined in Table 7-1. The estimated level of effort for this study is approximately 650 hours. Duke Energy estimates that the Visual Resources Study will cost approximately $100,000 to complete.

Table 7-1. Proposed Visual Resources Study Schedule

Task	Proposed Timeframe for Completion
Study Planning and Existing Data Review	August – December 2022
Tasks 1-2 (Existing Landscape Description and Seen Area Analysis)	January 2023 – March 2023
Tasks 3-7 (Field Investigation, Key Views Selection, Existing Visual Quality Assessment, Visual Analysis, Visual Consistency Review)	April 2023 – November 2023
Task 8 (Mitigation Assessment)	Spring – Summer 2024
Submit Initial Study Report	January 2024
Submit Updated Study Report	January 2025

8 References

Duke Energy Carolinas, LLC (Duke Energy). 2014. License Application Keowee-Toxaway Project FERC No. 2503. Environmental Report (Exhibit E).

_____. 2022. Pre-Application Document, Bad Creek Pumped Storage Project FERC Project No. 2740, Oconee County, South Carolina. February 23, 2022.

U.S. Department of Agriculture (USDA). 1995. Agriculture Handbook 701, Landscape Aesthetics-A Handbook for Scenery Management.

Appendix F

Appendix F – Recreational Resources Study Plan

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APPENDIX F

RECREATIONAL RESOURCES PROPOSED STUDY PLAN

Bad Creek Pumped Storage Project
FERC Project No. 2740

August 2022

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RECREATIONAL RESOURCES PROPOSED STUDY PLAN
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740

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Acronyms and Abbreviations

ADA	American with Disabilities Act
Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
CFD	Computational Fluid Dynamics
Duke Energy or Licensee	Duke Energy Carolinas, LLC
FERC or Commission	Federal Energy Regulatory Commission
KT Project	Keowee-Toxaway Hydroelectric Project
MOA	Memorandum of Agreement
PAD	Pre-Application Document
RMP	Recreation Management Plan
RUN Study	Recreation Use and Needs Study
SCDNR	S.C. Department of Natural Resources
WMA	Wildlife Management Area

1 Study Requests and Formal Comments

The Federal Energy Regulatory Commission's (FERC or the Commission) April 22, 2022 Scoping Document 1 identified the following environmental resource issue to be analyzed in the National Environmental Policy Act document for the Bad Creek Pumped Storage Project (Project) relicensing related to recreational resources. The resource issue addresses the effects of continued Project operations under the Existing License as well as potential construction and operation of a second powerhouse during the New License term (Bad Creek II Power Complex [Bad Creek II Complex]):

- Effects of proposed project construction, operation, and maintenance on recreational use in the project-affected area.

In Section 7.1.6.3 of the Pre-application Document (PAD) (Duke Energy 2022), Duke Energy Carolinas, LLC (Duke Energy or Licensee) proposed to conduct a Recreational Resources Study in support of the proposed the Bad Creek II Complex. No formal study requests related to recreational resources were received during the scoping process; however, formal comments regarding recreational resources were received from Upstate Forever and the Foothills Trail Conservancy. Requests and comments pertinent to the Recreational Resources Study were considered in the development of this proposed study plan and summaries of comments and responses are included in Appendix A. Copies of all comments are provided in Appendix B.

2 Goals and Objectives

The Recreational Resources Study will have four main components: (1) a Recreation Use and Needs (RUN) Study for the 43-mile-long portion of the Foothills Trail managed by Duke Energy; (2) a Conditions Assessment of the 43-mile-long portion of the Foothills Trail managed by Duke Energy; (3) an Existing Recreational Use Characterization of Whitewater River cove; and (4) a Recreational Public Safety Evaluation of Whitewater River cove.

The goals of the RUN Study are to assess current recreation use and identify any future recreation needs along the 43-mile segment of the Foothills Trail and associated access areas that

Duke Energy maintains and referenced in the existing Recreation Plan for the Project.[1] Information collected during the RUN Study could be used to develop an updated Recreation Management Plan (RMP) for the New License term and will support characterization of existing recreational use levels for areas that could be temporarily impacted by the Bad Creek II Complex construction. An updated RMP for the Project will be developed with or following the Final License Application, as needed, to address existing and proposed facilities and arrangements. Duke Energy will consult with interested stakeholders throughout the relicensing process regarding necessary recreational facility maintenance or potential new enhancement measures. The goal of the Conditions Assessment will be to evaluate the current condition of trail surface and corridor included in the 43-mile segment of the Foothills Trail maintained by Duke Energy and identify key areas of future maintenance needs or improvements.

The goal of the Whitewater River cove Existing Recreational Use Characterization is to characterize recreation use in Whitewater River cove and inform Duke Energy of the level of boating use disruption that could occur associated with Bad Creek II Complex construction. The goal of the Recreational Public Safety Evaluation is to evaluate potential public safety risks, specifically those associated with recreation activities at or near Whitewater River cove, that may be created or exacerbated by the Bad Creek II Complex during both the construction and operation phases.

3 Study Area

The study area will include the 43-mile segment of the Foothills Trail (Figure 3-1) and associated access areas (Figure 3-2) on non-Project lands maintained by Duke Energy under the Original License as Project-related facilities. The 43-mile Duke Energy-maintained trail segment begins on the western end of the trail at the Duke Energy / U.S. Forest Service property line on the Whitewater River near the Bad Creek Project and extends east to the Duke Energy / Table Rock State Park property line approximately 1000 feet southwest of the top of Pinnacle Mountain. There are four spur trails that connect with the Duke Energy section of the Foothills

[1] Duke Energy filed a copy of the 1980 document, "A Plan for Development and Management of the Foothills Trail and a Supplement to the Bad Creek Pumped Storage Project #2740 Exhibit R," with the Commission on July 25, 2022, in response to additional information requested by FERC staff.

Trail that are managed and maintained by Duke Energy including Laurel Fork Falls, Hilliard Falls, Lower Whitewater Falls Overlook, and Coon Branch. The 43-mile segment includes four trailheads providing vehicular access including Sassafras Mountain Trail Access, Chimney Top Gap Trail Access, Laurel Valley Trail Access, and Bad Creek Hydro Project Trail Access, and four trailheads providing boat-in only trail access, including Laurel Fork Falls Spur Trail Access, Toxaway River Trail Access, Canebrake Trail Access, and Horsepasture River Trail Access[2]. The study area will also include the entrance road to Musterground Road which is accessed via the Bad Creek Hydro Project Trail Access.

The study will also include an evaluation of recreation use in Whitewater Cove that may be temporarily affected if the Bad Creek II Complex is constructed. Whitewater Cove is identified in Figure 3-3.

[2] The PAD references 10 trailhead access points on the Foothills Trail. For clarity this document categorizes trailheads as areas managed by Duke Energy where users may access the trail from a parking facility or Lake Jocassee and a spur trail as providing access to a specific point off of the main Foothills Trail. This classification is consistent with the 1996 Duke Power Company Lake Management Foothills Trail Maintenance Program Policy and Procedures.

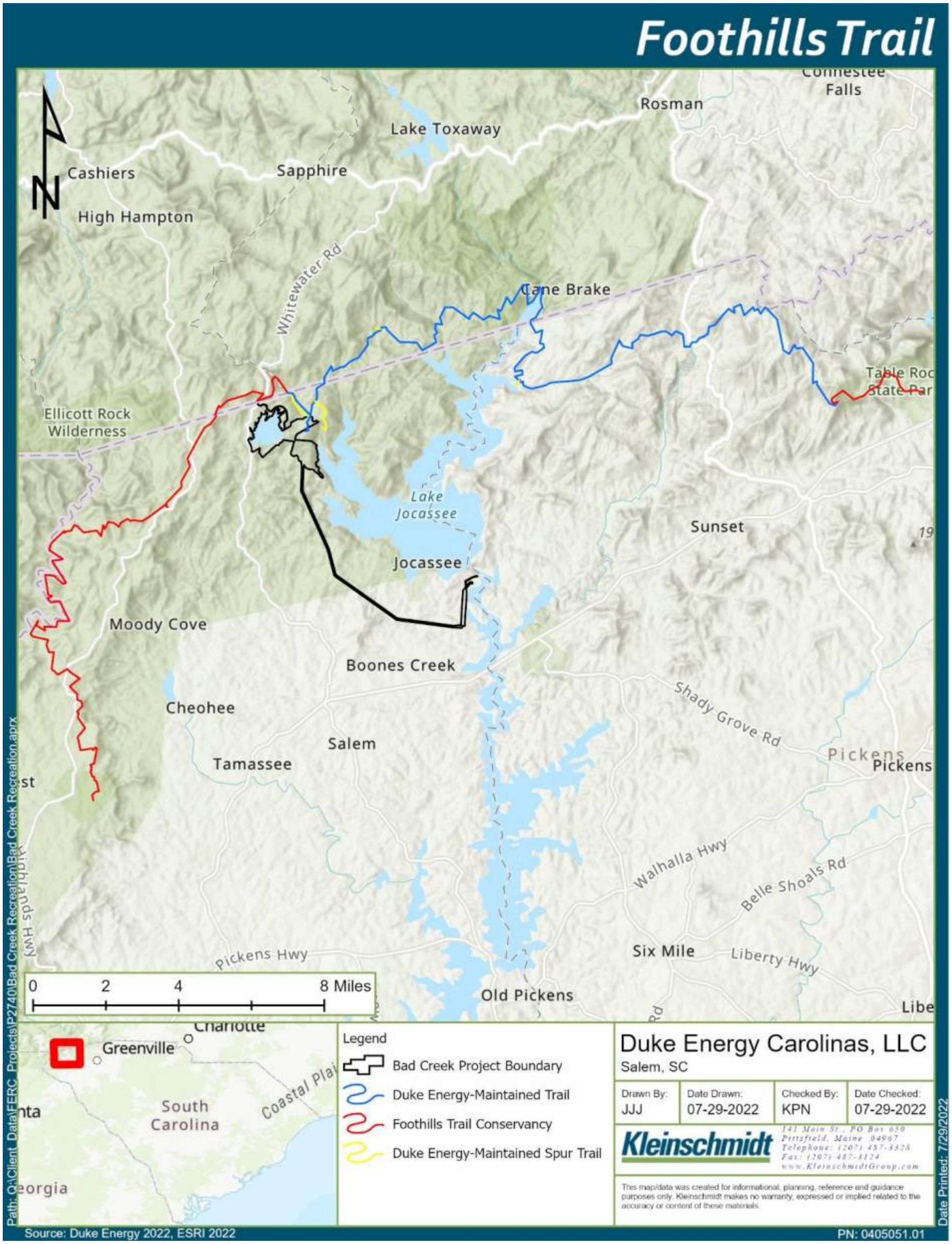

Figure 3-1. Existing FERC Project Boundary and Foothills Trail

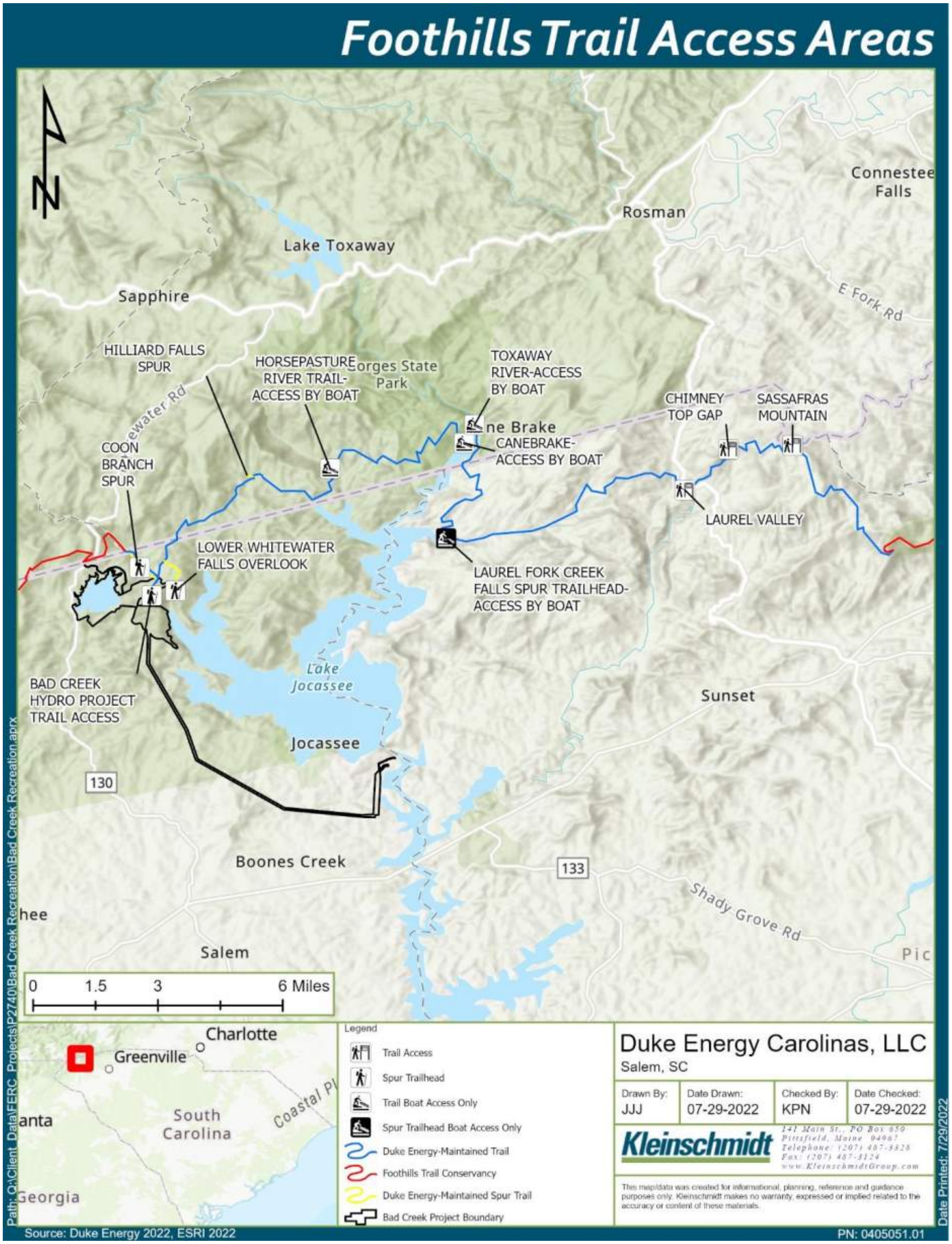

Figure 3-2. Duke Energy-Maintained Foothills Trail Access Areas

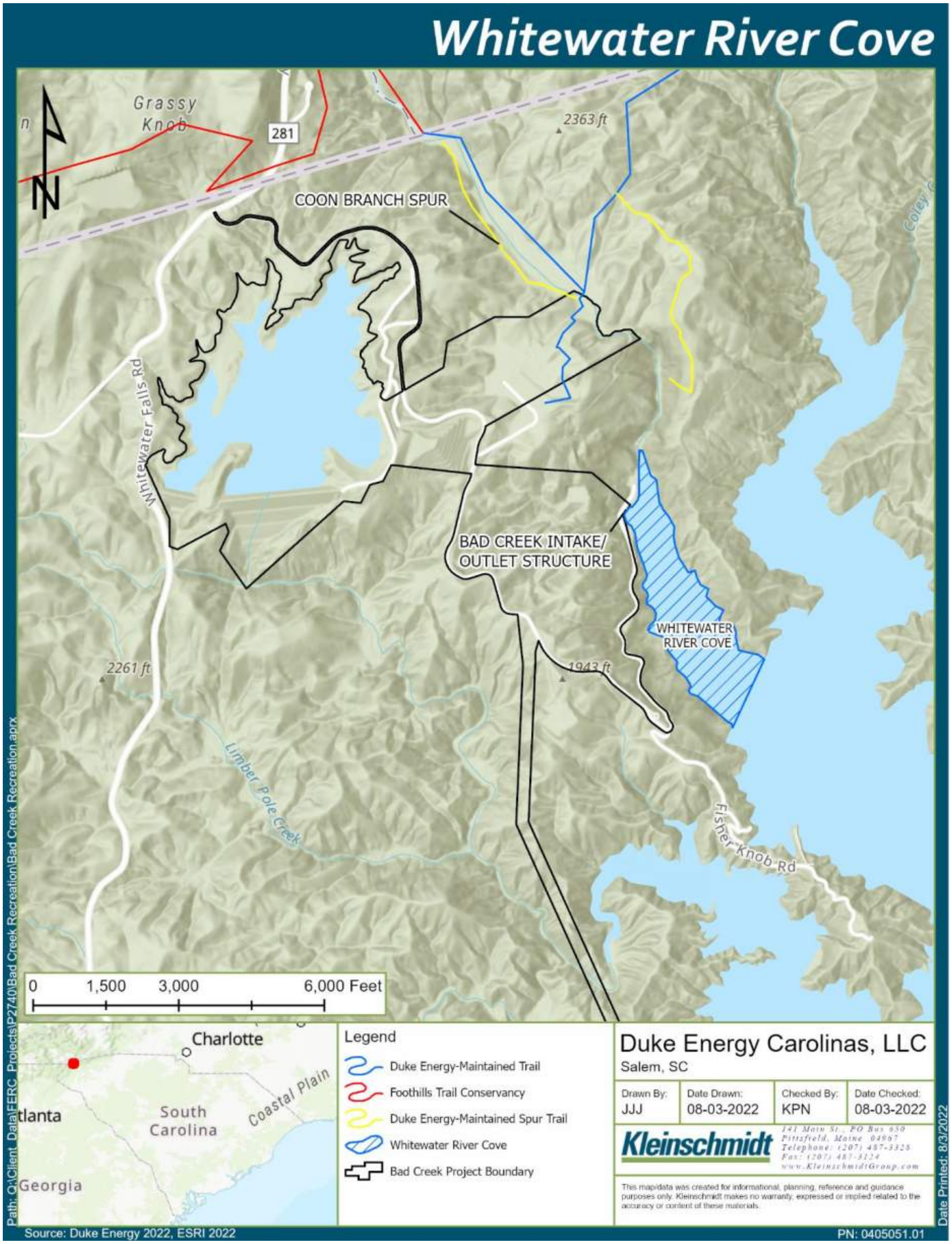

Figure 3-3. Existing FERC Project Boundary and Whitewater River Cove

4 Background and Existing Information

Existing relevant and reasonably available information regarding recreational opportunities in the Project vicinity is presented in Section 6.8 of the PAD (Duke Energy 2022). The Project is located in a remote area in the Blue Ridge Mountains in South Carolina, just south of the North Carolina state border. Lake Jocassee, which serves as the Project's lower reservoir but is not included within the Project Boundary, provides nearby recreational opportunities for visitors. Lake Jocassee is surrounded by a series of steep-sided gorges with minimal residential development along the shoreline; the only developed public access is via Devils Fork State Park. Lake Jocassee provides opportunities for boating (i.e., motor, sailing, canoeing, kayaking, paddle boarding, etc.), fishing, swimming, and scuba diving. The surrounding area also offers visitors opportunities for hiking, camping, hunting, whitewater rafting, and viewing wildlife and waterfalls. The Project is surrounded by public non-Project recreation facilities and opportunities including the Whitewater River, Lake Jocassee, Jocassee Gorges, Devils Fork State Park, Keowee-Toxaway State Park, Toxaway Game Land, and Sumter National Forest, which all provide a wide range of recreational activities.

The Foothills Trail is a 77-mile trail linking Oconee and Table Rock State Parks that was completed in 1981. Portions of the Foothills Trail not managed by Duke Energy are managed by the Foothills Trail Conservancy, a non-profit 501(c)(3) membership organization composed of government agencies, recreational outfitters, and non-governmental organizations. As shown on Figure 3-3, a small segment of the Foothills Trail near the Bad Creek Trail Access, including both Foothills Trail Conservancy and Duke Energy-maintained segments of the trail, is located within the Project Boundary. However, no facilities other than the small segment of trail are located within the existing Project Boundary.

During the original licensing of the Project, Duke Energy agreed to build and maintain the central section of the Foothills Trail as mitigation for the loss of recreation opportunities associated with the Bad Creek Project construction, and in response to stakeholder request for a recreation trail in the area. Duke Energy constructed the approximately 43-mile trail[3] with approximately three miles of spur trails from Pinnacle Mountain (Table Rock State Park) west to the Whitewater River (Nantahala National Forest), following the northern shoreline of Lake Jocassee (Duke Energy 1981). While the 43-mile trail segment is located on non-Project lands[4], it is maintained by Duke Energy and private contractors with coordination and assistance from the Foothills Trails Conservancy. The Foothills Trail Conservancy is responsible for major and minor maintenance for the remaining 34 miles of the Foothills Trail on non-Duke Energy owned property.

The 43-mile trail segment includes four trailheads providing vehicular access, four trailheads providing boat-in only trail access and four spur trails. Horsepasture Trail Access, Toxaway River Trail Access, Canebrake Trail Access, and the Laurel Fork Creek Falls Spur Trail Access provide access to/from Lake Jocassee via trail or boat. These access points do not have developed parking or recreation facilities and there is no vehicular access. Sassafras Mountain Trail Access, Chimney Top Gap Trail Access, Laurel Valley Trail Access, and Bad Creek Hydro Project Trail Access are all trailheads that provide vehicular access to the Foothills Trail.

The shoreline of Lake Jocassee is managed and protected through the Keowee-Toxaway Hydroelectric (KT) Project Shoreline Management Plan (Duke Energy 2014). For the benefit of natural, cultural, and recreation resources, Duke Energy plans to continue operating the KT Project with the existing restrictions on land and shoreline development in the vicinity of the Bad Creek Project Boundary as defined in the KT Project Shoreline Management Plan.

Current construction planning for the potential Bad Creek II Complex anticipates access to the Bad Creek Hydro Project Trail Access to remain open to provide continued access to the western portion of the Foothills Trail as well as the Wildlife Management Area (WMA) lands accessed by Musterground Road. Impacts to recreation due to construction of the Bad Creek II Complex

[3] While the original Exhibit R states 31 miles of trail were to be constructed, and the updated Exhibit R identifies approximately 38 miles, modern documents and the easement for the trail corridor identify 43 miles of main trail and 3 miles of spur trail. The spur trails are managed by Duke Energy.

[4] Duke Energy holds a 200-foot wide (100 feet from center line) lease for the main portion of the trail, 4 spur trails, and Sassafras Mountain, Chimney Top Gap, and Laurel Valley Trail Access areas. This easement is not located within the Bad Creek Project Boundary.

are believed to be limited to water-based recreation in the Whitewater River arm of Lake Jocassee where restrictions will be necessary during the construction. If closures of the Bad Creek Hydro Project Trail Access parking area are necessary during construction, there would be short-term impacts to recreational opportunities for the public on the western portion of the Foothills Trail and Musterground Road WMA lands. Other parking areas do, however, provide Foothills Trail access, and trail access to the Upper and Lower Whitewater Falls would not be impacted by construction.

5 Project Nexus

Most recreation opportunities in the Project vicinity consist of water-based activities on Lake Jocassee and use of the Foothills Trail. Although considered non-Project recreation facilities, the 43-mile segment of the Foothills Trail was developed as a requirement of the Original License for Bad Creek. Currently, Duke Energy also maintains eight access areas and four spur trails along that 43-mile trail segment. Duke Energy proposes that these will continue to be maintained as non-Project facilities for the New License term and therefore, proposes to assess recreation use and needs associated with the 43-mile trail segment, spur trails and access areas. Duke Energy also maintains a Memorandum of Agreement (MOA) with South Carolina Department of Natural Resources (SCDNR) for the maintenance and management of the Musterground Road within the SCDNR-managed WMA near the Project. Duke Energy plans to continue activities established by the MOA with SCDNR, as may be modified in consultation with stakeholders through the relicensing process, in the New License term.

In addition, Duke Energy anticipates development of an updated RMP to address management of existing and proposed recreation facilities associated with the Project. The RUN Study will be used to inform development of the updated RMP. The RUN Study will provide information on existing recreational use around the Project that may be temporarily impacted during construction if the Bad Creek II Complex is pursued.

6 Methods

6.1 Task 1 – Foothills Trail Corridor Recreation Use and Needs Methodology

A variety of data collection methods will be employed to characterize current recreational use and determine future needs at the access areas on the Foothills Trail. A detailed description of each data collection method is included below and summarized in Table 6-1.

Table 6-1. Summary of Data Collection Methods

	Data Collection Methods			
Access Area	**Recreation Site Inventory**	**Traffic Counter**	**Trail Counter**	**User Surveys**
Table Rock State Park[a]			*	
Sassafras Mountain Trail Access	*	*	*	
Chimney Top Gap Trail Access	*		*	
Laurel Valley Trail Access	*	*	*	*
Laurel Fork Creek Falls Spur Trail Access	*		*	
Toxaway River Trail Access[b]	*		*	*
Canebrake Trail Access	*		*	
Horsepasture River Trail Access	*		*	
Lower Whitewater Falls Overlook	*		*	
Bad Creek Hydro Project Trail Access[c]	*	*	*	*
Coon Branch Spur Trail			*	
Musterground Road[d]		*		

[a] This site is not maintained by Duke Energy.
[b] If water levels on Lake Jocassee do not allow for boat-in access to the Toxaway River Trail Access, surveys will be conducted at an alternative boat-in access point as identified in consultation with the Recreational Resource Committee.
[c] Two traffic counters will be installed near Bad Creek Hydro Project Trail Access, including one south of the parking area and one north of the parking area.
[d] This access road is managed via the Jocassee Gorges Road Management MOA between SCDNR and Duke Energy.

6.1.1 Recreation Site Inventory

A recreation site inventory form (Attachment 1) will be completed for each Duke Energy-managed access area along the Foothills Trail. The inventory will document the type, number, and size of facilities and amenities (restrooms, parking areas, boat ramps, picnic shelters and tables, etc.) located at each access area. The general condition of all facilities will be noted during the inventory and any facilities that qualify as American with Disabilities Act (ADA) or barrier-free will be identified as such.

In addition, detailed maps of the Duke Energy-maintained portion of the Foothills Trail will be developed that identify parcel boundaries, current property owner(s), access locations, spur trails, and facilities/amenities.

6.1.2 Traffic and Trail Counts

Traffic and trail counters will be installed at the access areas as noted in Table 6-1. For all areas except Musterground Road, data will be collected from installation in March through November 2023. A traffic counter will be installed at the gate to Musterground Road only when public access is allowed, or from September 15, 2022 - January 15, 2023, and again March 20 – May 10, 2023. Data will be downloaded approximately every two weeks to ensure the counters are working properly and no vandalism has occurred.

Traffic and trail counter data will be used to determine recreation use at each access area. At access areas where traffic counters are installed, traffic counter data will be used to provide total daily and average vehicles that entered the access area by month and by day type. At access areas where trail counters are installed, trail counter data will be used to provide total daily and average visitors that used the access area by month and by day category type.

Approximate locations for traffic and trail counters at the access areas included in the study are listed in Table 6-2.

Table 6-2. Approximate Locations for Traffic and Trail Counters by Access Area

Access Area	Traffic Counter Locations	Trail Counter Locations
Table Rock State Park		35° 1'56.00"N, 82°42'2.19"W
Sassafras Mountain Trail Access	35° 3'52.12"N, 82°46'32.93"W	35° 3'51.62"N, 82°46'36.79"W
Chimneytop Gap Trail Access		35° 3'42.25"N, 82°47'52.87"W

Access Area	Traffic Counter Locations	Trail Counter Locations
Laurel Valley Trail Access	35° 2'56.97"N, 82°48'50.11"W	35° 3'2.85"N, 82°48'44.00"W
Laurel Fork Creek Falls Spur Trail Access		35° 1'58.15"N, 82°53'48.90"W
Toxaway River Trail Access		35° 4'18.26"N, 82°53'14.12"W
Canebrake Trail Access		35° 3'56.79"N, 82°53'25.45"W
Horsepasture River Trail Access		35° 3'22.81"N, 82°56'13.90"W
Lower Whitewater Falls Overlook		35° 0'48.11"N, 82°59'22.12"W
Bad Creek Hydro Project Trail Access	35° 0'43.73"N, 83° 0'0.59"W	
	35° 0'40.31"N, 83° 0'0.58"W	
Coon Branch Spur Trail		35° 1'6.96"N, 82°59'51.36"W
Musterground Road	35° 0' 41.9832" N, 82° 59' 58.2" W	

6.1.3 User Surveys

User surveys will be collected at three access areas— Laurel Valley Trail Access, Toxaway River Trail Access, and Bad Creek Hydro Project Trail Access. Surveys will be collected on a statistically determined mix of weekdays, weekends, and holiday weekends. Survey clerks will collect surveys on 30 days between March and November at each access area during 4-hour shifts (Table 6-3). Surveys will include questions regarding user demographics, group size, length of stay, type of recreation activities participated in, and perceptions of crowdedness and condition of recreation facilities. A sample user survey form is included in Attachment 2. The data collected will be used to identify recreation use patterns and use estimates at the access areas. The data on user perceptions of crowdedness will also be used to determine future expansion needs at the access areas.

Table 6-3. Survey Schedule by Month

Month	Weekday	Weekend Day	Holiday
March	1	1	0
April	1	1	0
May	1	1	1
June	2	2	0

Month	Weekday	Weekend Day	Holiday
July	2	2	1
August	2	2	0
September	1	2	1
October	2	2	0
November	1	1	0
Total	**13**	**14**	**3**

6.1.4 Parking Demand Analysis

Traffic counters will also be used to conduct a parking demand analysis at access areas with parking lots. To determine parking demand using traffic counter data, the average number of vehicles that utilize the access area on a specific day type will be divided by the estimated turnover. Since traffic counter data only accounts for vehicles entering an access area, length of stay must be considered. Length of stay is the average amount of time (hours) a visitor spends at an access area per recreation trip. Length of stay will be estimated using information collected during surveys. Length of stay is ultimately used to determine turnover at an access area. Turnover is how often a vehicle leaves an access area and is replaced over a 24-hour period. Turnover is applied to the average total vehicles, which is then compared to the total parking spaces available at the access area.

The formula for determining average percent capacity is shown below.

$$\left(\frac{\frac{Total\ Average\ Vehicles}{Turnover}}{Available\ Parking\ Spaces}\right) * 100$$

6.1.5 Future Recreation Use Analysis

Future annual visitation to the 43-mile Foothills Trail segment will be estimated based on review of existing population forecasts for Oconee and Pickens counties, SC and Jackson and Transylvania counties, NC. The population forecasts will be applied to the annual use estimates for the Project to determine a future recreation use estimate. Duke Energy will also review South

Carolina and North Carolina State Comprehensive Outdoor Recreation Plans, Oconee and Pickens County Master Plans, and the South Carolina and North Carolina State Park Master Plans during the future recreation use analysis. This information will be considered when determining future recreation needs at the Project.

6.1.6 Recreation Needs Assessment

The need for recreation and site development or modifications of existing recreation resources will be assessed based on the inventory, condition assessment results, parking demand assessment, user survey results and future recreation use estimates. The needs assessment will focus on the existing condition and user opinions of access areas, the presence of barrier free or ADA facilities at access areas, and the ability of access areas to meet current and anticipated future recreation demand. The need for new access areas, facilities, and/or amenities, and improvements to existing access areas will be determined through assessment of the information collected and consultation with stakeholders.

6.2 Task 2 – Foothills Trail Corridor Conditions Assessment

An assessment of the Foothills Trail corridor will be conducted between October 2022- October 2023 by a professional trail builder not currently providing maintenance on any portion of the Foothills Trail maintained by Duke Energy. All 43 miles of the main trail corridor as well as spur trails will be assessed for trail tread, shoulder, backslope, constructed structures (not including engineered bridges) and corridor condition. A final report will summarize conditions and identify and prioritize immediate as well as deferred maintenance needs.

An inspection of engineered bridges on the Foothills Trail is performed every five years by a licensed Professional Engineer in accordance with the Duke Energy Foothills Trail Maintenance Program[5].

[5] The latest engineering inspection was conducted in 2021 and a detailed report of the engineer's findings will be included in the 2024 Recreational Resources Study Report.

6.3 Task 3 – Whitewater River Cove Existing Recreational Use Evaluation

The Project's existing lower reservoir inlet/outlet structure is located on the western shore of the Whitewater River arm of Lake Jocassee. If Duke Energy constructs the Bad Creek II Complex, construction of the new inlet/outlet structure will occur in this general area, requiring the Whitewater River cove to be substantively closed to public boating use for an approximately five-year period. Duke Energy will develop more specific schedules and plans for closures as construction plans for the Bad Creek II Complex advance and in consultation with stakeholders. To establish a baseline of recreational use in Whitewater River cove, Duke Energy proposes to conduct a recreational use evaluation within the cove. This evaluation will inform Duke Energy of the level of boating use disruption that could occur associated with the construction of the Bad Creek II Complex.

Duke Energy will deploy a drone over the Whitewater River cove to capture images of recreation use within the cove. This imagery will be used to create a comprehensive overview of boating use in the Whitewater River cove. Drone flights will occur on 10 individual days scheduled between Memorial Day weekend and Labor Day weekend to evaluate use. Drone flights will be conducted on a mix of weekdays, weekends, and holidays and imagery will be collected multiple times per day (such as morning, afternoon, and early evening). Boats within the Whitewater River cove will be categorized as either a motorboat, non-motorized boat (such as canoe or kayak), personal watercraft (such as Jet-Ski), or paddleboard. Each category of boat will be tallied, and totals will be reported by day type.

6.4 Task 4 – Whitewater River Cove Recreational Public Safety Evaluation

The proposed Bad Creek II Complex would have an inlet/outlet structure on the western shore of the Whitewater River cove of Lake Jocassee upstream from the existing Project inlet/outlet structure. For the protection of the public, recreational activities would be prohibited in the Whitewater River cove through much of the expanded Project construction. Operation of the Bad Creek II Complex, alone or in combination with operation of the existing Project powerhouse, has the potential to impact surface water velocities in the Whitewater River cove of Lake

Jocassee, particularly during periods of generation. A three-dimensional Computational Fluid Dynamics (CFD) model has been developed as a part of the Water Resources Study for Duke Energy to support the evaluation of the second inlet/outlet structure's effects within the Whitewater River cove. This study is applicable for the potential for increased bank erosion on the eastern shoreline of the cove as well as effects on recreation (i.e., boaters) near the discharge area. Discussions of increased water velocities in the Whitewater River arm are included in Appendix C (Water Resources Study).

A Recreational Public Safety Evaluation will be carried out in consultation with agencies and other Project stakeholders to evaluate potential public safety risks that may be created or exacerbated by the Bad Creek II Complex during both the construction and operation phases. This evaluation will include but not be limited to identification of areas where access will be temporarily or permanently restricted to the public as well as a boater safety for the Whitewater River arm of Lake Jocassee. Duke Energy proposes a desktop study to evaluate impacts of operation of the expanded Project (i.e., two powerhouses) on water velocities released to the Whitewater River arm of Lake Jocassee through development and use of the CFD model. The updated CFD model will be available to analyze a range of potential operating scenarios to evaluate impacts to water-based recreation in the Whitewater River arm of Lake Jocassee. Information gained from this study will be used to update the Bad Creek FERC Public Safety Plan as necessary.

6.5 Analysis and Reporting

Results of this study will be summarized in the Initial and Updated Study Reports. Duke Energy anticipates that the Recreational Resources Study report will include Project information and background, a depiction and description of the study area, methodology, results, and analysis and discussion. The report will also include relevant stakeholder correspondence and/or consultation, as well as literature cited.

7 Schedule and Level of Effort

The preliminary schedule for this study is outlined in Table 7-1. Cost estimates for the Recreational Resources Study are shown in Table 7-2.

Table 7-1. Proposed Recreational Resources Study Schedule

Task	Proposed Timeframe for Completion
Study Planning and Existing Data Review	August – December 2022
Study Tasks	January 2023 – November 2023
Distribute Draft Study Report with the ISR	January 2024

Table 7-2. Recreational Resources Study Cost Estimates

Study Component	Estimated Cost
Foothills Trail Corridor Recreation Use and Needs Study	$450,000
Foothills Trail Corridor Conditions Assessment	$125,000
Whitewater River Cove Existing Recreational Use Evaluation	$30,000
Whitewater River Cove Recreational Public Safety Evaluation	$50,000

8 References

Duke Energy Carolinas, LLC. 2014. Shoreline Management Plan. Keowee-Toxaway Project FERC Project No. 2503. September 1, 2014.

_______. 2022. Pre-Application Document, Bad Creek Pumped Storage Project FERC Project No. 2740, Oconee County, South Carolina. February 23, 2022.

Attachment 1

Attachment 1 – Recreation Site Inventory Form

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DUKE ENERGY CAROLINAS, LLC

RECREATION STUDY

BAD CREEK PUMPED STORAGE PROJECT

(FERC NO. 2740)

Recreation Site Inventory Form

Inspector: ____

Date: ____

Site Name: ____

Site Coordinates: ____

Site Address: ____

City: _________________________________ **State:** _____________ **Zip Code:** _______________

Road Access:

	Paved	Unpaved/Gravel
Road Access		

Parking (# of spaces):

	Paved	Unpaved/Gravel
Vehicle Spaces		
Vehicle with Trailer Spaces		
ADA/Barrier Free Spaces		

Restrooms:

	Flush Toilets	Vault Toilets	Portable Toilets	ADA/Barrier Free
Women				
Men				
Unisex				

Shoreline Access Condition:

	Beach Areas	Ease of Accessibility (consider slope and substrate)
Condition (Scale of 1-poor to 5-excellent)		
Notes		

Camping:

	# of Sites	ADA/Barrier Free	Fire Rings
Tent Sites			
Primitive Sites			

Operations (circle the one that applies):

Manning	Manned	Unmanned
Availability	Seasonal	Year Round
Fees	Yes	No

Amenities:

	Yes	No	Additional Information/ADA/Barrier Free
Portage			
Reservoir Fishing			
Swim Area			
Trails (other than the Foothills Trail)			
Active Recreation Area			
Picnic Area			
Overlook/Vista			
Interpretive Display (Signage/Kiosk/Billboard)			
Hunting Area			
Trash Cans			
Other			

Attachment 2

Attachment 2 – Sample Survey Form

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Duke Energy Bad Creek Pumped Storage Project Recreation Use Survey	Duke Energy is conducting this survey to learn about recreational use of the Foothills Trail, user satisfaction with existing recreation facilities, and whether facility improvements may be needed. Please take a few minutes to answer some questions about your visit today. Thank you for your participation.

Location:	Date:	Time:
Interviewer:		
1. What is your county and state of residence?	County:	State:

2. How many people are in your vehicle today? ________ people

3. What is your age?	___18-24	___25-34	___35-44	___45-54	___55+

4. If you came with others, what are their age groups? (check all that apply)

____Children (Infants-12)	____Youth (13-17)	____Adults (18-55)	____Senior Adults (over 55)

5. How did you hear about the area?

_____Friend/Relative	_____Social Media	______________________Other

6. How many times (including today), have you visited the Trail in the last 30 days? _________

7. What is the primary reason for your visit today? (check all that apply)

___Boating	___Picnicking	___Hiking	___Canoeing/kayaking
___Camping	___Swimming	___Biking	___Wildlife viewing
___Shoreline relaxation	___Hunting	___Other:	

8. If you came to hike today, how would you rate your hiking experience?

___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)

9. Please rate the quality of the existing facilities at this access area. (choose one for each)

Trails:	___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)
Bridges:	___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)
Restrooms:	___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)
Parking:	___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)
Picnic Areas:	___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)
Campsites:	___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)
Fishing Areas:	___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)
Crowdedness:	___Very Low (5)	___Low (4)	___Mid (3)	___High (2)	___Very High (1)
Cleanliness:	___Very Good (5)	___Good (4)	___Fair (3)	___Poor (2)	___Very Poor (1)

10. List any specific improvements you would like to see for the Foothills Trail, and any other comments or suggestions.

Appendix G

Appendix G – Cultural Resources Study Plan

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APPENDIX G

CULTURAL RESOURCES PROPOSED STUDY PLAN

Bad Creek Pumped Storage Project

FERC Project No. 2740

August 2022

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CULTURAL RESOURCES PROPOSED STUDY PLAN
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
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ATTACHMENTS

Section	Title	Page No.

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

APE	Area of Potential Effects
Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
Duke Energy or Licensee	Duke Energy Carolinas, LLC
FERC or Commission	Federal Energy Regulatory Commission
KT Project	Keowee-Toxaway Hydroelectric Project
NRHP	National Register of Historic Places
PAD	Pre-Application Document
SHPO	State Historic Preservation Office

1 Study Requests and Formal Comments

The Federal Energy Regulatory Commission's (FERC or the Commission) April 22, 2022 Scoping Document 1 identified the following environmental resource issue to be analyzed in the National Environmental Policy Act document for the Bad Creek Pumped Storage Project (Project) relicensing related to cultural resources. This resource issue addresses the effects of continued Project operations under the Existing License as well as potential construction and operation of a second powerhouse during the New License term (Bad Creek II Power Complex [Bad Creek II Complex]):

- Effects of Project construction, operation, and maintenance activities on historic and archaeological resources, traditional cultural properties, and access to exercise traditional practices and treaty rights.

In Section 7.1.8.3 of the Pre-Application Document (PAD), Duke Energy proposed to conduct a Cultural Resources Study in support of the proposed Bad Creek II Complex, including an archaeological study and an architectural survey of structures more than 40 years old. No formal study requests were received related to cultural resources during the scoping process; however, Duke Energy Carolinas, LLC (Duke Energy) will continue consultation with Indian Tribes and other stakeholders during the preparation of the Cultural Resources Study Plan. An Environmental Justice study was requested by the FERC and it will be developed in a separate study (Appendix H of the Proposed Study Plan).

2 Goals and Objectives

While there are no anticipated additional adverse effects to cultural resources due to the continued operation of the Project, potential adverse effects resulting from the potential addition of the Bad Creek II Complex need to be evaluated. These effects include the possibility of construction activities in previously undisturbed lands, and in areas to be used for rock and soil spoil disposal, access roads, and staging areas. Duke Energy will conduct a Cultural Resources Study for this relicensing to include and address the following:

- Duke Energy plans to coordinate with the State Historic Preservation Office (SHPO), Indian Tribes, and other stakeholders regarding potential issues with respect to cultural resources that may be located within the area of influence of the Bad Creek II Complex construction.

- Separate from the Bad Creek relicensing process, Duke Energy has completed an Architectural Survey and National Register Evaluation for the Jocassee Pumped Storage Hydro Station (Dorn et al. 2022). Lake Jocassee (SHPO Site No. 0156) and Lake Keowee (SHPO Site No. 0155), however, were not included in this study and may need to be evaluated for National Register eligibility.

3 Study Area

The study area for the Cultural Resources Study is the Area of Potential Effects (APE) for Project relicensing (Figure 3-1). Duke Energy intends to define the APE in consultation with the SHPO and Indian Tribes as a component of this Cultural Resources Study.

Duke Energy tentatively proposes the following APE which may be refined through consultation:

> "The APE includes all lands within the Project boundary. The APE also includes any lands outside the Project boundary where cultural resources may be affected by Project-related activities that are conducted in accordance with the FERC license."

The Commission has not yet defined an APE for the Bad Creek II Complex. The Project Boundary encompasses all lands necessary for Project purposes. All Project-related operations, potential enhancement measures, and routine maintenance activities associated with the implementing a New License issued by the FERC are expected to take place within the Project Boundary.

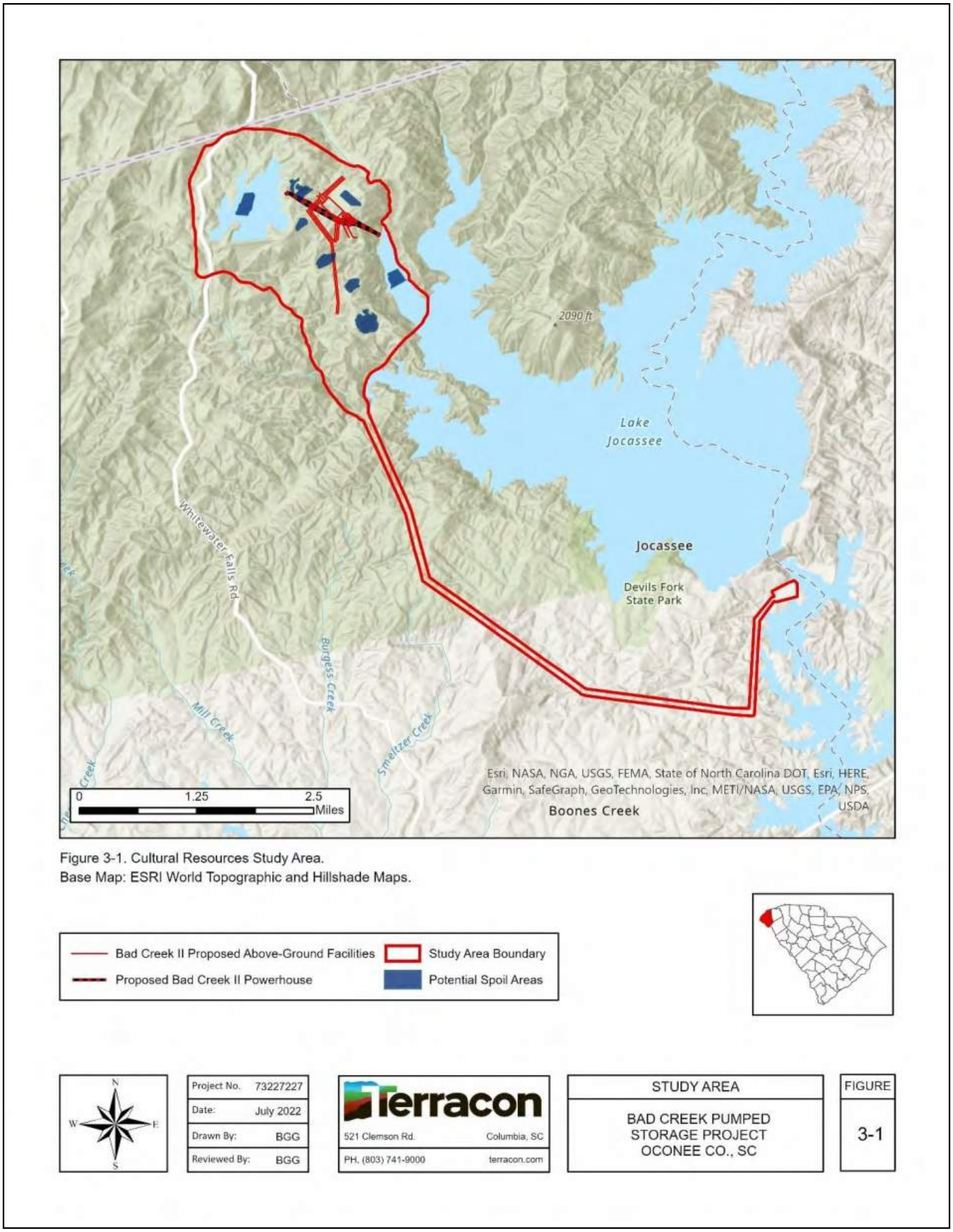

Figure 3-1. Cultural Resources Study Area

4 Background and Existing Information

Existing relevant and reasonably available information regarding cultural resources is provided in Section 6.10.2 of the PAD. The cultural resources information related to the Project was obtained from the ArchSite, an online cultural resources database maintained by the South Carolina Department of Archives and History and the South Carolina Institute of Archaeology and Anthropology.

The portions of the existing Project's footprint that underwent extensive land modification (i.e., removal of trees/stumps, soil, and/or bedrock to a depth of 1+ feet) in the past, or those that are currently under Lake Jocassee (lower reservoir), are unlikely to contain any significant archaeological resources or historical architectural resources other than the elements of the Project greater than 50 years of age. Portions of the Project were subject to previous cultural resource surveys (Benson 2018; Brockington 1978; Gardner et al. 1988; Grunden 2007; Stallings 2012). Figure 6.10-1 in the PAD displays the locations of previous cultural resources surveys near the Project.

The Cultural Resources Study area contains 12 known archaeological sites that are within or immediately adjacent to the Project (i.e., within 50 meters). These resources are depicted in Figure 4-1 and are summarized in Table 4-1. Three of the sites, 38OC249, 38OC250, and 38OC251, are potentially eligible for inclusion in the National Register of Historic Places (NRHP) and require additional evaluation. Site 38OC249 is within the proposed impact area for the Bad Creek II Complex, site 38OC250 is within the northern portion of the study area, and 38OC251 lies just outside of the study area (Figure 4-1). There are also three historic resources, Lake Keowee (SHPO Site No. 0155), Lake Jocassee (SHPO Site No. 0156), and the Jocassee Hydroelectric Station (SHPO Site No. 0198) that are within the Project APE. Jocassee Hydroelectric Station was determined to be eligible for the NRHP (Dorn et al. 2022), whereas Lakes Keowee and Jocassee developments were recommended for additional evaluation once they reached 50 years of age in 2022 (Stallings 2012).

Table 4-1. Previously Recorded Cultural Resources within and adjacent to the Project

Resource ID	Description	NRHP Eligibility	Source
38OC101	Pre-contact isolated find	Not Eligible	Brockington 1978
38OC102	Pre-contact lithic scatter	Not Eligible	Brockington 1978; Gardner et al. 1988
38OC103	Pre-contact lithic scatter	Not Eligible	Brockington 1978
38OC242	Middle Archaic lithic scatter	Not Eligible	Gardner et al. 1988
38OC243	Pre-contact lithic scatter	Not Eligible	Gardner et al. 1988
38OC244	Pre-contact lithic scatter	Not Eligible	Gardner et al. 1988
38OC246	Pre-contact lithic scatter	Not Eligible	Gardner et al. 1988
38OC247	Pre-contact lithic scatter	Not Eligible	Gardner et al. 1988
38OC248	Pre-contact lithic scatter	Not Eligible	Gardner et al. 1988
38OC249	Late Archaic through Mississippian rockshelters	Potentially Eligible	Gardner et al. 1988
38OC250	Mississippian short-term encampment	Potentially Eligible	Gardner et al. 1988
38OC251	Middle Archaic through Woodland/ Mississippian lithic and ceramic scatter; 19^{th}/20^{th} century artifact scatter	Potentially Eligible[1]	Gardner et al. 1988
0155	Lake Keowee	Not Evaluated	Stallings 2012
0156	Lake Jocassee	Not Evaluated	Stallings 2012
0198	Jocassee Hydroelectric Station	Eligible	Dorn et al. 2022

1. The historic component of site 38OC251 was recommended as being ineligible for the NRHP.

CUI // PRIVILEGED INFORMATION

Figure 4-1. Cultural Resources within and Adjacent to the Study Area [CUI // Privileged Information Filed Separately]

Construction of the proposed powerhouse complex adjacent to the existing powerhouse will result in ground-disturbing activities. As currently planned, these activities could impact archeological site 38OC249, which requires additional evaluation. Currently, there are no anticipated impacts to sites 38OC250 and 38OC251. Should redesign of the construction of the proposed powerhouse or other Project-related activities include these sites, Phase II evaluative testing will be conducted prior to any land disturbance within 50 feet of the sites. If any of these sites is determined to be ineligible for the NRHP, they will require no further management consideration and land disturbing activities may occur within the site. Should any of these sites be determined eligible for the NRHP, planned land disturbing activities should be redesigned to avoid the site. If the site cannot be avoided through redesign, it will result in an adverse effect and appropriate mitigation measures should be implemented to resolve the adverse effects following the procedures outlined in 36 CFR § 800.6.

Construction of the proposed powerhouse and the facilities necessary for its operation will include peripheral connections with Lakes Keowee and Jocassee (SHPO Site Nos. 0155 and 0156) and the Jocassee Hydroelectric Station (SHPO Site No. 0198). The addition of the Bad Creek II Complex will not result in operational changes to the Keowee-Toxaway Hydroelectric Project (KT Project) and is not expected to alter any aspects of the KT Project that could compromise its NRHP eligibility.

Identification of Project impacts and determinations of appropriate mitigation measures to be applied will be developed with input from the SHPO, FERC, federally recognized Indian Tribes, and additional interested parties.

5 Project Nexus

Presently, there is no evidence that archaeological or historic resources are currently being affected by the Project’s operations. However, the proposed Bad Creek II Complex has the potential to affect historic properties that may be eligible for inclusion in the NRHP.

6 Methods

6.1 Task 1 - APE Determination

Duke Energy has tentatively proposed an APE as defined in Section 6.10.3 of the PAD. Pursuant to implementing regulations of Section 106 at 36 CFR § 800.4(a), Duke Energy will consult with the SHPO and Indian Tribes, and other parties, as appropriate, to determine and document the APE for the Project as defined in 36 CFR § 800.16(d).

6.2 Task 2 - Cultural Resources Survey of the APE

Duke Energy expects the SHPO will request a cultural resources survey of portions of the APE potentially impacted by the Project. A cultural resources survey would likely include shovel testing of all non-steep (less than 15 percent slopes) landforms, a pedestrian survey and/or drone survey of steeply sloped and rocky areas to look for rockshelters and/or petroglyphs, as well as an architectural survey of any structures on or near the Project that are 40+ years old. Traditional Cultural Properties will also be identified in consultation with Indian Tribes. A desktop geomorphological assessment indicates there are six areas within the anticipated APE having the potential to contain archaeological resources in buried contexts (Attachment A). One of these areas contains site 38OC250. If any of these six areas are to be impacted, then an archaeological survey, including potential deep testing, may be necessary.

7 Analysis and Reporting

Results of this study will be included in the Initial and Updated study reports. Duke Energy anticipates the Cultural Resources Study report will include Project information and background, a depiction and description of the study area, methodology, results, analysis, and discussion. The report will also include relevant stakeholder correspondence and/or consultation, as well as literature cited.

8 Schedule and Level of Effort

The preliminary schedule for this study is outlined in Table 8-1. The estimated level of effort for this study is approximately 880 hours. Duke Energy estimates the Cultural Resources Study will cost approximately $125,000 to complete, which includes Phase II evaluative testing of archaeological site 38OC249.

Table 8-1. Proposed Cultural Resources Study Schedule

Task	Proposed Timeframe for Completion
Consultation with SHPO and other stakeholders	July – November 2022
Fieldwork, Analysis, and Reporting	Spring 2023 – Fall 2023
Distribute Draft Study Report with the ISR	January 2024

9 References

Benson, R. 2018. Cultural Resources Survey of the FY2018 Andrew Pickens District Southern Pine Beetle Timber Salvage Project Andrew Pickens Ranger District Sumter National Forest. Report prepared for the Francis Marion and Sumter National Forests, U.S. Forest Service, by Southeastern Archaeological Services, Athens, Georgia.

Brockington, P. 1978. An Archaeological Survey of Duke Power's Oconee – Bad Creek 500 kV and Jocassee 100 kV Transmission Lines, Oconee County, South Carolina. Report prepared for Duke Power, Charlotte, North Carolina, by the South Carolina Institute of Archaeology and Anthropology, Columbia, South Carolina.

Dorn, M., B. Harvey, and W. Green. 2022. Architectural Survey and National Register Evaluation of the Jocassee Pumped Storage Hydro Station and Keowee-Toxaway Hydroelectric Project, Oconee and Pickens Counties, South Carolina. Report prepared for Duke Energy, Charlotte, North Carolina, by Terracon Consultants, Inc., Columbia, South Carolina.

Gardner, J., B. Southerlin, and R. Mitchell. 1988. Archaeological Survey of the Jocassee to Bad Creek to Coley Creek Transmission Corridors, Oconee County, South Carolina. Report prepared for Duke Power Company, Charlotte, North Carolina, by Brockington and Associates, Atlanta, Georgia.

Grunden, R. 2007. A Cultural Resources Survey of the Lake Jocassee Shoreline, Oconee and Pickens Counties, South Carolina. Report prepared for Duke Energy, Charlotte, North Carolina, by TRC, Inc., Columbia, South Carolina.

Stallings, P. 2007. NRHP Evaluation of the Keowee-Toxaway Hydroelectric Development, Oconee and Pickens Counties, South Carolina. Report prepared for Duke Energy, Charlotte, North Carolina, by Brockington and Associates, Inc., Atlanta, Georgia.

Attachment 1

Attachment 1 – Desktop Geomorphological Assessment

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Seramur & Associates, PC
165 Knoll Drive
Boone, NC 28607

July 13, 2022

Bill Green, M.A., RPA
Principal
Terracon
521 Clemson Road
Columbia, SC 29229

Re: Geomorphology Investigation of the Bad Creek Pumped Storage Project, Oconee County, SC

Dear Mr. Green:

Seramur & Associates, PC has completed a desktop geomorphology investigation of the Bad Creek Pumped Storage Project in Oconee County, SC (Figure 1). The goal of this investigation is to determine if soils and alluvium that could contain buried cultural deposits are present within the study area. The project area is located in the Blue Ridge physiographic province of northwestern South Carolina. Bedrock is mapped as schist of the Tallulah Falls Formation and Toxaway Gneiss (Schaeffer 2016). The desktop survey included reviewing soil survey maps, digital elevation models, and topographic maps.

Figure 1. Topographic map of the study area showing the location of the six areas containing alluvial landforms.

Archaeology sites in the study area could be buried by either alluvial sedimentation or deposition of colluvium. Burial by colluvial processes or landslides would destroy the cultural integrity of the sites and therefore areas with colluvial deposits were not considered. Elevated landforms with well-drained soils

Phone: 828.264.0289 seramur@icloud.com Cell: 828-773-0499

would be favorable for occupation. Topographic maps and LiDAR digital elevation models were used to identify alluvial landforms. The USDA Soil Survey maps indicated the type of soils present in each area of interest (Table 1).

Six areas were identified that had the potential to contain alluvial landforms (Figure 1). Five soil units are mapped in these six areas (Table 1). The geomorphic setting, lithology, parent material and depth to groundwater for each soil unit is listed in Table 1.

Map Unit	AsF – Ashe sandy loam	HaE – Halewood fine sandy loam
Landform	Convex mountain slopes	Convex mountain slopes
Lithology	Sandy loam over gravelly sandy loam and unweathered bedrock	Fine sandy loam and sandy clay loam over sandy loam and loamy sand
Depth to Groundwater	More than 80 inches	More than 80 inches
Parent Material	Loamy residuum weathered from metamorphic rock	Loamy residuum weathered from metamorphic rock
Alluvial Landform Area	AL-6	AL-3
Map Unit	HaF – Halewood fine sandy loam	HcE – Hayesville and Cecil fine sandy loams
Landform	Convex mountain slopes	Convex interfluves
Lithology	Fine sandy loam and sandy clay loam over sandy loam and loamy sand	Fine sandy loam over clay loam and loam
Depth to Groundwater	More than 80 inches	More than 80 inches
Parent Material	Loamy residuum weathered from metamorphic rock	Clayey residuum weathered from granite and gneiss
Alluvial Landform Area	AL-1 through AL-6	AL-6
Map Unit	Mv – Riverview-Chewacla complex	
Landform	Floodplains	
Lithology	Loam over sandy clay loam and sandy loam	
Depth to Groundwater	About 39 to 60 inches	
Parent Material	Loamy alluvium derived from igneous and metamorphic rock	
Alluvial Landform Area	AL-4 and AL-6	

Table 1. Characteristics of the five soil units mapped in the alluvial landform areas.

Alluvial Landform Area 1

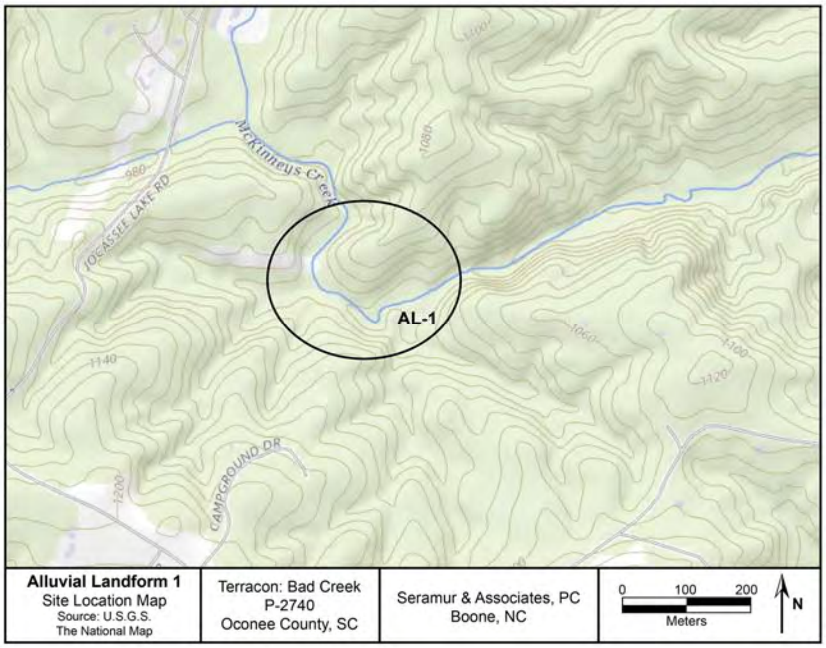

Figure 2. Topographic map of transmission line crossing of McKinney's Creek.

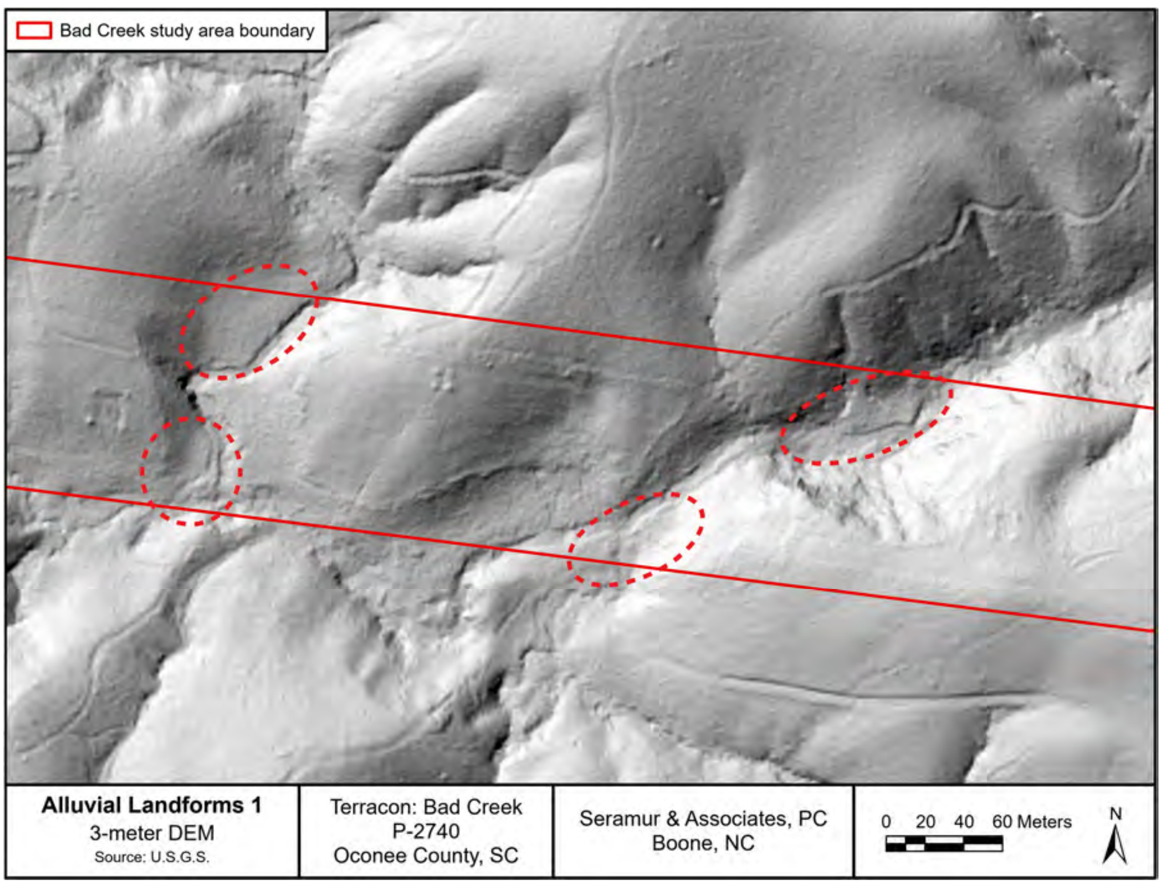

Figure 3. LiDAR DEM of transmission line crossing of McKinney's Creek. Alluvial landforms are circled in a red dashed line.

Alluvial Landform Area 1 is located where the transmission line crosses McKinney's Creek (Figures 1 and 2). The DEM shows four areas where it appears alluvial terraces are present along McKinney's Creek (red ovals on Figure 3). The soil survey map indicates that this area is underlain by the Halewood fine sandy loam (Figure 4). The parent material for this soil unit is described as residuum, as it appears that the soil survey did not map soil on the alluvial landforms along these narrow mountain streams.

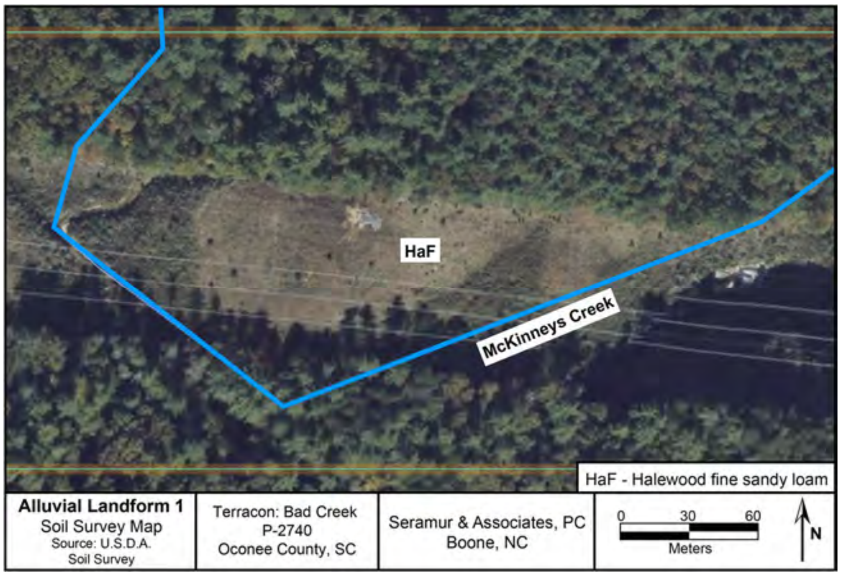

Figure 4. Soil survey map of transmission line crossing of McKinney's Creek.

Alluvial Landform Area 2
Alluvial Landform Area 2 is located where the transmission line crosses Bad Creek (Figures 1 and 5). The DEM shows alluvial terraces on each side of Bad Creek (Figure 6). The soil survey map indicates that this area is underlain by the Halewood fine sandy loam (Figure 7). The parent material for this soil unit is described as residuum, although there are clearly alluvial landforms present.

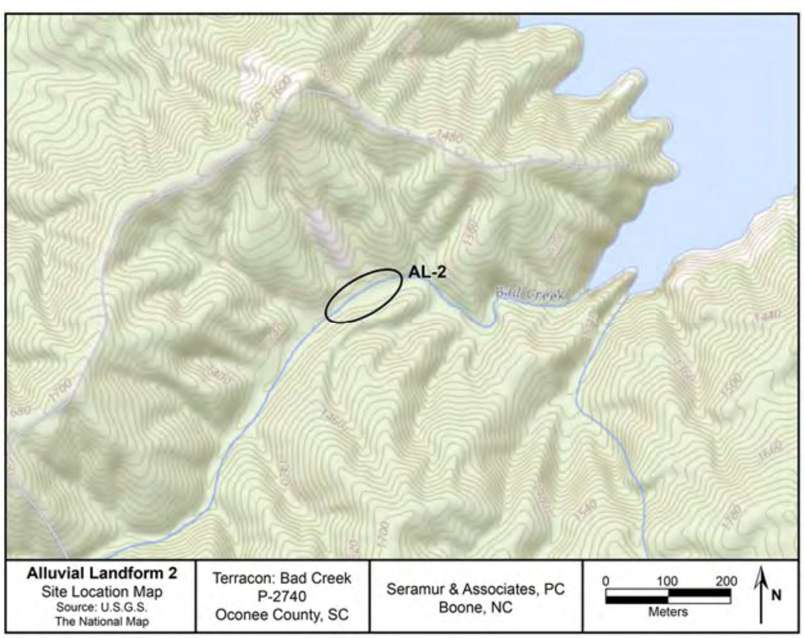

Figure 5. Topographic map of transmission line crossing of Bad Creek.

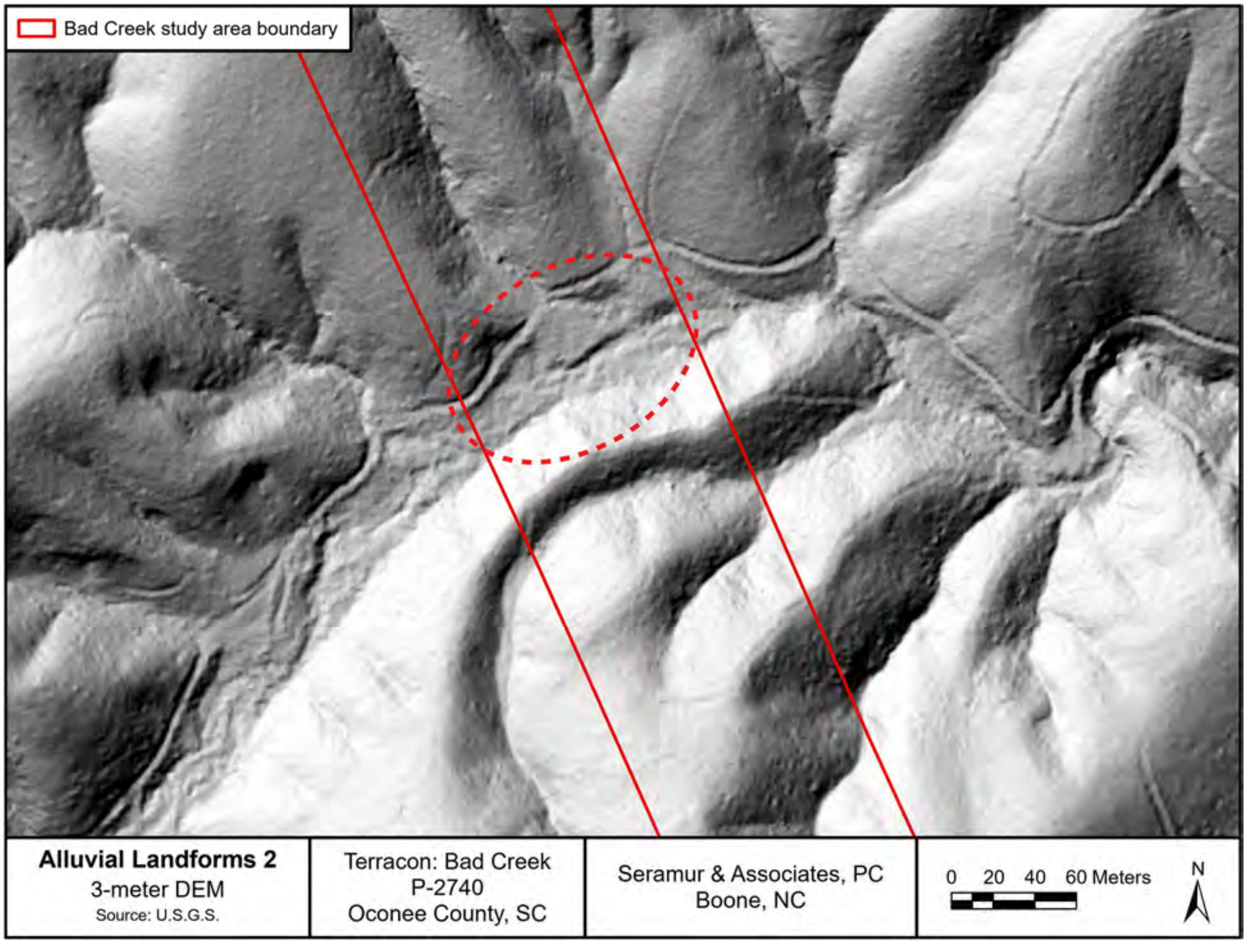

Figure 6. LiDAR DEM of transmission line crossing of Bad Creek. Alluvial landforms are circled in a red dashed line.

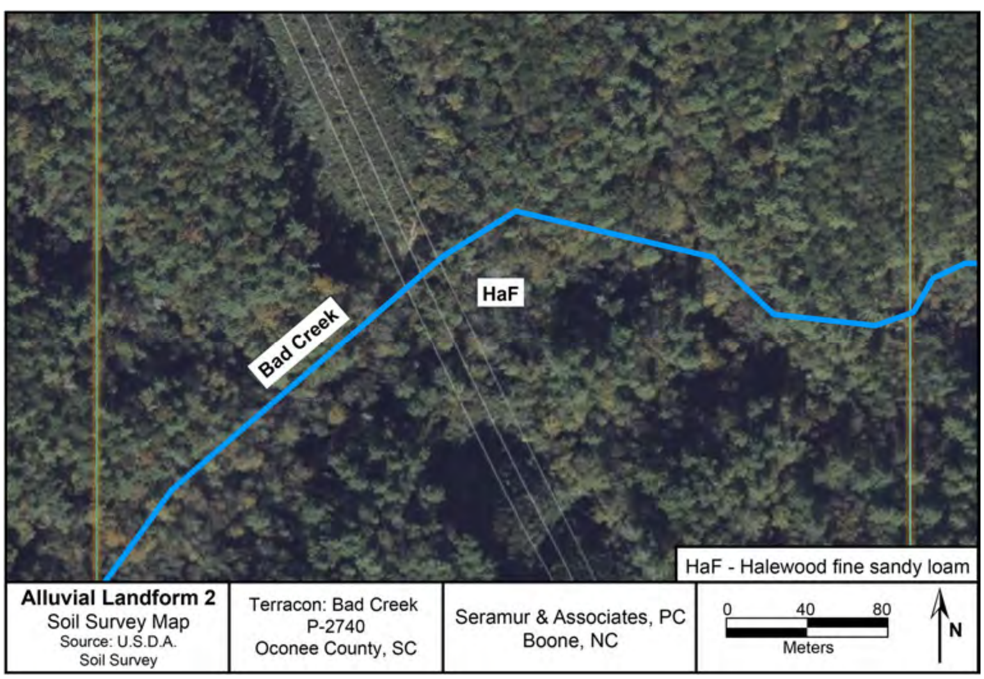

Figure 7. Soil survey map of transmission line crossing of Bad Creek.

Alluvial Landform Area 3

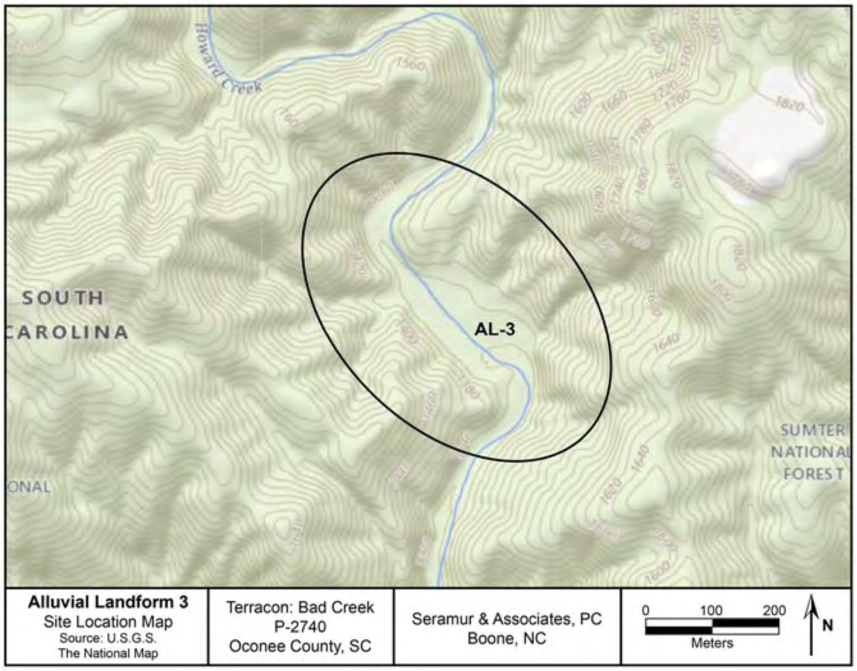

Figure 8. Topographic map of wide terrace along a southern reach of Howard Creek.

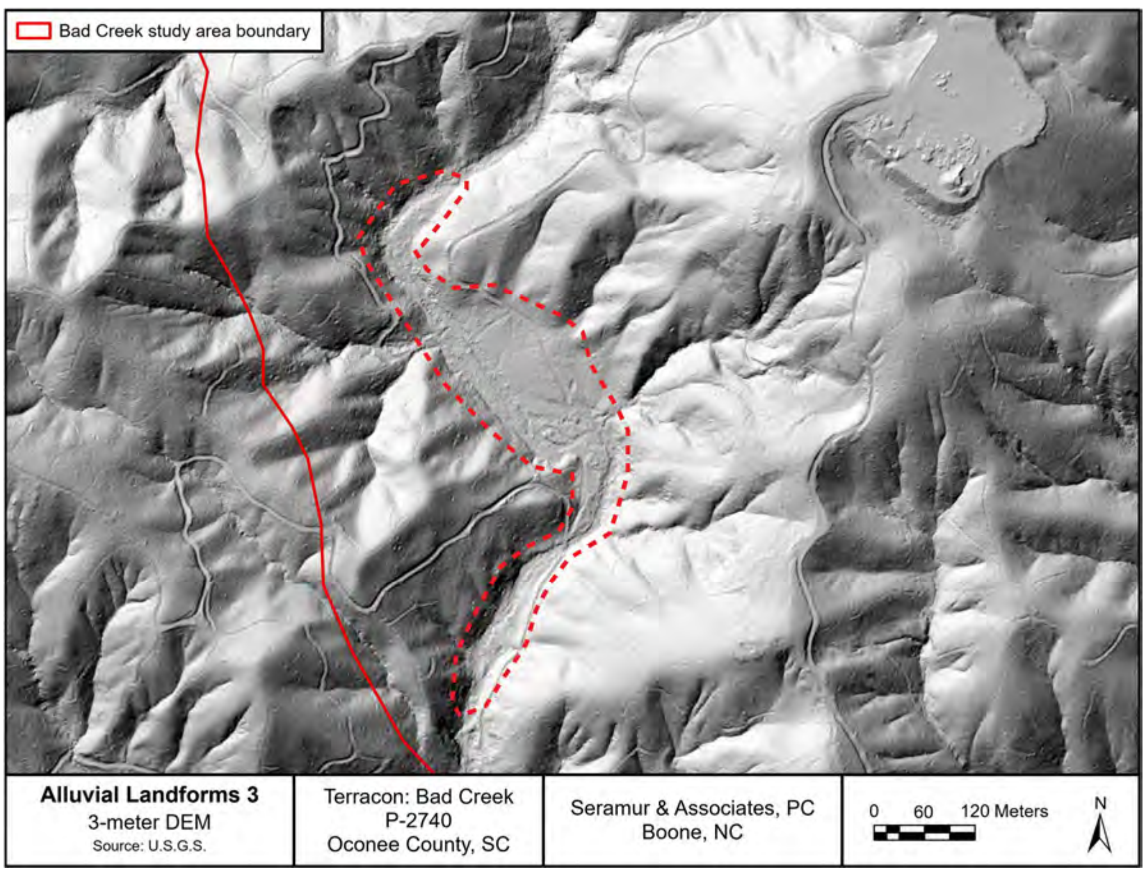

Figure 9. LiDAR DEM of wide terrace along a southern reach of Howard Creek.. Alluvial landforms are outlined in a red dashed line.

Alluvial Landform Area 3 is located in a wide section of the Howard Creek stream valley in the southern portion of the study area (Figures 1 and 8). The DEM shows a broad alluvial terrace in the central portion of AL-3 and narrow terraces to the north and south (Figure 9). The soil survey map indicates that this area is underlain by the Halewood fine sandy loam (Figure 10). The parent material for this soil unit is described as residuum, although there are clearly alluvial landforms present.

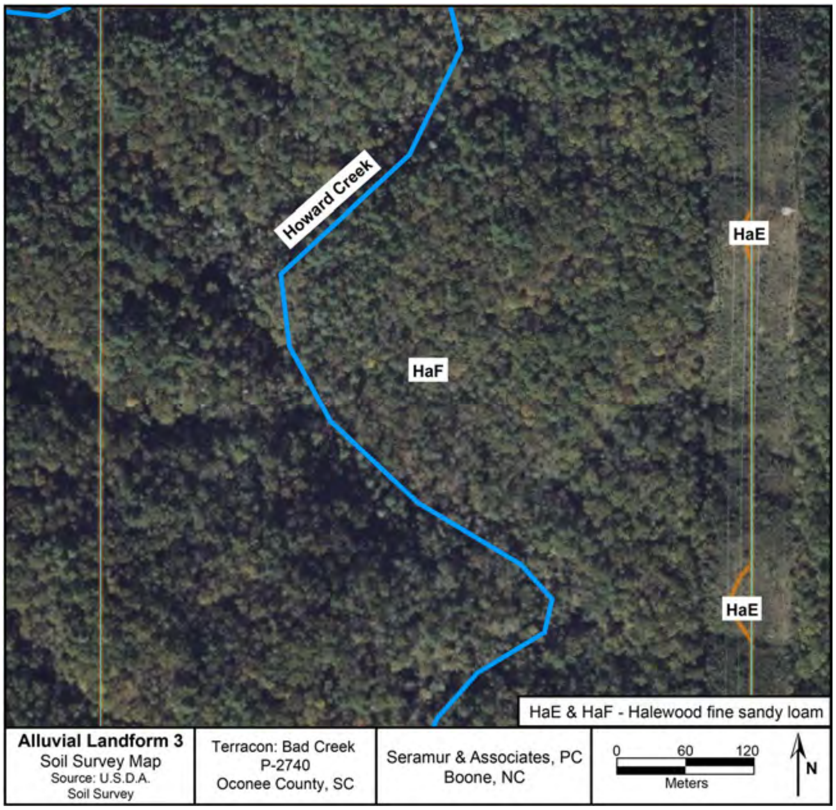

Figure 10. Soil survey map of wide terrace along a southern reach of Howard Creek.

Alluvial Landform 4

Alluvial Landform Area 4 is located in a wide section of the Howard Creek stream valley in the northern portion of the study area (Figures 1 and 11). The DEM shows a stream meandering across a broad alluvial terrace in AL-4 (Figure 12). The soil survey map indicates that this area is underlain by the Halewood fine sandy loam (Figure 13). The parent material for this soil unit is described as residuum, although there are clearly alluvial landforms present. A unit of the Riverview-Chewacla Complex soil is mapped on the western slope of the stream valley and is described as an alluvial soil. The USDA Web Soil Survey program appears to have a projection issue in this part of the study area as this alluvial soil unit should be mapped along Howard Creek.

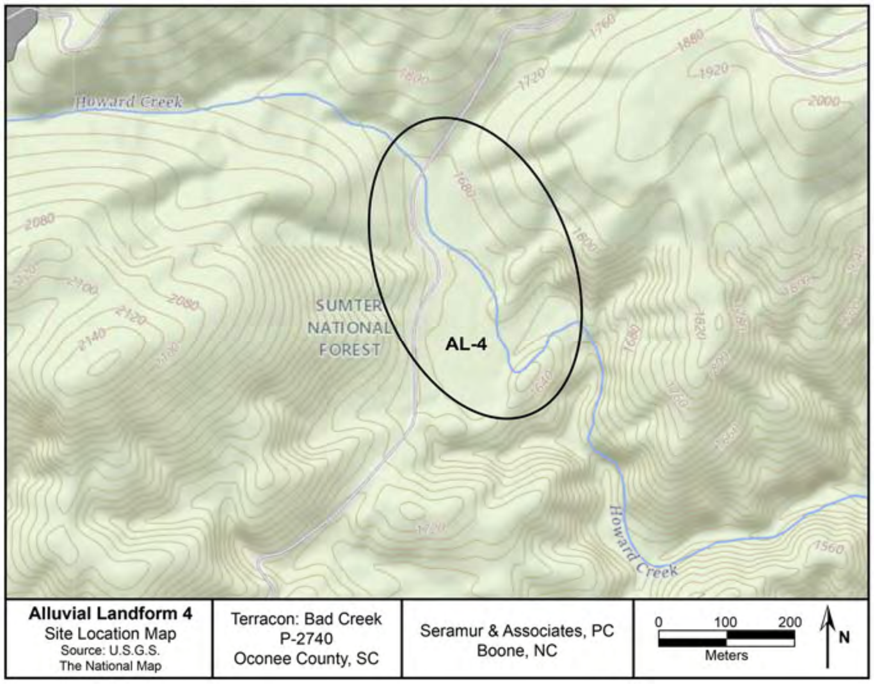

Figure 11. Topographic map of wide terrace along a northern reach of Howard Creek.

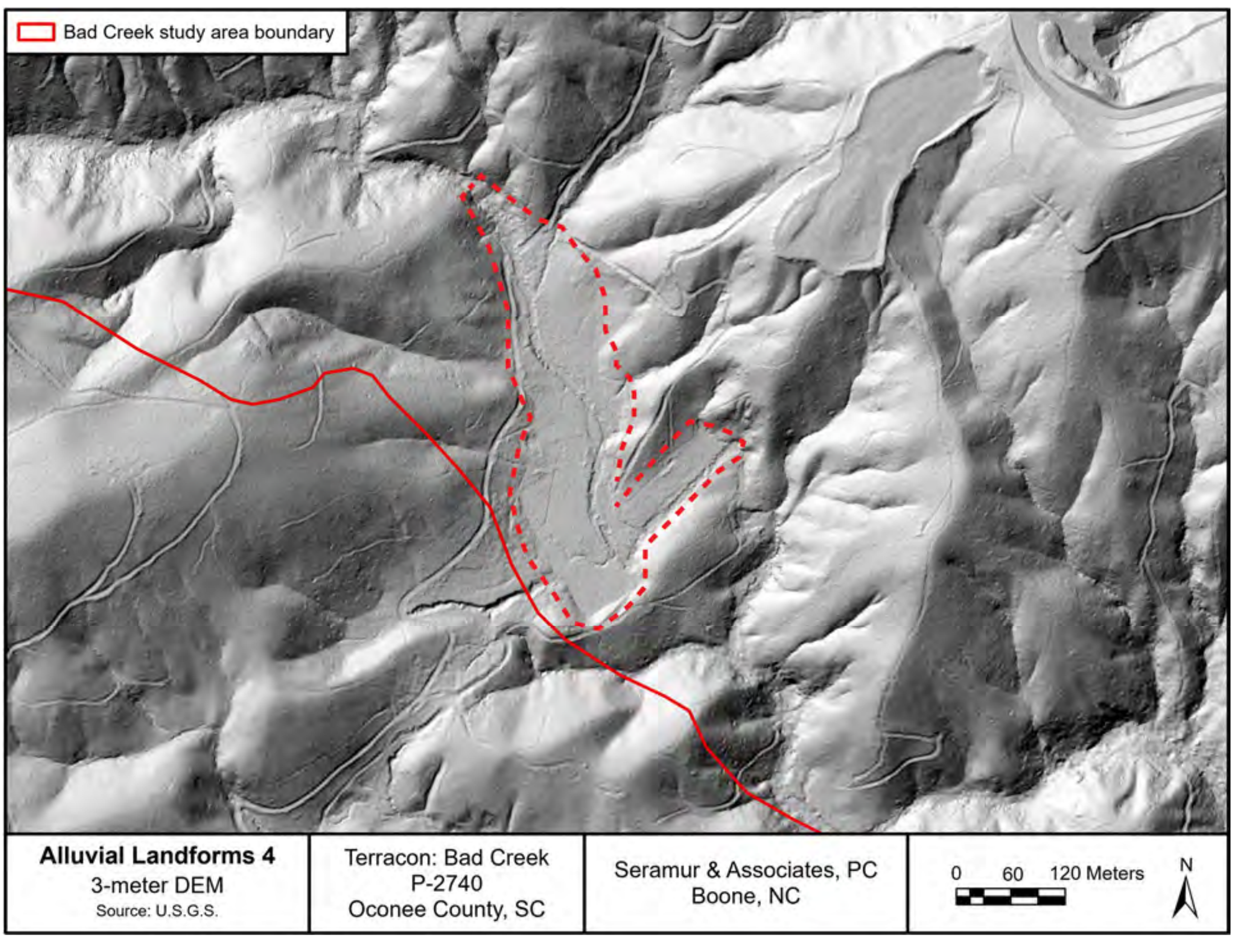

Figure 12. LiDAR DEM of wide terrace along a northern reach of Howard Creek.. Alluvial landforms are outlined in a red dashed line.

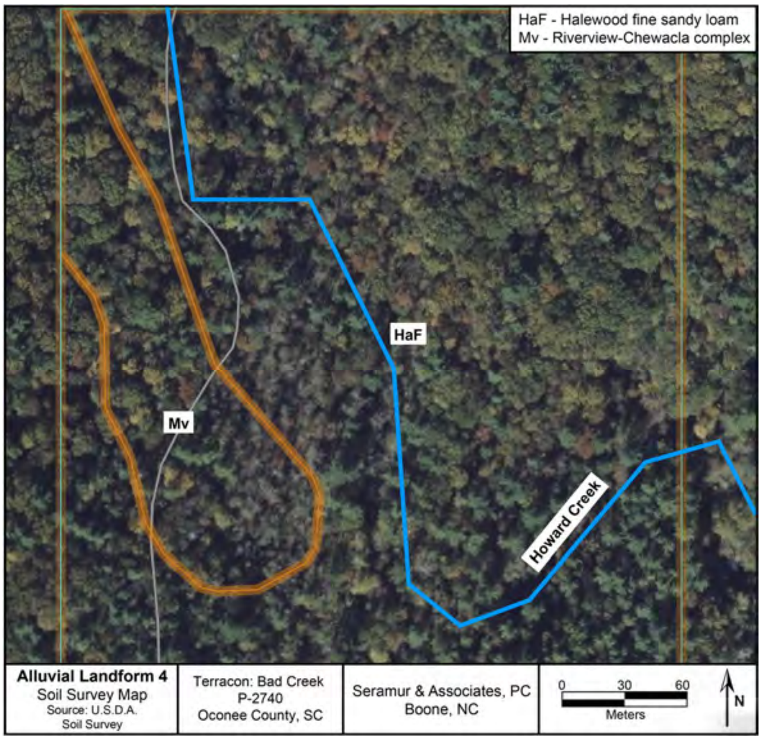

Figure 13. Soil survey map of wide terrace along a northern reach of Howard Creek.

Alluvial Landform Area 5

Alluvial Landform Area 5 is located in the headwaters of Devils Fork which is a small tributary to Lake Jocassee (Figures 1 and 14). The DEM shows a terrace on a wide section of the stream valley at the confluence of four small drainages (Figure 15). The soil survey map indicates that this area is underlain by the Halewood fine sandy loam (Figure 16). The parent material for this soil unit is described as residuum, although there is an alluvial landform present.

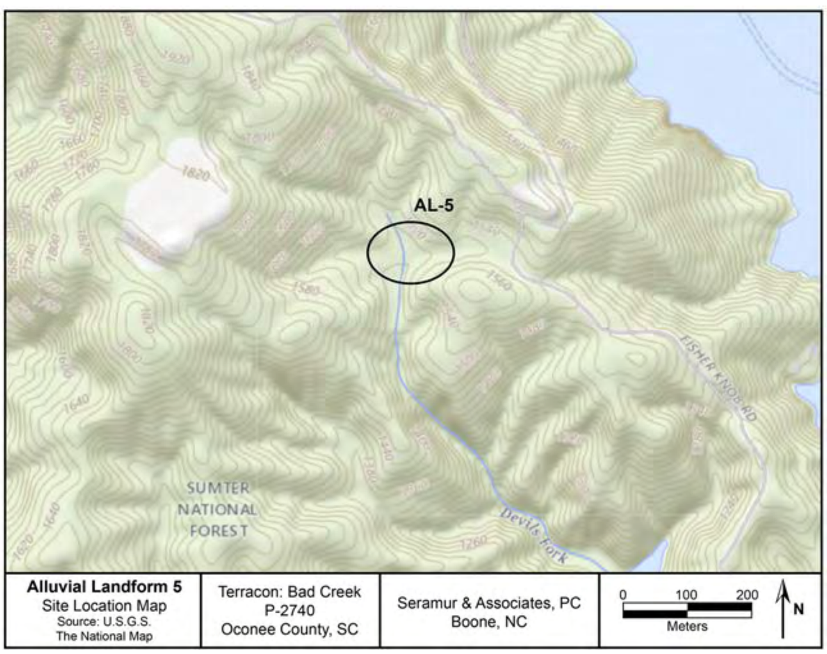

Figure 14. Topographic map of the headwaters of Devils Fork.

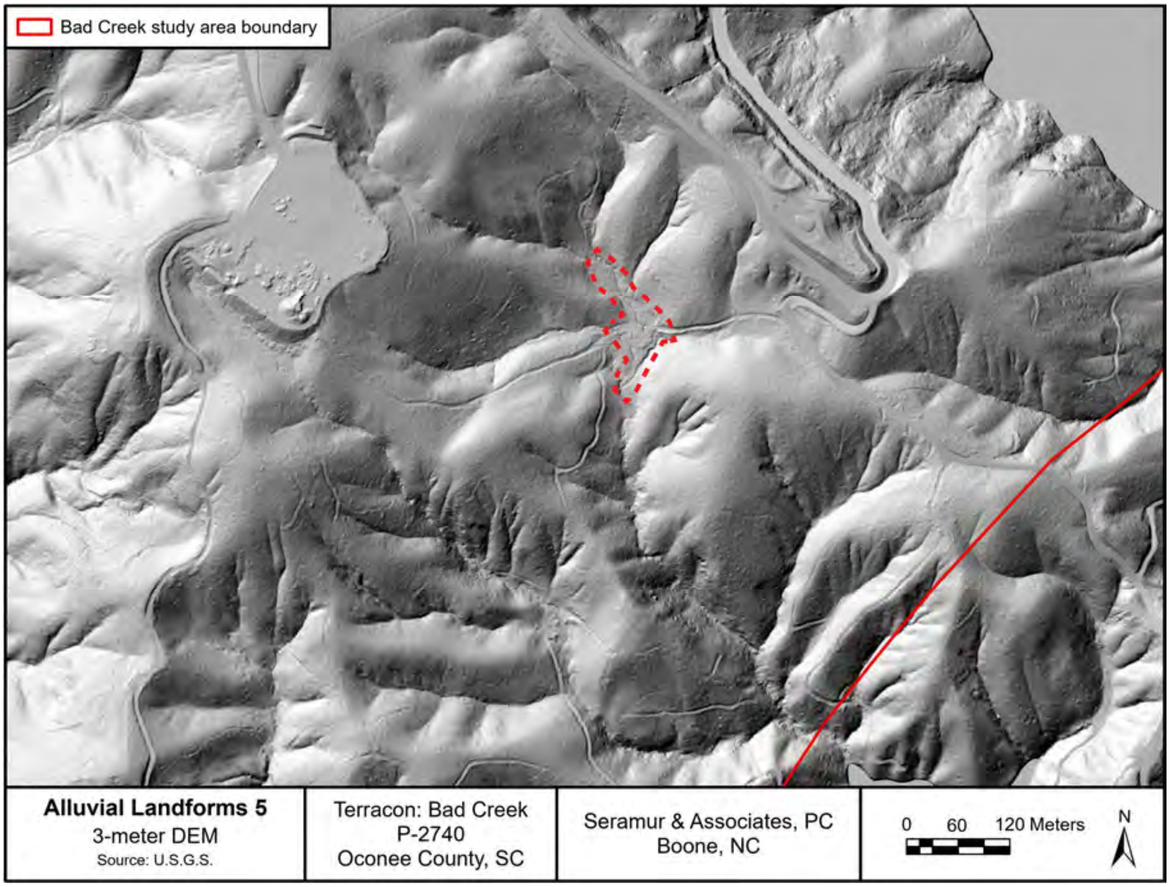

Figure 15. LiDAR DEM of the upper reaches of Devils Fork. Alluvial landforms are outlined in a red dashed line.

Figure 16. Soil survey map of the upper reaches of Devils Fork.

Alluvial Landform Area 6

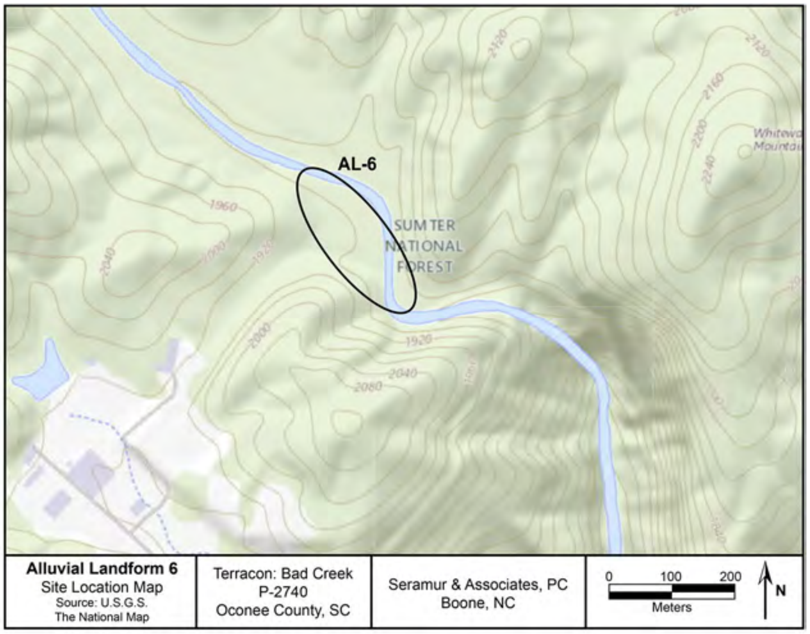

Figure 17. Topographic map of a section of the Whitewater River along the northeast edge of the study area.

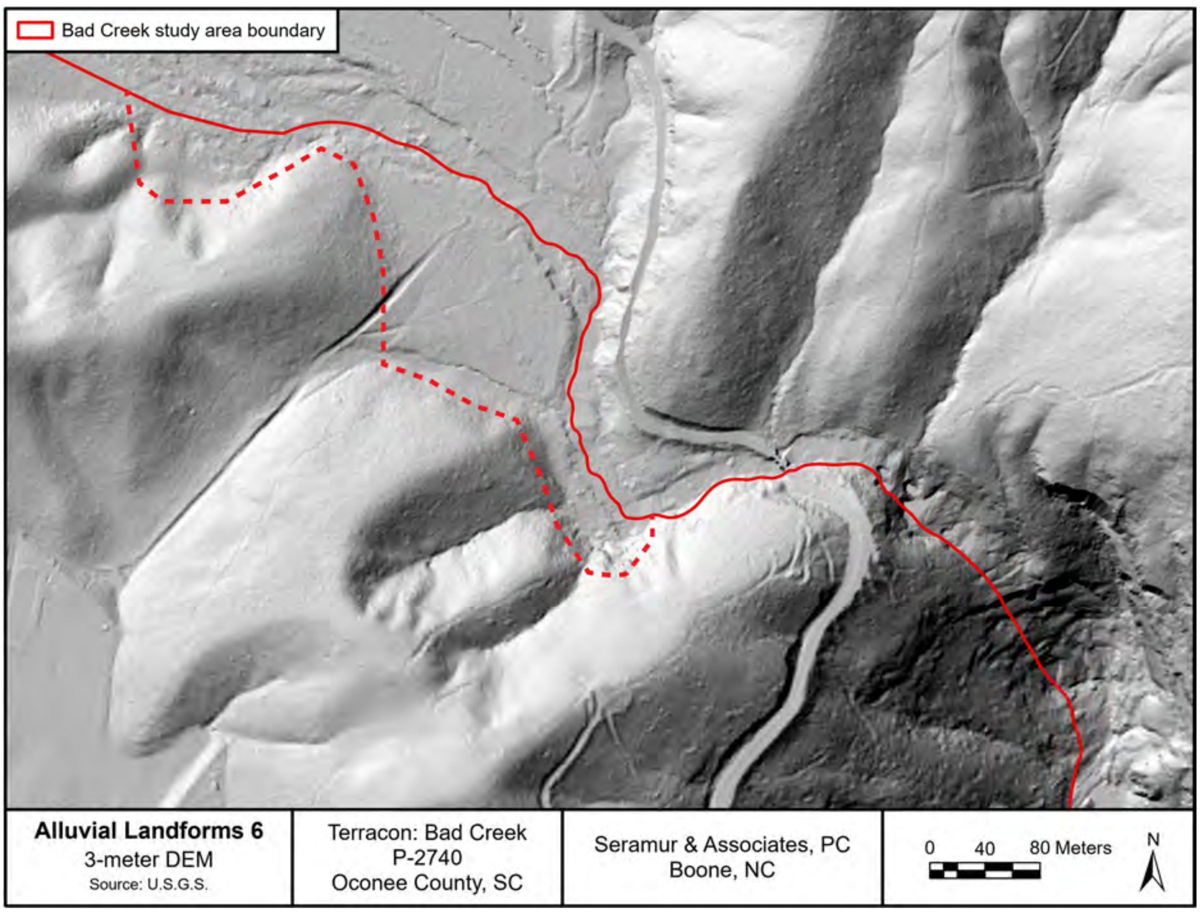

Figure 18. LiDAR DEM of a section of the Whitewater River along the northeast edge of the study area. Alluvial landforms are outlined in a red dashed line.

Alluvial Landform Area 6 is located along the Whitewater River on the northeastern edge of the study area (Figures 1 and 17). The study area is limited to the southwestern side of the stream valley (Figures 17 and 18). The DEM shows a broad terrace along the southwest side of the stream valley (Figure 18). The soil survey map indicates that this area is underlain by the Riverview-Chewacla Complex and the Halewood fine sandy loam (Figure 19). The Riverview-Chewacla Complex is described as an alluvial soil and the Halewood fine sandy loam is a residual soil.

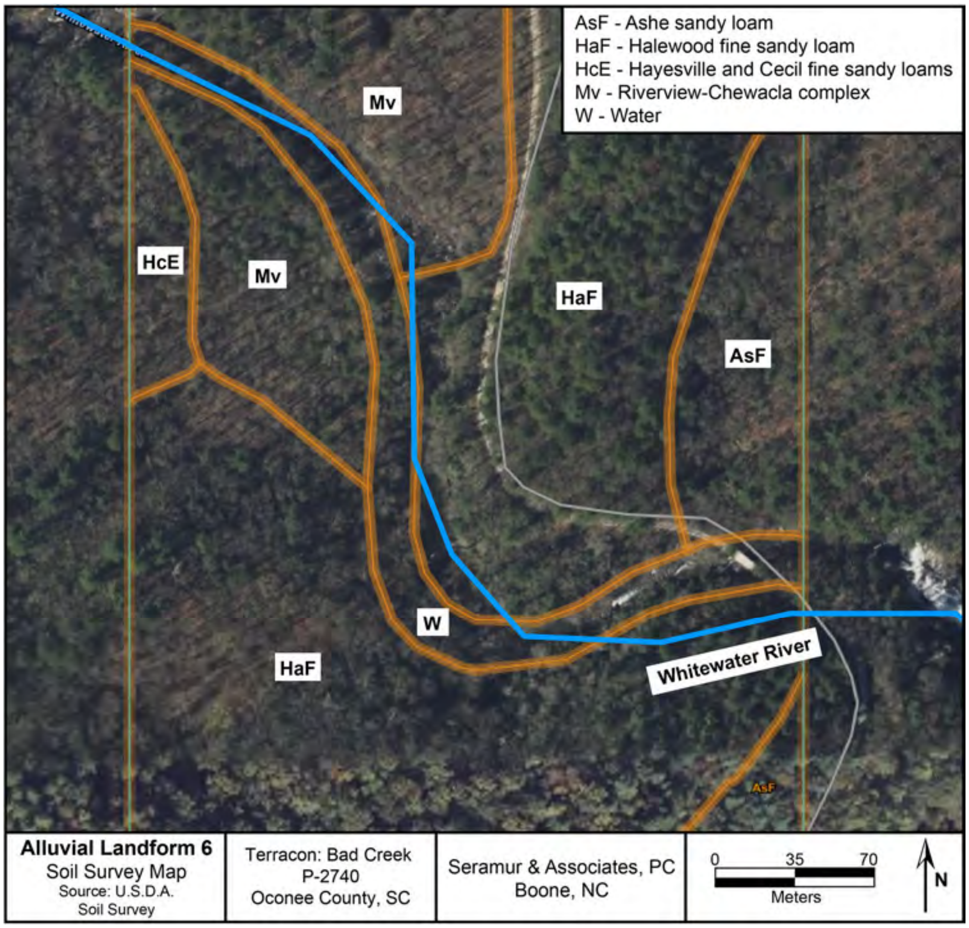

Figure 19. Soil survey map of a section of the Whitewater River along the northeast edge of the study area.

Alluvial landforms mapped in the six areas across the study area should be evaluated further for their potential to contain buried soils and cultural deposits. Seramur & Associates appreciates the opportunity to provide a desktop geomorphology investigation for this project. Please let us know if you have any questions or if we can be of further assistance.

Sincerely,

Keith C. Seramur, P.G.
Consulting Geomorphologist

References

Schaeffer, M. F. 2016. Engineering Geology of the Bad Creek Pumped Storage project, northwestern South Carolina. In: 24th Annual David S. Snipes/Clemson Hydrogeology Symposium Guidebook, March 30, April 1, and April 28, 2016.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. http://websoilsurvey.sc.egov.usda.gov/. Accessed [07/12/2022].

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Appendix H

Appendix H – Environmental Justice Study Plan

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APPENDIX H

ENVIRONMENTAL JUSTICE PROPOSED STUDY PLAN

Bad Creek Pumped Storage Project
FERC Project No. 2740

August 2022

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ENVIRONMENTAL JUSTICE PROPOSED STUDY PLAN
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740

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Section	Title	Page No.

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Acronyms and Abbreviations

Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
CT	Census Tract
Duke Energy or Licensee	Duke Energy Carolinas, LLC
FERC or Commission	Federal Energy Regulatory Committee
NEPA	National Environmental Policy Act
PAD	Pre-Application Document
USEPA	U.S. Environmental Protection Agency

1 Study Requests and Formal Comments

On June 16, 2022, the Federal Energy Regulatory Commission (FERC or the Commission) staff issued comments on the Bad Creek Pumped Storage Project (Project) Pre-Application Document (PAD) and requested that Duke Energy Carolinas, LLC (Duke Energy) conduct an Environmental Justice Study for the Project relicensing pursuant to Section 5.9 of the Commission's regulations. The request for an Environmental Justice Study aligns with the socioeconomic resource issues identified by the Commission in Scoping Document 1 issued for the Project relicensing on April 22, 2022; resource issues address the effects of continued Project operations under the Existing License as well as potential construction and operation of a second powerhouse during the New License term for the Bad Creek II Power Complex (Bad Creek II Complex).

- Effects of Project construction and operation activities on local roads (including traffic), housing, businesses, employment opportunities, and government services.
- Effects of Project construction and operation activities on human health or the environment in identified environmental justice communities.

In addition to the Commission's study request, Upstate Forever submitted a formal comment in support of an environmental justice study. Requests and comments pertinent to the Environmental Justice Study were considered in the development of this PSP and summaries of comments and responses are included in Appendix A. Copies of all comments are provided in Appendix B.

2 Goals and Objectives

The goal of the Environmental Justice Study is to define the potential effects of continued Project operations during the term of a New License issued by FERC, including construction and operation of a second powerhouse (i.e., Bad Creek II Complex), on disadvantaged environmental justice communities that may be present in the study area.

The Environmental Justice Study goal will be accomplished by completing the following six (6) objectives:

1. Identify the presence of environmental justice communities that may be present within the study area.
2. Identify the presence of non-English speaking populations that may be present within the study area.
3. Identify sensitive receptor locations in the study area.
4. Identify outreach strategies to engage environmental justice communities and non-English speaking populations in the relicensing if present within the study area.
5. Discuss (a) the effects of the relicensing and Bad Creek Complex II construction on any identified environmental justice communities, (b) effects that are disproportionately high and adverse, and (c) potential effects on non-English speaking communities and sensitive receptor locations, if present within the study area.
6. Identify mitigation measures to avoid or minimize project effects on environmental justice communities, non-English speaking communities, and sensitive receptor locations, if present within the study area.

3 Study Area

The geographic scope (i.e., study area) of the Environmental Justice Study will include all areas within one mile of the existing FERC Project Boundary, and within five miles around the proposed construction of the Bad Creek II Complex (Figure 3-1). Each state, county, and applicable census blocks within the Project Boundary and proposed Bad Creek II Complex study area will be analyzed, as identified in Tables 1 and 2 provided in Attachment 1.

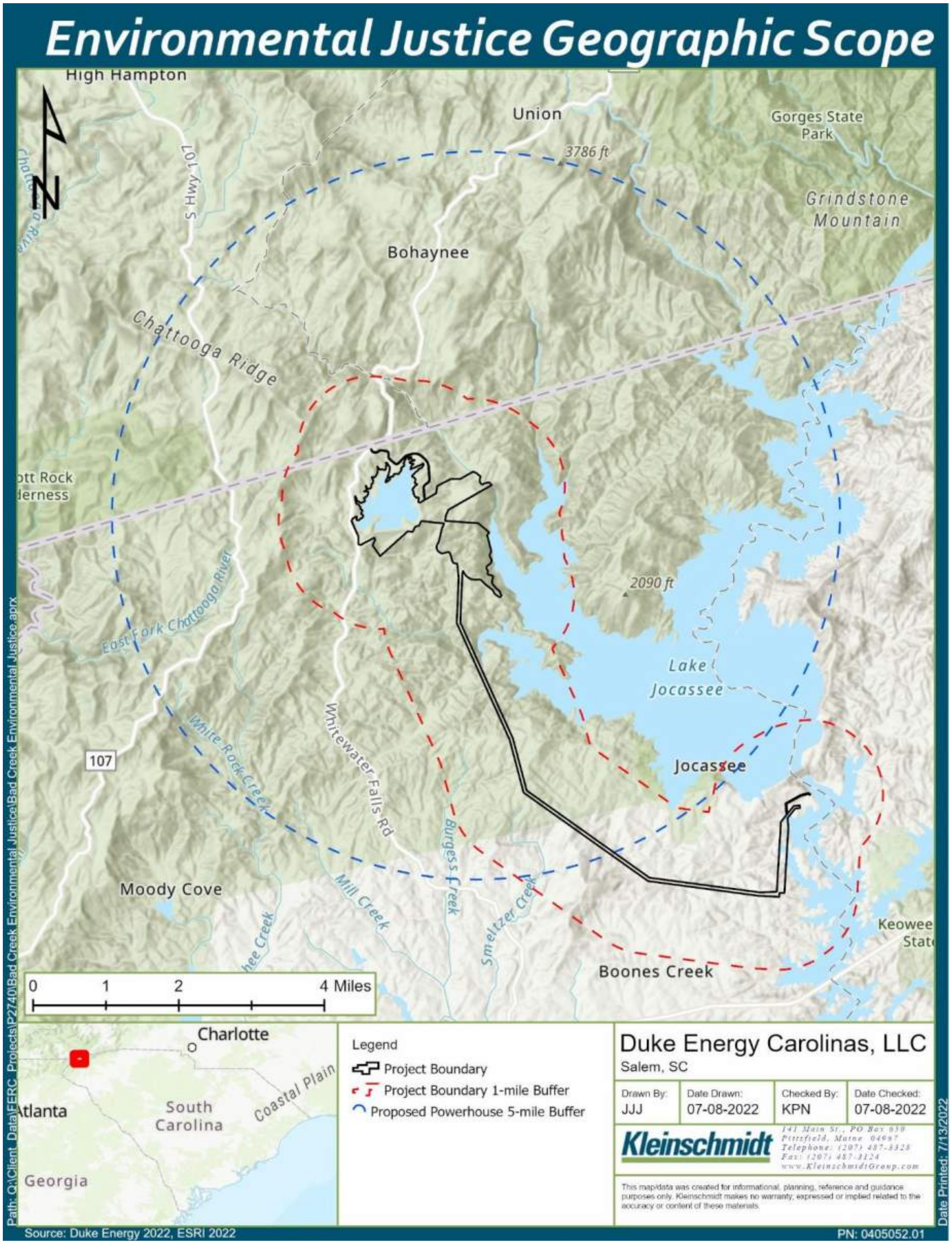

Figure 3-1. Environmental Justice Study Area

4 Background and Existing Information

The U.S. Environmental Protection Agency (USEPA) (2016) defines Environmental Justice as the "fair treatment and meaningful involvement of all people regardless of race, color, culture, national origin, income, and educational levels with respect to the development, implementation, and enforcement of protective environmental laws, regulations, and policies." The goals, objectives and study methodology outlined below is consistent with the June 16, 2022 study request, as well as the USEPA's Promising Practices for EJ Methodologies in NEPA Reviews (USEPA 2016). Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, most recently requires federal agencies to achieve environmental justice as "part of their missions by developing programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities, as well as the accompanying economic challenges of such impacts" (Executive Order 14008 2021). Additionally, Sections 4(e) and 10(a) of the Federal Power Act include provisions for the equal consideration of environmental, recreational, fish and wildlife and non-developmental values of the project in addition to the power and developmental values.

Existing relevant and reasonably available information concerning the presence of environmental justice communities near the Bad Creek Project in Oconee County, SC was presented in Section 6.11.4 of the PAD developed for the Project relicensing. The PAD identifies environmental justice populations within Census Tract (CT) 302, Oconee County, SC. The total minority population within CT 302 constitutes 12.2 percent of the total minority population in Oconee County and 2.4 percent of the total population of CT 302 (USCB 2021). No individual minority percentages within CT 302 exceed those of the county. There was no measurable population of Native Americans (American Indian or Alaskan Native; 0.0 percent), and no tribal communities are known in the Project vicinity (USCB 2022). The poverty rate of all people in Oconee County was 17.5 percent. CT 302 had a poverty rate for all people of 9.0 percent, lower than the county, state, and nation. Similarly, the per capita income of all people in CT 302 ($53,898) is higher than the county ($29,844), state ($29,426), and nation ($34,103). No identifiable low-income population is present in the Project vicinity within Oconee County. While a small minority population exists, overall, the percentages are well below the county percentages (Duke Energy 2022).

5 Project Nexus

Project construction, operation, and maintenance has the potential to affect human health or the environment within environmental justice communities, disadvantaged communities, and sensitive receptor locations that may be present within the geographic scope of analysis. If present, appropriate protection, mitigation and enhancement measures may be developed for the New License term to minimize identified affects to these communities and/or sensitive receptor locations.

6 Methods

The methodology for the Environmental Justice Study will be consistent with the Environmental Protection Agency's Promising Practices for Environmental Justice Methodologies in NEPA Reviews (2016). The study will be conducted in eight (8) steps, as outlined below. For the purposes of this study, minority population percentages that are considered significant for environmental justice purposes will either exceed 50 percent of the general population or be meaningfully greater than the minority population percentage in the general population. Minority populations are defined herein as people who identify themselves as Asian or Pacific Islander, American Indian or Alaskan Native, Black (not of Hispanic origin), or Hispanic, either alone or in combination with other ethnicities. Low-income populations are identified using the annual statistical poverty threshold from the U.S. Census Bureau Current Population Reports Series P-60 on Income and Poverty (Duke Energy 2022).

6.1 Step 1 – Statistics Table

A table will be prepared that includes the racial, ethnic, and poverty statistics for each state, county, and census block group within the study area. The table will include the following information from the U.S. Census Bureau's most recently available American Community Surveys 5-Year Estimates for each state, county, and block group:

- Total population;
- Total population of each racial and ethnic group (i.e., White Alone Not Hispanic, Black or African American, American Indian and Alaska Native, Asian, Native Hawaiian and

Other Pacific Islander, some other race, two or more races, Hispanic or Latino origin [of any race]) (count for each group);

- Minority population including individuals of Hispanic or Latino origin as a percentage of total population[1]; and
- Total population below poverty level as a percentage.[2]

6.2 Step 2 – Identification of Environmental Justice Communities Based on Minority Populations

Utilizing data gathered in Step 1, environmental justice communities will be identified by block group based on the presence of minority populations by applying the "50-percent" and the "meaningfully greater" analysis methods. As described above, the "50-percent" analysis method will be used to determine whether the total percent minority population of any block group in the affected area exceeds 50 percent. The "meaningfully greater" analysis will be used to determine whether any affected block group is 10 percent greater than the minority population percent in the county.

6.3 Step 3 – Identification of Environmental Justice Communities Based on Low-Income Populations

The "low-income threshold criteria method" will be used to determine environmental justice communities based on the presence of low-income populations. To qualify, the percent of the population below the poverty level in the identified block group must be equal to or greater than that of the county.

6.4 Step 4 – Identification of Non-English-Speaking Groups

Non-English-speaking groups within the study area will be identified using U.S. Census Bureau data, regardless of whether the group is part of an identified environmental justice community. Previous or planned efforts to identify and communicate with these non-English speaking groups

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[1] To calculate the percent total minority population, subtract the percentage of "White Alone Not Hispanic" from 100 percent for any given area.

[2] To calculate percentage of total population below poverty level, divide the total households below the poverty level by the total number of households and multiply by 100.

will be reported as well as any proposed measures to avoid and minimize any Project-related effects to these communities.

6.5 Step 5 – Outreach Efforts (if Environmental Justice Communities are Present)

If environmental justice communities are present, Duke Energy will conduct public outreach efforts regarding the Project relicensing and proposed Bad Creek Complex II development. Information regarding outreach efforts will be provided, including a summary of any outreach efforts and consultation to the communities, a description of the information provided to environmental justice communities, and any planned future outreach activities with the communities.

6.6 Step 6 – Identification of Sensitive Receptor Locations

Sensitive receptor locations (e.g., schools, day care centers, hospitals, elderly care facilities) will be identified if they occur within the geographic scope of the analysis. A table will be provided that includes their distances from Project facilities. These facilities will also be identified on the map described under Step 7, below.

6.7 Step 7 – Mapping Efforts

Maps will be developed to include the FERC Project Boundary, Project construction areas, identified environmental justice communities, and sensitive receptor locations. If environmental justice communities are present, the map will denote whether this community is based on the presence of minority populations, low-income populations, or both.

6.8 Step 8 – Project Effects on Environmental Justice Communities and Sensitive Receptor Locations and Proposed Mitigation Measures

The Environmental Justice Report will summarize the information gathered through steps 1 through 7 and include a discussion on the anticipated Project-related effects on any environmental justice communities for all the resources where there is a potential nexus between the effect and the environmental justice community. For identified effects, the report will describe whether the effects would be disproportionately high and adverse. Additionally, the report will include a description of mitigation measures proposed to avoid and/or minimize Project effects on environmental justice communities and non-English speaking groups.

7 Analysis and Reporting

Results of this study will be summarized in the Initial and Updated Study Reports. Duke Energy anticipates that the Environmental Justice Study report will include Project information and background, a depiction and description of the study area, methodology, results, and analysis and discussion. The report will also include relevant stakeholder correspondence and/or consultation, as well as literature cited.

8 Schedule and Level of Effort

The preliminary schedule for this study is outlined in Table 8-1. The estimated level of effort for this study is approximately 330 hours. Duke Energy estimates that the Environmental Justice Study will cost approximately $50,000 to complete.

Table 8-1. Proposed Environmental Justice Study Schedule

Task	Proposed Timeframe for Completion
Study Planning and Existing Data Review	August – December 2022
Study Tasks	Spring 2023-Fall 2023
Distribute Draft Study Report with the ISR	January 2024

9 References

Duke Energy Carolinas, LLC (Duke Energy). 2022. Bad Creek Pumped Storage Project (FERC 2740). Pre-Application Document. February 23, 2022.

Executive Order 14008. Tackling the Climate Crisis at Home and Abroad. 86 Fed. Reg. 7,619-7,633 January 27, 2021.

U.S. Census Bureau. 2021. Explore Census Data. [Online Database]. [Online] URL: https://data.census.gov/cedsci/. Accessed August 2021

______. 2022. My Tribal Area. [Online] URL: https://www.census.gov/tribal. Accessed February 2022.

U.S. Environmental Protection Agency (USEPA). 2016. Promising Practices for EJ Methodologies in NEPA Reviews. [Online] URL: https://19january2021snapshot.epa.gov/sites/static/files/2016-08/documents/nepa_promising_practicies_document_2016.pdf.

Attachment 1

Attachment 1 – Environmental Justice Analysis Areas

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Table 1. Analysis Areas within the Project Boundary 1-Mile Buffer Zone

State	County	Block Group	Block Name	
South Carolina	Oconee County	1	Block 1000	Block 1074
			Block 1004	Block 1075
			Block 1005	Block 1076
			Block 1006	Block 1077
			Block 1007	Block 1078
			Block 1009	Block 1079
			Block 1011	Block 1080
			Block 1012	Block 1081
			Block 1014	Block 1082
			Block 1022	Block 1083
			Block 1023	Block 1084
			Block 1024	Block 1085
			Block 1025	Block 1086
			Block 1026	Block 1087
			Block 1027	Block 1088
			Block 1028	Block 1089
			Block 1063	Block 1090
			Block 1067	Block 1091
			Block 1068	Block 1093
			Block 1069	Block 1094
			Block 1070	Block 1095
			Block 1071	Block 1116
			Block 1072	Block 1117
			Block 1073	Block 1121
	Pickens County	1	Block 1060	Block 1088
			Block 1085	Block 1051
			Block 1062	Block 1084
			Block 1120	Block 1123
			Block 1052	Block 1089
			Block 1061	Block 1122
			Block 1048	Block 1063
			Block 1087	Block 1086
			Block 1091	Block 1090
North Carolina	Jackson County	2	Block 2109	
			Block 2080	
			Block 2110	
	Transylvania County	1	Block 1050	
			Block 1053	
			Block 1052	

Table 2. Analysis Areas within the Proposed Bad Creek II Complex 5-Mile Buffer Zone

State	County	Block Group	Block Name	
South Carolina	Oconee County	1, 2	Block 1000	Block 1022
			Block 1001	Block 1023
			Block 1002	Block 1024
			Block 1003	Block 1025
			Block 1004	Block 1026
			Block 1005	Block 1027
			Block 1006	Block 1028
			Block 1008	Block 1034
			Block 1009	Block 1072
			Block 1010	Block 1074
			Block 1011	Block 1116
			Block 1012	Block 1117
			Block 1013	Block 1119
			Block 1014	Block 1120
			Block 1015	Block 2000
			Block 1016	Block 2001
			Block 1017	Block 2002
			Block 1018	Block 2003
			Block 1020	Block 2004
			Block 1021	
	Pickens County	1	Block 1015	Block 1050
			Block 1047	Block 1051
			Block 1048	Block 1052
			Block 1049	
North Carolina	Jackson County	2	Block 2007	Block 2081
			Block 2048	Block 2082
			Block 2053	Block 2083
			Block 2054	Block 2109
			Block 2079	Block 2110
			Block 2080	
	Transylvania County	1	Block 1026	Block 1046
			Block 1028	Block 1047
			Block 1029	Block 1048
			Block 1034	Block 1049
			Block 1038	Block 1050
			Block 1039	Block 1051
			Block 1044	Block 1052
			Block 1045	Block 1053

Appendix I

Appendix I – Supplemental Information - Geology and Project Feasibility

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APPENDIX I

SUPPLEMENTAL INFORMATION – GEOLOGY AND PROJECT FEASIBILITY

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

August 2022

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GEOLOGY AND PROJECT FEASIBILITY
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
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ACRONYMS AND ABBREVIATIONS

Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
CFD	Computational Fluid Dynamics
Duke Energy or Licensee	Duke Energy Carolinas, LLC
FERC or Commission	Federal Energy Regulatory Commission
PM&E	Protection, Mitigation, and Enhancement

1 Study Requests and Formal Comments

The Federal Energy Regulatory Commission's April 22, 2022 Scoping Document 1 identified the following environmental resource issues to be analyzed in the National Environmental Policy Act document for the Bad Creek Pumped Storage Project (Project) relicensing related to geology and soil resources. These resource issues address the effects of continued Project operations under the Existing License as well as potential construction and operation of a second powerhouse during the New License term for Bad Creek II Power Complex (Bad Creek II Bad Creek II Complex]):

- Effects of expanded Project operation on shoreline erosion along the lower reservoir.
- Effects of expanded Project construction on slope instability in the Project area.
- Effects of seismic activity in the Project area on construction of the Bad Creek II Complex, and vice versa.
- Effects of expanded Project construction and rock and spoil disposal on soil erosion and sedimentation.

In Section 1.3 of the Pre-Application Document (Duke Energy 2022), Duke Energy Carolinas, LLC (Duke Energy or Licensee) stated a full engineering feasibility study in support of the proposed Bad Creek II Complex was underway and would be complete by the end of 2022. Results of the feasibility study will address some of the environmental resource issues identified in Scoping Document 1 and activities carried out through additional studies proposed as part of the Project relicensing would address the remainder; therefore, Duke Energy does not propose to conduct a separate relicensing study focused on geology and soils and no formal study requests related to geology and soil resources were received during the scoping process. Stakeholder and FERC comments relevant to geology and soils were considered in the development of this PSP and summaries of comments and responses are included in Appendix A. Copies of all comments are provided in Appendix B.

2 Goals and Objectives

While there are no anticipated additional adverse effects to geology and soils resources due to the continued operation of the Project, potential adverse effects resulting from the construction and operation of the Bad Creek II Complex need to be evaluated. More specifically, the feasibility study results will include the following, which will be summarized in the License Application and will address the first three resource issues listed above:

- Geology and Seismology Study Results: Extensive geotechnical and geologic field and laboratory investigations were carried out to support the feasibility design of the Bad Creek II Complex and results will be available to support the current relicensing. The geologic study included 1) a review of existing geological information from the investigations for and during construction of the Bad Creek Project and 2) incorporation of geotechnical and geophysical data from the geotechnical exploration program, which included geophysical field testing and subsurface drilling. The geology report (Attachment 1 – to be included in the Revised Study Plan) also describes site and regional geology, lithology, structural geology and shear zones, in-situ stress measurements, and regional and local seismology.
- Computational Fluid Dynamics (CFD) Model Results: A three-dimensional CFD model was developed to support the feasibility design of the Bad Creek II Complex and results will be available to support the current relicensing. The goal of the modeling effort included determining the effect of the existing velocities of water discharge to the Whitewater River arm (also called Whitewater River cove) of Lake Jocassee as well as estimating velocities under a two-discharge scenario resulting from the addition of the Bad Creek II Complex. Results will identify potential operational impacts of the Bad Creek II Complex during turbine mode and effects on shoreline erosion potential on the east bank of the Whitewater River arm of Lake Jocassee.

There are no known additional adverse effects to geology or soils in the upper or lower reservoirs areas due to the continued operation of the Project, therefore, no additional Protection, Mitigation, and Enhancement (PM&E) measures beyond the existing Shoreline Management Plan for Lake Jocassee (pursuant to the Keowee-Toxaway Project No. 2503 Operating License) to limit/prevent/mitigate potential erosion are warranted. Additionally, Duke Energy plans to continue operating the KT Project with the existing restrictions on land and shoreline development in the vicinity of the Bad Creek Project Boundary as defined in the KT Project Shoreline Management Plan.

Potential shoreline erosion in the Whitewater River cove on the bank opposite the potential new inlet/outlet structure is evaluated in the CFD modeling report which will be included as Attachment 2 – to be included in the Revised Study Plan. Additional CFD modeling will be carried out as a study activity under the Water Resources Study Plan.

There is minor active slope movement in the Project area and evidence of previous mass wasting events; however, these areas are routinely monitored and the Project vicinity is considered to have low to moderate seismic risk (there are no known Quaternary/active faults in the site vicinity), therefore, no further PM&E measures are proposed for the existing Project. Slope monitoring will continue during the New License term.

Effects of potential expanded Project construction and rock and spoil disposal on soil erosion and sedimentation in the Project site will be evaluated as part of the Water Resources Study.

Duke Energy believes the ongoing and planned evaluations and studies for the Bad Creek II Complex will be sufficient to inform the relevant geological requirements of the draft and final license applications, including preparation of a preliminary Supporting Design Report for the Bad Creek II Complex.

3 References

Duke Energy Carolinas, LLC (Duke Energy). 2022. Pre-Application Document, Bad Creek Pumped Storage Project FERC Project No. 2740, Oconee County, South Carolina. February 23, 2022.

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Attachment 1

Attachment 1 – Bad Creek Geology Report

(To Be Filed Under Separate Cover With the Revised Study Plan)

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Attachment 2

Attachment 2 – Bad Creek CFD Modeling Report

(To Be Filed Under Separate Cover With the Revised Study Plan)

Appendix J

Appendix J – Duke Energy Avian Protection Plan (2020)

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Duke Energy Avian Protection Plan

Prepared by:

Duke Energy
Environmental Services
Natural Resources
526 South Church Street
Charlotte, NC 28202

Final
January 2020

Avian Protection Plan

Summary of Revisions and Changes

Date Revised/Reviewed	Summary of Revisions and Changes (Include Page Number)	Revision By
12/10/2013	New Integrated Plan	Scott Fletcher
08/24/2015	Corrections to branded items; expanded Key Terms & Acronyms	Tonya Corder
09/21/2015	Language corrections to various sections; correction of SMEs (15.0)	Tonya Corder
01/26/2016	Document updates, formatting changes, content changes to the Appendices	Misti Sporer
01/20/2017	Document updates and corrections. Inclusion of Piedmont Natural Gas and additional renewable sites.	Misti Sporer
01/15/2018	Document updates and corrections. Updated permits. Removal of duplicative Appendices.	Misti Sporer
11/31/2018	Document updates. Updated permits.	Misti Sporer
11/21/2019	Document updates. Building participation in "Lights Out" program added. Updated permits and record keeping system. Additional renewables sites added.	Misti Sporer

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Executive Summary

State and federal laws protect all species of native birds found throughout the entire Duke Energy service area. Interactions of birds with generating facilities, transmission and distribution lines, substations, other structures and equipment, and operations and maintenance can be harmful or fatal to birds. Bird interactions can result in significant outages, grass and forest fires, violations of bird protection laws, and raise concerns by employees, resource agencies, stakeholder groups, and our customers.

Duke Energy is committed to the protection of migratory, and threatened and endangered birds while providing safe and reliable power to our customers. Duke Energy is an active member of the Avian Power Line Interaction Committee (APLIC), working with the organization and its membership in the advancement and implementation of electric utility best practices for avian protection. This commitment to protection of avian resources extends to its subsidiary companies, including Duke Energy Renewables (DER).

It is the responsibility of our employees and contractors to adhere to all federal, state, and local laws that are designed to protect our environment. The Migratory Bird Treaty Act of 1918 (MBTA), the Bald and Golden Eagle Protection Act (BGEPA), and the Endangered Species Act (ESA), administered by the U.S. Fish and Wildlife Service (USFWS), are the driving legislation that provides regulatory protection to birds throughout the Duke Energy service area as well as the entire United States.

In an ongoing commitment to environmental stewardship and associated avian protection, Duke Energy has revised and enhanced the corporate Avian Protection Plan (APP) based on the guidelines set forth in *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006* and *Reducing Avian Collisions with Power Lines: The State of the Art in 2012* (APLIC 2006; APLIC 2012).

Duke's APP is designed to help the corporation and its employees ensure compliance with requirements of bird protection laws, manage bird interactions with power and facility structures, provide proper training on regulatory and corporate requirements, reduce risk, and thereby reduce costly system interruptions that are caused by birds. It is the intent of this APP to condense all the avian protection measures and best management practices into a single corporate resource to provide Duke Energy personnel and contractors with the most updated avian related information.

The APP is a living document and will be revised, as needed, based on regulatory and procedural changes, internal operational and maintenance changes, revisions to design standards, and improvements in avian protection equipment and techniques.

1.0 Key Terms and Acronyms

Below are several terms, acronyms and their definitions that are used throughout this document. These terms and acronyms will be helpful when reading this document.

ACA – Avian Concentration Area. An area (e.g., lakes, wetlands, estuaries, aquaculture facilities) frequented by significant numbers of migratory birds.

Active Nest – A bird nest with eggs and/or young present. Protected under the MBTA.

APLIC – Avian Power Line Interaction Committee. APLIC leads the electric utility industry in protecting avian resources while enhancing reliable energy delivery. APLIC works in partnership with over 75 utilities, state and federal resource agencies, and the public to develop and provide educational resources, identify and fund research, develop and provide cost-effective management options, and serve as the focal point and clearinghouse for avian interaction utility issues. Duke Energy is an active member of this organization.

APP – Avian Protection Plan. A utility-specific document that describes a program designed to reduce the operational and avian risk from avian interactions with electric utility facilities.

Avian – Relating to or characteristic of birds.

Avian Friendly – Implies that a particular structure, segment, or line has been designed or retrofitted with measures intended to reduce avian impacts by providing sufficient separation between phases and between phases and grounds to accommodate the wrist-to-wrist or head-to-foot distance of a bird. The determination of avian friendly considers APLIC suggested practices for avian protection.

BBCS – Bird and Bat Conservation Strategy. A plan typically associated with renewable wind energy projects, that documents adherence to the 2012 Voluntary Land Based Wind Energy Guidelines and describes the avian and bat risk assessment, project-specific avoidance and minimization measures, post-construction monitoring, best management practices, and adaptive management associated with a project. A BBCS may also be associated with a solar renewable energy project.

BGEPA – Bald and Golden Eagle Protection Act of 1940. Federal legislation that provides specific protections to both bald and golden eagles.

BMP – Best Management Practice

CBT – Computer-Based Training

Corporation or Corporate – As it pertains to Duke Energy.

Depredation – Damage or loss of property due to wildlife such as birds; may also refer to an act to reduce the impacts from wildlife by legally eliminating those species causing the damage.

Distribution Line – A circuit of low voltage wires, energized at voltages from 2.4 kV to 60 kV, and used to distribute electricity to residential, industrial, and commercial customers.

ESA – Endangered Species Act of 1973. Federal legislation that provides protection to species that are listed as threatened or endangered (T&E) under the regulations.

Eagle Permit Rule – A rule updated in 2016 to allow for the issuance of eagle take permits.

ECP – Eagle Conservation Plan. Provides a plan and framework to support the application for a programmatic eagle take permit. The 2013 Eagle Conservation Plan Guidance – Module 1 – Land Based Wind Energy – Version 2 is the guidance from USFWS to an applicant in order to prepare an ECP that meets issuance criteria for a utility scale wind energy facility. Additional information on ECP contents was provided in the 2016 regulatory update to the BGEPA.

EPS – Eagle Protection Strategy. A framework developed in 2018 by APLIC to help guide utilities in determining and documenting risk to eagles from utility operations. Duke Energy's EPS focuses on bald eagles in the Florida service territory.

FWC – Florida Fish and Wildlife Conservation Commission

GIS – Geographic Information System

IDNR – Indiana Department of Natural Resources

Inactive Nest – A bird nest without eggs and/or flightless young present. Not protected under MBTA.

Insulation – Suggested avian-friendly practice of covering distribution line phases or grounds where adequate separation is not feasible; provides "brush-by-contact" protection. Avian-friendly products are not intended for human protection.

Isolation – Suggested avian-friendly practice of providing a minimum separation distance between energized and/or non-energized electrical components to accommodate the wrist-to-wrist measurements of the largest avian species expected within the local environment.

KDFWR – Kentucky Department of Fish and Wildlife Resources

kV – Kilovolt

Migratory Birds – All birds listed in 50 CFR 10.13. This list of birds covered under the MBTA includes 1026 species. Generally speaking, in the United States, this means all birds except non-native exotic and invasive species, such as English sparrows, European starlings, Eurasian collared doves, pigeons (rock doves), monk parakeets, Nanday conures, and certain non-migratory game birds (e.g., wild turkey, ruffed grouse, bobwhite quail).

MBTA – Migratory Bird Treaty Act of 1918. Federal legislation that provides regulatory protection to native birds, eggs, and active nests throughout the Duke Energy service area as well as the entire U.S.

MW – Megawatt

NCDEQ – North Carolina Department of Environmental Quality

NCWRC – North Carolina Wildlife Resources Commission

ODNR – Ohio Department of Natural Resources

Problem Structure – A utility structure where there has been a documented avian electrocution, collision, problematic nest, or where there is a high risk of an avian fatality.

Raptor – A bird of prey (e.g., hawks, eagles, osprey, kites, vultures, and owls). Raptors have a sharp, hooked bill and sharp talons used for killing and eating prey.

Retrofitting – The modification of an existing electrical power line structure to accommodate an avian-friendly practice.

ROW – Rights-of-way. Strips of land leased or otherwise acquired for the purpose of constructing and maintaining a utility corridor. These are also called utility easements.

SCDNR – South Carolina Department of Natural Resources

SME – Subject-Matter Expert

SPUT – Special Purpose Utility. A type of permit issued under the MBTA that allows utilities to relocate or remove active nests that are under threat of electrocution or that pose a threat to safe utility operations. This permit also allows for the collection and temporary possession of dead or injured birds found on ROW or other corporate property.

Take – Term defined under the MBTA to include pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect a migratory bird, or any part, nest, or egg of any such bird. Also, separately defined under the ESA and BGEPA, with differences present in all three regulations.

Transmission Line – Power lines designed and constructed to support voltages greater than 60 kV.

USFWS – United States Fish and Wildlife Service. The federal agency charged with administering the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act.

WEG – 2012 Voluntary Land Based Wind Energy Guidelines. A set of voluntary guidelines provided by the USFWS to outline the processes for siting, developing, constructing, and operating land based, utility scale wind energy projects in a way that avoids, minimizes and mitigates impacts to birds, bats and other wildlife resources.

2.0 Statement of Purpose

State and federal laws protect all species of native birds found throughout the Duke Energy service area. Interactions of birds with generating facilities, transmission and distribution lines, substations, other structures and equipment, and the operation of equipment can be harmful or fatal to birds. Bird interactions can result in violations of bird protection laws, cause significant outages, or cause grass and forest fires; all of these can raise concerns with employees, resource agencies, stakeholder groups and our customers.

The purpose of the Duke Energy Avian Protection Plan (APP) is to ensure compliance with requirements of all bird protection regulations and laws promulgated to reduce avian mortality. In addition to protecting migratory birds, it is the corporation's intent to manage bird interactions with electric utility structures and facilities and thereby reduce system interruptions, outages, and operational risks that are caused by bird interactions. This APP also provides corporate level commitment and governance to Duke Energy's various subsidiary companies.

3.0 Corporate Philosophy and Commitment

Duke Energy is one of the largest electric utility holding companies in the United States; Duke Energy offers energy services to approximately 7.7 million customers in the Carolinas, Florida, Ohio, Kentucky and Indiana, and retail natural gas services to more than 1.6 million customers in the Carolinas, Ohio, Kentucky and Tennessee. Duke Energy's fleet of power plants has approximately 50,200 megawatts of generating capacity from a variety of fuel sources – from hydroelectric to coal, oil and natural gas to nuclear.

Duke Energy Renewables (DER), is national leader in developing wind and solar generation projects throughout the U.S. The corporation's growing renewable portfolio of more than 2,900 MW includes 20 wind farms and 63 solar installations in operation in fourteen states including Arizona, California, Colorado, Florida, Georgia, Kansas, Kentucky, New Jersey, New Mexico, New York, North Carolina, Oklahoma, Pennsylvania, Texas, and Wyoming (Figure 3.0-2).

As Duke Energy strives to meet the electric demands of our customers, we constantly look for ways to minimize our impacts to the environment and operate in a sustainable manner. Duke Energy is committed to the protection of migratory birds while providing safe and reliable power to our customers. Duke Energy is an active member of the Avian Power Line Interaction Committee (APLIC), working with the organization and its membership in the advancement and implementation of electric utility best practices for avian protection. The 2018-2020 Chairmanship for APLIC is currently held by Duke Energy's Avian Protection Program Lead.

Duke Energy and its subsidiary companies are committed to siting, constructing, operating, and decommissioning their facilities in an environmentally responsible and sustainable manner. This environmental responsibility includes conserving and minimizing impacts to natural resources, including avian and bat species and the habitats they use. This environmental responsibility includes full adherence with the 2012 Voluntary Land Based Wind Energy Guidelines, which recommend the preparation of a Bird and Bat Conservation Strategy (BBCS) for each renewable wind energy facility. In some specific cases, BBCSs are required or necessary for a solar facility. When a BBCS is not required or warranted for a DER facility, this APP shall apply.

Figure 3.0-1. Map of Duke Energy Service Territories.

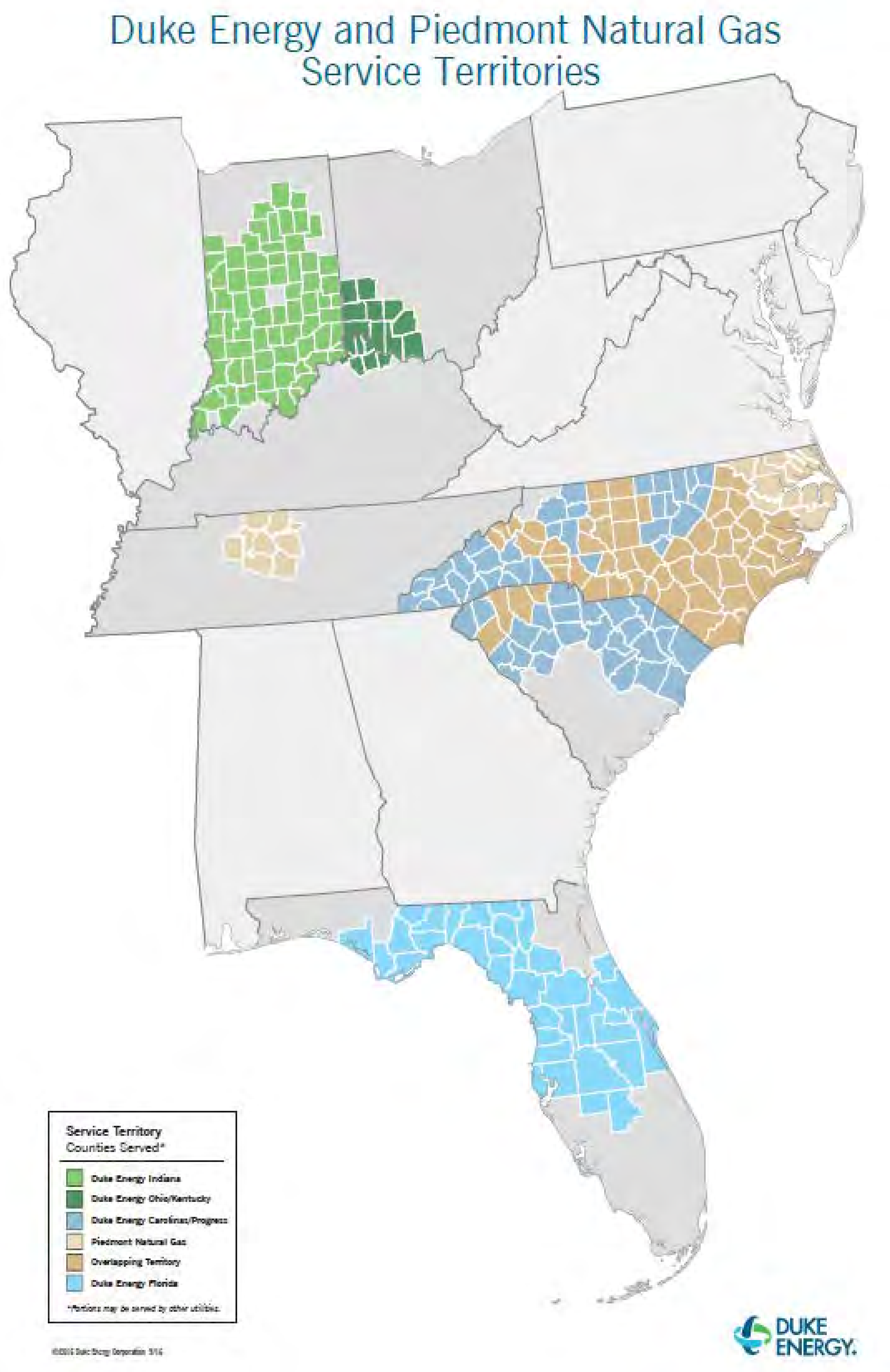
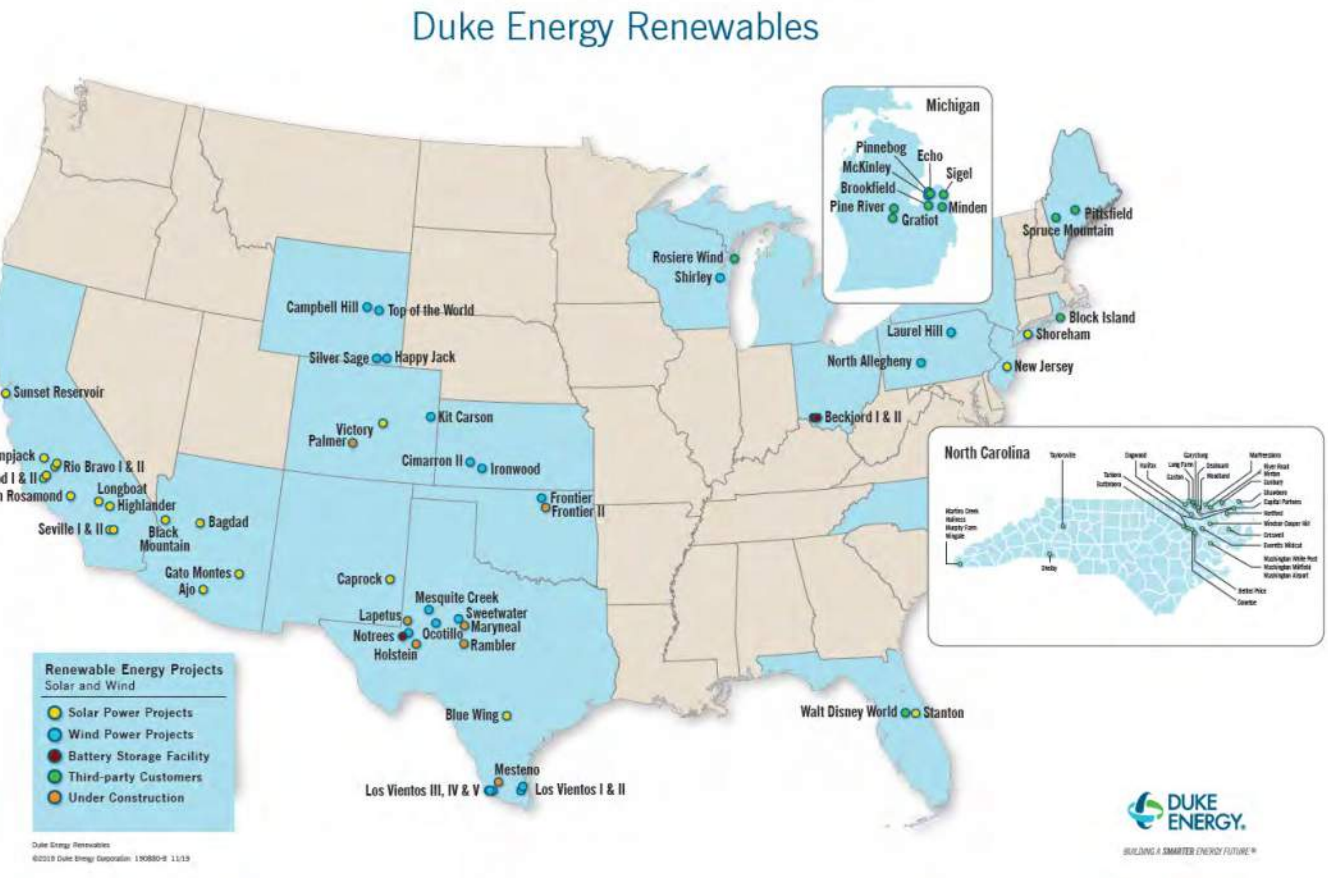


Figure 3.0-2. Map of Duke Energy's Renewable Energy Projects.



It is the responsibility of our employees and contractors to adhere to all federal, state, and local laws that are designed to protect our environment. The Migratory Bird Treaty Act (MBTA), the Bald and Golden Eagle Protection Act (BGEPA), and the Endangered Species Act (ESA), all administered by the U.S. Fish and Wildlife Service (USFWS), are the driving legislation that provides regulatory protection to birds throughout the Duke Energy service area as well as the entire U.S. All three statues prohibit "take" (a broad term that is defined under each statute) and are describe in Section 5 of the APP. Utilities such as Duke Energy may incur fines and other penalties from accidentally "taking" birds during their normal daily operations.

In an ongoing commitment to environmental stewardship and associated avian protection, Duke Energy has revised, integrated, and enhanced the corporate APP based on the guidelines set forth in *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006* and *Reducing Avian Collisions with Power Lines: The State of the Art in 2012* (APLIC 2006; APLIC 2012). Duke's APP is designed to help the corporation and its employees ensure compliance with requirements of bird protection laws, manage bird interactions with power and facility structures, and reduce regulatory risk, and thereby reduce costly system interruptions that are caused by birds. The plan provides information on the following elements:

- An introduction to avian interactions including avian risk factors due to structure types, avian biology, behavior, and weather.
- State and federal regulatory compliance with laws, regulations, and permit conditions.
- Employee and contractor training for avian awareness.
- Managing and reducing avian interactions with distribution and transmission lines, generation facilities, equipment, and electrical substations while increasing system reliability and safety.
- Procedures for responding to avian interaction incidents.

- Procedures for avian incident reporting.
- The siting of new electric facilities to avoid and minimize impacts to avian resources.
- Avian design standards, tools, and processes.
- Areas of avian concern through the development and implementation of an avian risk assessment.
- An Eagle Protection Strategy for our Florida service territory focused on bald eagles.
- Avian enhancement and public awareness measures.
- Key avian resources such as internal subject matter experts, resource agencies by state and region, conservation groups, and wildlife rehabilitation organizations.

The APP is a living document and will be revised, as needed, based on regulatory and procedural changes, internal operational and maintenance changes, revisions to design standards, and improvements in avian protection equipment and techniques.

4.0 Introduction to Avian Interactions

Avian interactions with power lines and structures, including collisions, electrocutions, and nesting have been documented since the early 1900s. It was not until the 1970s that biologists, engineers, resource agencies, and conservationists began to realize the extent of these interactions. It was then that they began investigating and addressing avian interaction issues.

4.1 General Background

Discoveries of large numbers of electrocuted raptors in the early 1970s prompted utilities and government agencies to initiate efforts to identify the causes of, and develop solutions to, this problem. With additional documentation and studies, the impacts of interactions on avian species and power reliability have become more evident.

In 1994, the APLIC, working closely with the USFWS, published *Mitigating Bird Collisions with Power Lines: State of the Art in 1994 (Collision Manual),* which became the companion of *Suggested Practices for Raptor Protection on Power Lines: State of the Art in 1981 (Electrocution Manual).* These publications have been expanded and updated over time (2012 and 2006, respectively) to reflect the most current information for reducing bird interactions, ensuring compliance with bird protection laws, and enhancing the reliability of electrical energy delivery. In 2005 APLIC, in cooperation with the UFWS, released the Avian Protection Plan Guidelines. The principles presented in these three documents intended to allow utilities to tailor an APP that will best fit their needs, while furthering conservation of avian species and improving reliability and customer service.

Utility transmission and distribution structures may pose risks to avian species primarily due to electrocution or collision. Factors that influence these risks relate to the avian species involved, the environment, and the configuration and location of the structures with respect to other structures or topographic and other landscape features.

Species-related factors that influence interactions include habitat use, body size, flight behavior, age, sex, and flocking behavior. Generally, the birds that are electrocuted are raptors, crows, thermal soaring species (ex. vultures and storks), cavity nesters, exotic species, and birds that nest on or in utility structures. These avian species are typically those that have large wingspans, occur in open habitats, and/or perch, or nest on power poles. Avian species that collide are generally poor flyers (ducks), heavy birds (ex. swans and cranes), and those that fly in flock formations (ex. swallows, geese, and cowbirds).

Environmental factors influencing avian collision risk include the effects of weather and time of day on utility structure visibility, surrounding land use practices that may attract birds, and human activities that may attract birds or flush birds into lines or structures.

4.2 Electrocutions

Avian electrocutions occur as a result of a combination of electrical design, biological, and environmental factors. The most critical electrical design factor that contributes to avian electrocution is inadequate spacing between two energized parts of an electrical structure or between an energized part and a grounded structure (APLIC 2006). Energized parts include, but are not limited to, the phases (i.e., wires), transformers, capacitors, and jumper wires. Electrocutions can occur when either two energized parts or grounded hardware and an energized part are separated by less than the wrist-to-wrist or head-to-foot distance of a bird (Figure 4.2-1). The wrist-to-wrist distance only considers the fleshy parts of the bird and does not include the feathered wing tips, as dry feathers act as insulation (APLIC 2006). This creates two points of contact for a bird, allowing an electrical circuit to run through it (APLIC 2006). Single-phase, two-phase, or three-phase configurations constructed of wood, concrete, metal, fiberglass, or other materials can pose avian electrocution risks if avian-friendly separation is lacking. Structures with transformers or other exposed, energized equipment account for a disproportionate number of avian electrocutions.

Larger birds of prey such as eagles (bald and golden), ospreys, and vultures (black and turkey), may have a higher risk of electrocution as some electrical design standards may not provide adequate spacing for them to land, perch, and nest on utility structures. An avian-friendly structure must provide proper clearance, insulation, or a barrier between differences of potential (i.e., two different energized phases/parts and between energized and grounded parts). The suggested spacing between energized and/or grounded parts for bald and golden eagle protection is 60 inches of horizontal separation and 40 inches of vertical separation (APLIC 2006).

Biological and environmental factors related to electrocutions are those that influence avian use of structures, including characteristics of the surrounding habitat, prey abundance and availability, species nest selection, foraging, hunting behavior, and weather conditions. Of the 31 species of diurnal raptors and 19 species of owls that regularly breed in North America, 29 have been reported as electrocution victims. Electrocutions have also been reported in over 30 non-raptor North American species, including crows, ravens, magpies, jays, storks, herons, pelicans, gulls, woodpeckers, sparrows, kingbirds, thrushes, starlings, pigeons, and others.

In habitats where natural nest substrates are scarce, utility structures may provide the only available nesting sites for raptors and other birds. Likewise, many birds use power poles and lines for perching, roosting, shading, or hunting which increases avian electrocution risks.

Figure 4.2-1. Avian Interaction with Typical Distribution Structure.

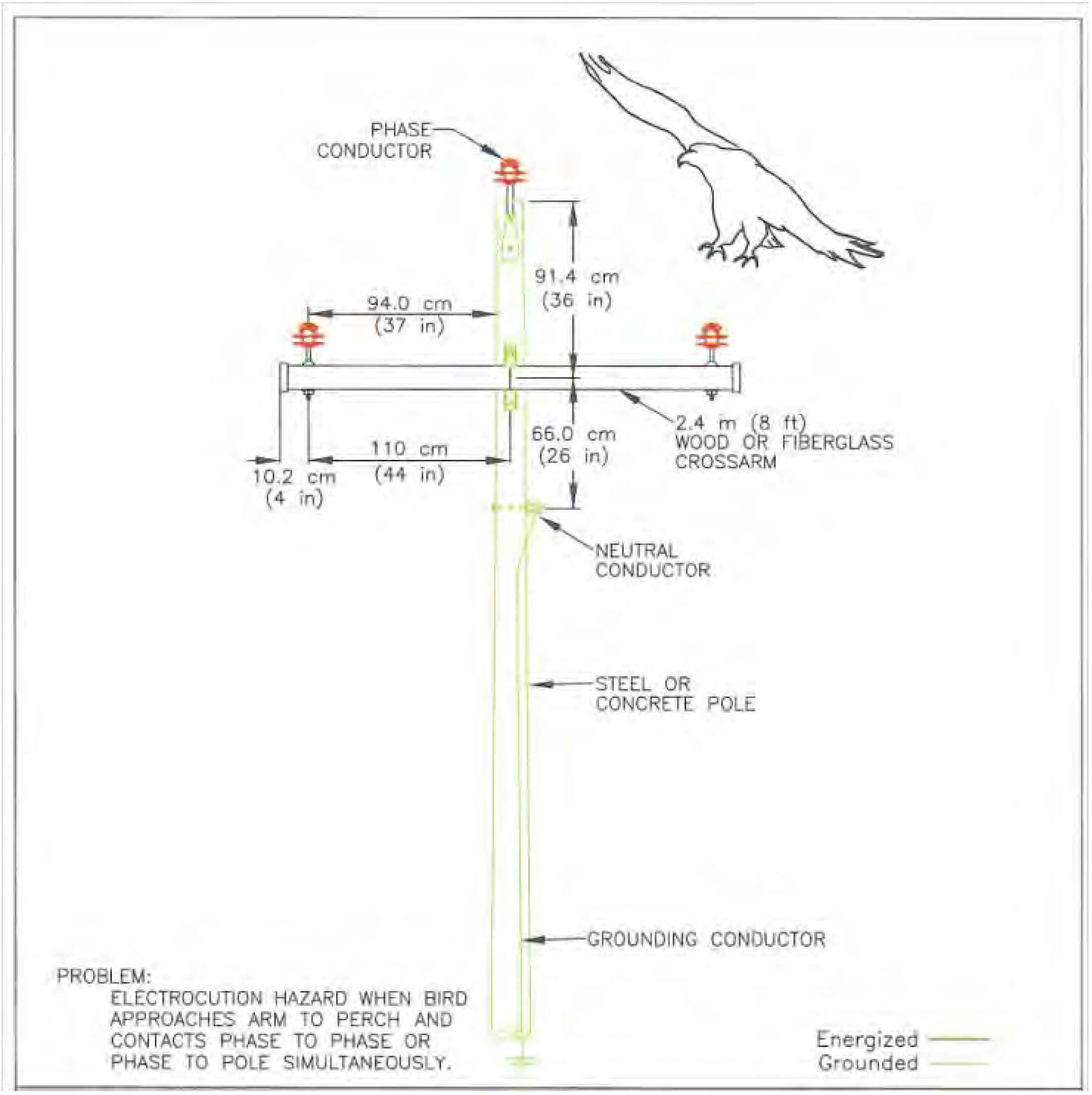


Diagram courtesy of Edison Electric Institute (APLIC 2006)

4.3 Collisions

Collision risk occurs when power lines and structures are not detected by flying birds. In the United States, most studies of bird collisions have occurred since the late 1970s. Results of these studies provided a better understanding of the collision problem and led to a growing awareness of the issue. Studies determined that bird collisions with power lines result from a complex mixture of biological characteristics, environmental factors, and power line configurations (APLIC 2012).

Biological factors include a bird's size, weight, maneuverability, vision, age, sex, health, flight characteristics, flight ability, and flocking behavior. Larger, slower-moving, less agile birds and birds that fly in large flocks (especially during low light conditions or at night) may collide more frequently with power lines and structures. Juvenile birds and birds distracted by hunting, territorial, or courtship activities may be at a higher risk of line collision as well. These species-related scenarios can affect a bird's ability to quickly navigate obstacles such as power lines (APLIC 2012).

Environmental factors that influence the risk of collision include reduced visibility resulting from inclement weather, time of day, season, sudden disturbances, or vegetation that may obscure the line. Surrounding habitats that attract birds to an area with power lines may also increase the chance of collision (APLIC 2012).

Power line configurations, such as size of lines, line placement, line orientation, structure type, and Federal Aviation Administration (FAA) obstruction lighting requirements influence the risk of collisions. Collisions are more likely to occur with line configurations that include an overhead static wire, which is less visible because of its small size (APLIC 2012).

As power line infrastructure expands to meet the growing demand for electricity, the collision risk to avian species also increases. In contrast, this risk may be reduced by assessing possible avian impacts during power line siting and routing, using more visible line and structure configurations, improving line marking devices, standardizing study methods, and increasing awareness of collision issues.

4.4 Other Interaction Sources

There are a number of other utility-related interaction sources that may be responsible for negative interactions with avian species. These sources include infrastructure associated with electrical generation and delivery, such as buildings, communication towers, roadways and vehicles, and maintenance activities, as well as renewable energy facilities.

4.4.1 Buildings

Migratory birds may collide with man-made structures during the day and night. The estimated annual mortality of birds resulting from window collisions in the United States is between 365-988 million birds (Loss et al. 2014). Birds are easily deceived by (and strike) reflected images of habitat and sky on windows installed in the conventional vertical position. Buildings and other structures that remain lit at night and in poor weather may attract migrating birds, resulting in disorientation and possible collision. Birds may also become trapped inside of buildings and be unable to escape, resulting in death from exhaustion or dehydration/starvation. In 2016, the USFWS issued best practices for reducing impacts to birds from buildings and glass. This document provides an excellent discussion and solution examples; the document can be found on the USFWS Division of Migratory Bird Management website.

4.4.2 Towers

Bird collisions with towers and stacks have been reported for over 50 years. The USFWS estimates that communication towers kill four to five million birds annually (Shire et al. 2000). Tall towers with lights and guywires kill significantly more birds than lower towers that are self-supporting (Gehring et al. 2004). Birds that migrate at night are drawn to tower lights, especially in poor weather.

The FAA issued Advisory Circular 70/7460-1L, on December 4, 2015, for guidance on lighting of tall structures. Unless otherwise required by the FAA, only white (preferable) or red strobe lights should be used at night, and these should be the minimum number, minimum intensity, and minimum number of flashes per minute (longest duration between flashes) allowable by the FAA. The use of solid red or pulsating red warning lights at night should be avoided since these lights attract night migrating birds. Tower designs using guywires for support that are located in known raptor or water bird concentration areas or daily and migratory movement routes, should have daytime visual markers (e.g., high-visibility sleeves or line marking devices) on the wires to prevent collisions by these species.

4.4.3 Roadways and Vehicles

Vehicle travel can result in the injury or death of birds due to collisions. The heat emitted by roads, water puddles that form on the roads, forage, and roadside vegetation are factors that may attract birds to roadway areas. In addition to collisions, other impacts to avian species from roadways can include behavior modification, decreased population density, diversity, and breeding success. Species such as killdeer and Canada geese tend to use roads and parking lots as nesting and loafing areas at several Duke Energy facilities.

4.4.4 Maintenance Activities

Vegetation management is conducted regularly to ensure power lines meet North American Electric Reliability (NERC) mandatory requirements; provide safe access for crews during outages or when they conduct inspection and maintenance activities; and reduce potential for wildfires. Crews remove vegetation within the rights-of-way (ROW) that currently, or with short term growth, interfere with safe operation of the line. Crews also remove hazard trees – trees that occur outside the ROW but pose an imminent risk of falling into the lines or structures.

Line clearing crews may encounter and affect active bird nests in vegetation, cavities, or on the ground during inspection, maintenance, or vegetation management activities. Inactive nests may be encountered outside the nesting season. In addition, birds injured from collision, electrocution, entanglement, or other interaction with company infrastructure may be incidentally encountered during these activities.

4.4.5 Renewable Energy Facilities

Increased energy demands and the nationwide goal to increase energy production from renewable sources have intensified the development of renewable energy facilities including wind turbines. Avian impacts from wind energy developments result from both direct and indirect causes. Direct impacts include collisions, and possible electrocution from associated energized infrastructure. Indirect impacts can include species displacement and disturbance, habitat fragmentation, and decreased breeding, population viability, and altered natural behaviors.

4.5 Avian Risk Factors

The risk level for a particular bird species is a composite of its biological characteristics, including its size, nesting behavior, foraging behavior, and habitat preference. Higher risk species tend to have a larger body size, have a larger wing span, perch on structures, nest on structures, or have low flight maneuverability. The following section discusses specific avian risk factors that lead to higher susceptibility to collisions and/or electrocutions.

4.5.1 Use of Structures

Raptors, passerines, and water birds use power structures for hunting, resting, roosting and nesting. Such behaviors are particularly prevalent in habitats where trees, cliffs, and other natural substrates are scarce. For water birds, power poles can provide sites to perch while drying their feathers. Raptors tend to use poles that facilitate hunting success. Poles that provide the greatest height above the surrounding terrain are often favored and may have a higher probability of causing electrocution. Prey density, prey types, and choice of prey can influence the use of structures by avian predators. Agricultural areas attract doves, blackbirds, and starlings, and other birds that may feed on grains or other small prey common to agricultural areas that include electrical infrastructure. Large flocks of birds perching on wires can result in wire damage and localized outages. Any increase in avian activity in or around power equipment yields an increased rate of exposure, and therefore, an increased risk of an interaction resulting in injury.

4.5.2 Avian Size and Age

Birds with large wingspans or very tall birds have the highest risk of electrocution. These birds have a greater probability of touching two energized parts or an energized part and grounded part when they land on, take off from, perch on, or stretch their wings on a utility structure. Tall birds and birds with large wingspans that routinely perch on utility structures such as bald and golden eagles, ospreys, hawks, and vultures, have a high electrocution risk if the vertical or horizontal spacing of two energized parts or an energized and grounded part is insufficient. The 60-inch avian-safe recommendation of horizontal separation between energized and/or grounded parts is intended to allow sufficient clearance for a golden eagle's wrist-to-wrist span, while the vertical separation of 36 to 40 inches allows for clearance of a golden eagle's head-to-foot distance. These avian-friendly separation recommendations will also afford protection to smaller species including hawks. Birds with tall bodies, long legs, long necks, limited maneuverability, or birds that fly with any extended body part may be at an increased risk for collision.

Overall, juvenile birds may be more susceptible to electrocution than adults. Birds that nest on power poles may be electrocuted if the combined wingspans and simultaneous flapping behavior of several young birds cause them to bridge energized conductors and grounded equipment. Inexperienced juvenile birds are also less agile at landing on and taking off from utility structures, increasing the risk of collision or electrocution.

4.5.3 Behavior

Nesting, courtship, and territorial behaviors influence the susceptibility of birds to collision and electrocution. The gregarious behavior of some birds increases interaction risk as multiple birds perch, roost, or nest together. Nest building and prey gathering activities can lead to electrocution when a carried item spans the gap between an energized and grounded conductor. Aggression between species can increase the risk of electrocution and or collision for individual birds. The use of power poles or other structures with energized components for protection from the elements will also increase the risk of electrocution.

4.5.3.1 Perching and Roosting

There is a strong association between raptor activity and utility ROW (Williams and Colson 1989). Raptors are opportunistic and may use power poles for several purposes, such as nest sites, high points from which to defend territories, and perches from which to hunt. Hunting from a perch is energy efficient for a bird, provided that the prey habitat is nearby. Birds prefer some structures because they provide considerable elevation above the surrounding terrain, thereby offering a wide field of view. Roosts may be selected for protection from predators, inclement weather, or for their proximity to food sources.

Identification and modification of these preferred structures may greatly reduce or minimize the electrocution risk on an entire line. However, in areas where lines run through homogeneous terrain, there is no apparent advantage of some poles over others. Favored perches can often be identified by examining crossarms and the ground beneath them for feces accumulation, pellets, or prey remains.

4.5.3.2 Nesting

Utility structures provide nesting opportunities for many species, especially in areas where other nesting habitat is limited. The greatest risk occurs to nesting birds when the nests are built near energized conductors and hardware. Even a nest that is not near energized parts may be a risk because it may draw the nesting birds and young to the area where they may land on an unsafe structure or collide with power lines (APLIC 2006). In addition, birds that nest on utility structures may have an increased chance of electrocution or collision while carrying prey or nesting material to the nest. Large raptors and other birds that nest on utility structures or near energized parts are considered high-risk species.

Because of the body size and site fidelity of bald eagles and ospreys, their nests can grow to be quite large and weigh over 440 pounds (Harness 2005). These large nests may create a structural concern when built on artificial structures. Furthermore, pole fires and electrocution are concerns because nesting material may contact energized wires on smaller distribution lines where parts are closer together. Any nesting material that hangs from talons while flying to nests can result in electrocution (APLIC 2006).

There has also been an increase in non-native species nesting on and in power line structures, including European starlings, house sparrows, Nanday conures, and monk parakeets. Monk parakeets are a communal nesting species that construct large nests from sticks and twigs in urban settings. The nests have been found on substation structures, on wooden poles and support structures, and adjacent to transformers. Pole fires and electrocution are concerns because nesting material may contact energized wires. House sparrows, European starlings, woodpecker species, and American kestrels are examples of cavity nesters. Cavity nesters in utility poles are typically not at risk unless the cavities are adjacent to energized parts (APLIC 2006).

4.5.3.3 Foraging

Foraging behavior may increase avian susceptibility to electrocution. Raptors often perch on high points to defend territories and hunt. Provided that good prey habitat is within view of the perch, certain species of raptors will hunt from a single perch because it is energy efficient (other species only hunt while flying or soaring). Birds may prefer some utility structures because they provide considerable elevation above the surrounding terrain, thereby offering a wide field of view for foraging activities. Certain structures also offer feeding platforms for raptors to consume captured prey. Any object (e.g., snakes, fish) that hangs from a raptor's talons while flying to these feeding platforms can narrow the gap between energized parts (APLIC 2006).

4.5.3.4 Habitat Preference

The Duke Energy service area encompasses a wide array of habitats within North Carolina, South Carolina, Indiana, Ohio, Kentucky, Tennessee, and Florida, consisting of freshwater and saltwater wetlands, coastal habitat, scrub habitat, large lakes, rivers and streams, along with large stands of upland forests and open pasture. Man-made habitats consisting of canals, stormwater ponds, fish hatcheries, and landfills occur within the Duke Energy service territory. Topography and elevation vary significantly throughout the service territory, and land use, vegetative land cover, and structural habitat varies greatly as a result. Within these variations, there are preferred habitats for avian nesting, roosting, foraging, and perching. When birds travel throughout these preferred habitats (e.g. foraging, nesting habitats), they may interact with electric utility structures, increasing the risks of electrocution or collision-related avian incidents.

4.5.3.5 Seasonal Patterns including Migration

Avian interaction risk can vary with season. An increased frequency of eagle electrocutions during winter months can be attributed to greater concentrations of these birds in open areas with power lines. Raptors and other birds are attracted to high seasonal prey concentrations that may occur along power line corridors.

Electrocution rates of avian species may also increase seasonally due to breeding behaviors and the presence of young. These increases relate to courtship, nest building, nest defense, and dispersal of fledglings during the breeding season.

Influxes of birds during spring and fall migratory activities can significantly influence and increase electrocution and collision rates. Biological characteristics, behavior, and local environmental conditions all contribute to avian risk during migratory activities.

4.5.4 Weather

Inclement weather increases the susceptibility of birds to collisions and electrocutions. Wet feathers increase conductivity, and birds have greater difficulty landing on power structures in high winds. The direction of the prevailing wind relative to the crossarm of a power pole can influence electrocution risk. Decreased visibility and maneuverability during weather events can increase the risk of collision with buildings and other structures.

5.0 Regulatory Compliance

5.1 Federal Regulations

5.1.1 Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA; 1918; 16 USC §§ 703-712) administered by the USFWS, is the driving legislation that provides regulatory protection to over 1,000 species of birds, eggs, and nests throughout the Duke Energy service area as well as the entire United States. The MBTA prohibits the "take" of essentially all native birds, their eggs, and active and nests. Exotic species including rock dove (pigeon), English sparrow, European starling, Eurasian collared dove, monk parakeet, Nanday conure, and certain non-migratory game birds (e.g., ruffed grouse, wild turkey, ring-necked pheasant) are not protected by the MBTA. "Take" is defined to include "pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect." The MBTA is a strict liability statute, which means that proof of intent is not required in the prosecution of a "taking" violation. Utilities such as Duke Energy may incur fines from accidentally or incidentally "taking" birds during their normal daily operations. For misdemeanors, the penalties include fines up to $15,000 per violation and/or up to six months imprisonment (see Appendices A, B, and C for additional details).

The MBTA does allow, by permit, some lethal "take" and/or possession of migratory birds. Examples include:

- harvest of ducks, geese and other water birds by hunters permitted by the purchase of a Federal Waterfowl Stamp
- lethal take of certain migratory birds that are causing property damage or creating a safety hazard permitted by the issuance of a depredation permit.
- lethal take of certain migratory birds for scientific research permitted by the issuance of a Scientific Research or Collection Permit.
- temporary possession of migratory birds permitted by a Special Purpose Utility Permit

Non-migratory game birds, including such species as wild turkey, ruffed grouse, bobwhite quail, and ring-necked pheasants may still be protected, however regulation and management of game birds falls under the jurisdiction of individual states.

Duke Energy maintains two federal Special Purpose Utility (SPUT) permits for Migratory Bird Mortality Monitoring. The permits cover Florida, Indiana, Kentucky, North Carolina, Ohio, South Carolina, and Tennessee (Appendix A; more information can be found at Title 50 parts 10, 13 and 21.27 of the Code of Federal Regulations). Under the terms of these permits, Duke Energy personnel in these states are permitted to retrieve, transport, temporarily possess, and dispose of migratory bird carcasses found on company/utility property or ROW. Additionally, Duke Energy personnel are permitted to relocate active nests of non-endangered, non-threatened migratory birds. Records must be maintained of all incidents and nest relocations. Duke Energy must submit an annual report of activities that take place under these permits to the USFWS.

5.1.2 Bald and Golden Eagle Protection Act

In addition to the protections provided to eagles under the MBTA, the Bald and Golden Eagle Protection Act (BGEPA; 1940; 16 USC §§ 668) provides further protection for both bald (*Haliaeetus leucocephalus*) and golden eagles (*Aquila chrysaetos*) (Appendix D). Initially, BGEPA gave legal protection to only the bald eagle. In 1962, it was expanded to include the golden eagle. It currently prohibits anyone without a permit issued by the Secretary of the Interior from taking bald or golden eagles. "Take" is defined under BGEPA as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." In BGEPA "disturb" means: "to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior."

The BGEPA provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald or golden eagle, alive or dead, or any part nest or egg thereof" without a valid permit (more information can be found in part 22 of title 50 of the Code of Federal Regulations). Maximum criminal penalties for misdemeanor violations of BGEPA include fines up to $100,000 for individuals and $200,000 for organizations, and/or up to one year of imprisonment. Second and subsequent violations of BGEPA are felonies with fines up to $250,000 for individuals and $500,000 for organizations, and/or up to two years of imprisonment. Duke Energy employees are expected to report any interaction or likely interaction with a bald or golden eagle, alive or dead, promptly to the Environmental Services' regional subject matter expert (SME) (see Section 15).

5.1.3. Endangered Species Act

The USFWS administers the Endangered Species Act (ESA 1973; 16 USC §§ 1531-1544) as it relates to terrestrial and freshwater species. One of dozens of environmental laws passed in the 1970s, the ESA is designed to protect critically imperiled species from extinction and to recover and maintain those populations by removing or lessening threats to their survival. The ESA requires the USFWS to maintain lists of threatened and endangered species and affords substantial protection to these listed species. An endangered species is at risk of extinction throughout all or a significant portion of its range and a threatened species is likely to become endangered within the foreseeable future. "Take", as defined by the ESA, means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct". Harm is defined as any act that kills or injures the species, including significant habitat modification.

Maximum penalties for misdemeanor violations of the take prohibition of the ESA include fines up to $50,000 and/or up to one year of imprisonment for endangered species and fines up to $25,000 and/or up to six months of imprisonment for threatened species. In the absence of permits or authorization by the USFWS (more information can be found part 17 of title 50 of the Code of Federal Regulations), a fatality of federally listed species from electrocution or collision may result in an enforcement action under the ESA. Additionally, state governments have enacted their own endangered species laws to protect threatened and endangered plants and wildlife that occur within their states.

5.2 State Regulations

Individual states have differing regulations that protect birds; some states have provisions in place that allow for permits. Duke Energy's state permits can be found in Appendix I.

5.2.1 Florida Regulations

Most Florida birds are protected under the Florida Fish and Wildlife Conservation Commission (FWC) regulations. Under Article IV, Section 9 of the Florida Constitution, the FWC has constitutional authority to exercise the regulatory and executive powers of the state with respect to wild animal life and fresh water aquatic life. Florida Administrative Code (FAC 68A-4.001) states that "no wildlife or freshwater fish or their nests, eggs, young, homes or dens shall be taken, transported, stored, served, bought, sold, or possessed in any manner or quantity at any time except as specifically permitted by these rules nor shall anyone take, poison, store, buy, sell, possess or wantonly or willfully waste the same except as specifically permitted by these rules." "Take" is defined to include taking, attempting to take, pursuing, hunting, molesting, capturing, or killing wildlife or freshwater fish or their nests, or eggs by any means whether or not such actions result in obtaining possession of such wildlife or freshwater fish or their nests or eggs" (FAC 68A-11.004). Thus, Florida's take prohibition applies to electrocution and collision of birds at Duke Energy facilities.

The Florida Administrative Code (68A-27) provides a list of protected species within the State. The categories of listed species include Endangered, Threatened, and Species of Special Concern. The specific rule that applies to the avian interactions is 68A-27.003, Killing Endangered Species. This rule states that no person shall kill, attempt to kill or wound any endangered species as designated in Rule FAC 68A-27.003.

Duke Energy Florida's Migratory Bird Nest Removal Permit issued by the FWC allows for the removal of inactive (no eggs or young present) osprey and other migratory bird nests in Florida pursuant to FAC 68A-9.002 and 68A-27.005.

The Florida Migratory Bird Nest Removal Permit also allows for the removal of active nests (eggs or young present), of osprey and other migratory birds in situations that pose a threat to the birds, eggs, or their nests, or pose a threat to human health and life. The Florida SME shall be contacted to determine the eligibility for relocation and to coordinate the proper protocol identified in the permit for the removal and/or relocation of an active nest (see Section 15 for a list of SME contacts). An annual report of all activities that occur under the conditions of this permit is required by the FWC.

The Florida permit does not take the place of a USFWS Special Purpose Utility Permit. The state permit requires a valid USFWS permit and authorizes activities in accordance with federal conditions and restrictions. Annual permit renewal is contingent on providing an annual summary of permitted activities such as monitoring relocated nests to determine the outcome.

5.2.2 Indiana Regulations

In 1973, Indiana passed the Nongame and Endangered Species Conservation Act (IC 14-22-34) which charges the Indiana Department of Natural Resources (IDNR), Wildlife Diversity

Program (WDP) with the management and conservation of nongame and endangered species. A nongame species is "any wild mammal, bird, amphibian, reptile, fish, mollusk, crustacean, or other wild animal" that is not hunted or trapped for sport or commercial use. IC 14-22-34-5 defines "take" to mean to harass, hunt, capture, or kill nongame wildlife including birds, eggs, offspring, or any part. IC 14-22-34-8 provides limits on taking or possession of nongame species relating to possession; transportation; exportation; use; processing; sale; or shipment of nongame species. IC 14-22-34-9 states that it is unlawful to take or possess nongame species. Indiana does not have a specific state permit associated with migratory bird protection.

5.2.3 Kentucky Regulations

Kentucky KRS 150.320 states that no person shall take any wild bird except game birds or live raptors for which there is an open season, either under the laws of Kentucky and the regulations of the Kentucky Department of Fish and Wildlife or the laws of the United States. This law does not protect or in any way limit the taking of the European starling or English sparrow, but any persons taking any of them must have a hunting license. Additionally, no person shall take, disturb, or destroy the nest or eggs of any wild birds except raptors as prescribed by regulation. Kentucky does not have a specific state permit associated with migratory bird protection.

5.2.4 North Carolina Regulations

North Carolina General Statutes § 113-274 allows the North Carolina Wildlife Resources Commission (NCWRC) to give written authorization to conduct an activity over which the NCWRC has jurisdiction including possession and removal of migratory birds and their nests. Duke Energy's Wildlife Migratory Bird Permit, issued annually by NCWRC, authorizes the removal of active nests of federal and state non-endangered, non-threatened migratory birds. It also includes a condition that "the observation of any bald eagle nest occurring on or near any electric power structure shall be reported to the Commission within twenty-four hours."

The North Carolina permit does not take the place of a USFWS Special Purpose Utility Permit. The state permit requires a valid USFWS permit and authorizes activities in accordance with federal conditions and restrictions. Annual permit renewal is contingent on providing an annual summary of permitted activities such as monitoring relocated nests to determine the outcome.

5.2.5 Ohio Regulations

Ohio Administrative Code 1501:31-19-01 provides for the regulations associated with wild animal importing, exporting, selling, and possession. The chapter states that it is unlawful for any person to sell any wild bird unless permitted by this rule, or other wildlife orders through the Ohio Department of Natural Resources, Division of Wildlife. Ohio does not have a specific state permit associated with migratory bird protection.

5.2.6 South Carolina Regulations

South Carolina Section 50-15-30, the Nongame and Endangered Species Conservation Act, prohibits the take, possession, transport, export, process, sale or offer for sale or shipment of nongame wildlife, including birds, except as provided in regulations issued by the state of

South Carolina. Duke Energy's Migratory Bird Depredation Permit, issued annually by the South Carolina Department of Natural Resources (SCDNR), permits the relocation of hazardous active nests of non-endangered, non-threatened migratory birds (Appendix I).

The South Carolina permit does not take the place of a USFWS permit; it requires a valid USFWS permit and authorizes activities in accordance with federal conditions and restrictions. Annual permit renewal is contingent on providing an annual summary of permitted activities such as monitoring relocated nests to determine the outcome.

5.2.7 Tennessee Regulations

Tennessee State Code Title 70-8-101-112, Wildlife Resources, Species Protection and Conservation, Nongame and Endangered species section establishes Tennessee's policy: "to manage certain nongame wildlife to ensure their perpetuation as members of ecosystems, for scientific purposes, and for human enjoyment; … the protection of species or subspecies of wildlife that are deemed to be endangered or threatened elsewhere by prohibiting the taking, possession, transportation, exportation, processing, sale or offer for sale or shipment within this state of species or subspecies of wildlife listed on the United States' List of Endangered Fish and Wildlife as set forth in this part, unless such actions will assist in preserving or propagating the species or subspecies".

Tennessee does not have a specific state permit associated with migratory bird protection, outside of hunting and falconry regulations.

5.2.8 Other State Regulations

DER and PNG currently have operating assets in eleven other states besides the ones listed above. State regulations and permitting requirements vary considerably among these states. In general, state level permits are needed to collect, possess, and dispose of migratory birds. These permits are typically applicable to pre- and post-construction monitoring at DER wind and solar sites throughout the United States.

5.3 Environmental Compliance Manual

Duke Energy's Environmental Compliance Manual's safety- and environmental-related work requirements apply to Duke Energy employees, all departments and subsidiaries, as well as Duke-employed contractors.

One of the chapters included in the Compliance Manual, ADMP-ENV-EVS-00013 - Avian Protection Procedure, provides an overview of the avian protection regulations and the process and procedures for compliance. The major premise of this chapter is that Duke Energy will comply with the MBTA, BGEPA, the ESA, and pertinent state avian protection regulations and laws and will maintain documentation of the company's processes to manage avian power line and facility interactions in an APP. The APP is based on guidelines set forth in APLIC 2005, 2006, and 2012 and forms the basis for the MBTA compliance manual section. This compliance procedure is reviewed annually and was last updated in September of 2019.

Any regulatory changes made to the MBTA, BGEPA, or Duke Energy's migratory bird and depredation permits are incorporated into this program, as well as the Migratory Bird training module, by the effective date of the revised legislation or mandated permit changes. The sections in the Avian Protection Procedure include:

- Purpose and Applicability
- Roles and responsibilities for
  - Subject-matter experts
  - Business unit management
  - EHS field professional
  - Business units
  - Contractors
- Preparation
- Materials and equipment
- Procedure/Process
  - Dead or injured birds
  - Birds in the work zone
- Definitions
- Record keeping
- Training/Qualifications
- State specific requirements
- Related links or information
- Annex: example of a SPUT permit

6.0 Avian Training Procedures

6.1 General Information

Business units shall ensure that Duke Energy's employees and contractors receive training on compliance with the MBTA, and the proper handling of encounters with migratory birds and their nests. The USFWS Special Purpose Utility Permit, issued to Duke Energy, specifically states as a condition that Duke Energy is legally responsible for ensuring adequate training of employees on the permit conditions and associated responsibilities. Duke Energy employees and contractors, who could realistically encounter birds or bird-related incidents during their everyday work activities, should receive an initial Migratory Bird Training and then a refresher course every third year. Environmental Services' designated SME shall review and update Duke Energy's avian protection activities, pertinent Environmental Services compliance manual sections, and avian training material on an annual basis.

6.2 Training Exposure Categories

Initial training is mandatory for employees and contractors within the High Exposure category (25-100% of the work effort outdoors). Employees and contractors within the Low Exposure category (<25% of the work effort outdoors) may only require initial training (Table 6.2-1). Local or department management can determine if "low exposure" employees warrant the training.

TABLE 6.2-1. Exposure categories and associated MBTA training requirements.

	High Exposure Amount of Outdoor Work: 25% or more of work outdoors	**Low Exposure** Amount of Outdoor Work: Less than 25% of work outdoors
Category Characteristics:	• Work around substations, or outdoor generation, distribution, transmission, meteorological, or communication structures • Work in or around a garage, warehouse, generation building/facility, or other structure where birds can easily access the site • Dispatch, supervise, manage, or provide technical support (e.g. engineering, environmental support) for the groups provided below • Provide MBTA training • MBTA subject matter expert (SME) • Environmental contact for the groups provided below	• Work indoors in an office setting for most of daily work responsibilities • Dispatch or supervise the groups provided below • Environmental contact for the groups provided below
Job titles in this category include but are not limited to:	• Distribution/Transmission tech/lineman • Distribution/Transmission C&M • Distribution/Transmission engineering • Distribution/Transmission C&M supervisors • Relay tech/Substation electrician/Telecommunications tech • Wind turbine tech • Facility engineering/Field engineer • Meter reader/ Field meter tech • R&D personnel • Field inspectors • Environmental specialist/scientist/field support/field tech • EHS professional • Material handling tech • Operations & maintenance personnel • Vehicle maintenance personnel • Site services personnel • Environmental chemistry personnel • Site security personnel • Vegetation management specialist/Forester/Landscaper	• Administrative support • Customer support • Lab analysts • Human Resources personnel • Information Technology personnel • Non-assigned individuals (Nuclear sites)
MBTA Training Requirement:	• Initial Computer Based Training (CBT: EN0070) or instructor led training. • A refresher training via CBT, or hardcopy read package, or instructor led training every three years.	• May undergo initial CBT: EN0071 or an instructor led training.

6.3 Computer Based Training

Initial and refresher training can be done via computer-based training module (CBT) slideshow. The slideshows are also available in hardcopy for those employees who do not have access to a computer. Additional training materials include a flowchart (Appendix E) and an MBTA information handout (Appendix F). Handouts and the CBT slideshow are also available in Spanish. The CBT is the primary and recommended method for MBTA training. The CBT requires 15-30 minutes to complete.

Elements of the Migratory Bird CBT include:

- Rationale for MBTA training
- Mission and purpose of Duke Energy's migratory bird management
- How the MBTA affects Duke Energy and its employees
- Instructions on reporting bird incidents

6.4 Site-Specific Training

In addition to the CBT training, instructor (i.e., SME) led training can also be provided (at request) through individual site or departmental workshops. Duke Energy also provides each facility and field office with posters (Appendix G) to remind employees of their responsibility and the corporation's responsibility to comply with migratory bird laws and how to access the 24-hour Migratory Bird Hotline. Business units should post the 24-hour Migratory Bird Hotline number in prominent locations and encourage employees to use this in-house service whenever the need arises. Wallet cards (Appendix G) with basic instructions and resource phone numbers are distributed to each employee who receives Migratory Bird Training.

DER wind sites and some solar sites have specific training requirements that address avian and bat resources. The elements of these training requirements are outlined in each site's BBCS.

7.0 Construction Design Standards for Avian-Safe Structures and Mortality Reduction Measures

7.1 Suggested APLIC Practices

Distribution, transmission, and substation construction standards must meet National Electric Safety Code (NESC) requirements and should provide general information on specialized construction designs for avian use areas. In addition to these design standards Duke Energy will (1) implement and comply with this comprehensive APP; (2) ensure its actions comply with applicable laws, regulations, and permits; (3) document bird mortalities and problem structures, lines, and nests; and (4) provide information, resources, and training to improve employee knowledge and awareness of the APP (APLIC 2005; APLIC 2006; APLIC 2012).

Duke Energy relies, in part, on construction configurations recommended by APLIC including *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006* (APLIC 2006) and *Reducing Avian Collisions with Power Lines: The State of the Art in 2012* (APLIC 2012). These designs are used in areas where new construction should be avian friendly, as well as where existing infrastructure (e.g., distribution lines) is to be retrofitted or modified to provide avian safety (APLIC 2006). Modifications and retrofits of existing facilities are necessary when dead or injured protected birds are found and where high-risk lines are identified (e.g., near bald eagle nests) (APLIC 2006). Retrofitting to prevent avian fatalities and increase system reliability can include covering jumper cables, conductors, and equipment; discouraging perching through deterrents; and reframing or replacing the structure (APLIC 2006).

Two basic principles are considered when constructing avian-friendly structures: isolation and insulation. Isolation refers to providing a minimum separation between phase conductors or conductors and hardware (APLIC 2006); it is most often applied to new or rebuilt structures where avian electrocution is a risk. Insulation refers to covering phases or grounds (e.g., phase covers, covered jumper wires, bushing covers, cutout covers) where adequate separation is not feasible (APLIC 2006).

Avian-friendly structures are those that provide adequate clearances to accommodate a large bird between energized and/or grounded parts (APLIC 2006). Therefore, 60 inches of horizontal separation, which accommodates the wrist-to-wrist distance of an eagle (approximately 54 inches), is used as the Duke standard for raptor protection (APLIC 2006). In addition, vertical separation of at least 36 inches can accommodate the height of an eagle from its feet to the top of its head (approximately 31 inches). Distribution lines are constructed with smaller separations between energized conductors and between energized conductors/hardware/grounded wires than transmission structures. Therefore, avian electrocution risk is greater at distribution lines (APLIC 2006).

The following general guidance is provided for retrofitting/modification of existing facilities (APLIC 2006):

- In areas of vulnerable or high-risk avian populations (e.g., near bald eagle nests, adjacent to large wetlands and waterbodies, near wading bird rookeries, near fish hatcheries), lines built to past construction standards may present threats to birds.
- Phase to phase and phase to ground separation of most transmission lines is typically greater than 60 inches and the likelihood of avian electrocution occurring at voltages over 60 kV is low.
- Electrocutions that have occurred on distribution lines with crossarm construction should be evaluated carefully. Modifications on entire sections of line are generally not necessary in response to an isolated electrocution event.
- Poles supporting additional electrical equipment (e.g., switches, transformers, jumpers) in avian use areas are more likely to cause electrocutions.
- Double dead-end structures and three-phase corner configurations are favorite raptor (e.g., ospreys) nesting and perching structures. Covered phases and jumpers can provide solutions to avian issues on these structure types.

In areas where birds frequently collide with conductors, ground wires, and shield wires, or where large listed species (e.g., whopping cranes, wood storks, California condors) are present, appropriate siting and line placement will reduce the likelihood of collisions (APLIC 2012). Implementing Duke's avian-friendly construction standards will reduce future legal and public relations problems, enhance service reliability, and significantly reduce avian fatalities. If siting and line placement, are still not effective or not feasible, visual enhancement devices such as line marking devices can reduce collisions on new or existing lines (APLIC 2012).

7.2 General Corporate Design

Duke Energy avian-friendly construction, designed to reduce electrocutions, provides conductor separation of 60 inches (on the horizontal) between energized conductors and grounded hardware, or covers energized parts and hardware if such spacing is not possible. In areas where birds frequently collide with conductors/ground wires, or where agencies are concerned about the safety of protected birds (e.g., near wildlife refuges), appropriate siting and placement of lines reduces the likelihood of collisions. When possible, siting new lines in areas where birds concentrate (e.g., wetlands, stream crossings, historic staging areas, roosts, and nesting colonies) is avoided and vegetation or topography that naturally shields birds from colliding with the wires (e.g., placement next to cliffs or trees) is used to help reduce collisions. Where line siting is not feasible (e.g. in an existing ROW) line marking devices can be used.

Avoiding or reducing bird collisions with windows for commercial and institutional buildings can be challenging. Most avian collisions with buildings happen during the day, as birds are foraging; however, night time inclement weather (especially during spring and fall bird migration), can create a situation in which birds are attracted to lighted buildings or site flood lights. These light "clouds" can cause birds to collide with the building or become trapped in the "cloud" and fly until exhaustion.

The USFWS has stated that 56 percent of avian mortality occurs at low-rise (i.e., one to three story) buildings while less than 1 percent occurs at high rises. Duke Energy has many facilities, both manned and unmanned. When possible, all Duke Energy building exterior and interior lights should be turned off during the spring and fall migration periods (April-May and September-October) from 11 pm to 5 am. Certain locations may be required to maintain lighting for human health and safety, lighting should be reduced to the minimal requirements during the two-month spring and two-month fall migration periods. Additionally, exterior treatments applied on the outside of see-through windows and reflective glass (UV sensitive films or decals) can be used to prevent bird-glass collisions. Individual site assessments can be completed to determine the appropriate solution. These assessments will consider the facility needs, human health and safety, bird use of the surrounding habitat/site, alternative lighting regimes, and history of interactions.

7.3 Regional and Facility-Type Design Specifics

7.3.1 Florida

Duke Energy Florida has established avian-friendly construction as 60 inches of spacing on horizontal structures and 36 inches of spacing for vertical construction. These specifications were established based on common sizes of Florida's raptors, in particular bald eagles, which range from 18" to 28" in height (head to foot) (APLIC 2006). As an alternative to these spacing guidelines, appropriate protective insulation and/or barriers can be used between differences of potential.

Many species of birds in Florida that spend much of their time in or near water, such as herons, egrets, ibises, storks, pelicans, cormorants, and osprey, may be at increased risk of electrocution due to wet wing feathers. In addition, wing-spreading behavior exhibited by cormorants or vultures increases electrocution risk.

Installing various line marking devices has been shown to reduce avian power line collisions. In cases of known electrocution or multiple collisions, lines or poles are retrofitted to reduce future risks. Design standards for new and retrofitted lines in Florida have been developed that are appropriate for the species and conditions that are known or expected to exist.

Ospreys are common in Florida and use utility structures for nesting more than any other raptor. They typically select poles that are located near or over waters where fish are abundant. The greatest risk occurs when the nests are built near energized conductors and hardware. Additional information can be found in Appendix J.

7.3.2 Carolinas

Duke Energy Carolinas has established avian-friendly construction as 60 inches of spacing on horizontal structures and 36 inches of spacing for vertical construction. These specifications were established based on common sizes of North and South Carolina raptors, in particular bald eagles, which range from 18" to 28" in height (head to foot) (APLIC 2006). As an alternative to these spacing guidelines, appropriate protective insulation and/or barriers can be used between differences of potential.

Installing various line marking devices has been shown to reduce avian power line collisions. In cases of known electrocution or multiple collisions, lines or poles are retrofitted to reduce future risks. Design standards for new and retrofitted lines in the Carolinas have been developed that are appropriate for the species and conditions that are known or expected to exist. Additional information can be found in Appendix J.

7.3.3 Midwest

Duke Energy Midwest has established avian-friendly construction as 60 inches of spacing on horizontal structures and 36 inches of spacing for vertical construction. These specifications were established based on common sizes of Indiana, Ohio, Kentucky, and Tennessee raptors, in particular bald eagles, which range from 18" to 28" in height (head to foot) (APLIC 2006). As an alternative to these spacing guidelines, appropriate protective insulation and/or barriers can be used between differences of potential. Increased spacing for golden eagles is not warranted at this time; since the species has yet to establish a persistent population in the Midwest.

Installing various line marking devices has been shown to reduce avian power line collisions. In cases of known electrocution or multiple collisions, lines or poles are retrofitted to reduce future risks. Design standards for new and retrofitted lines in the Midwest have been developed that are appropriate for the species and conditions that are known or expected to exist. Additional information can be found in Appendix J.

7.3.4 Renewables

7.3.4.1 Wind Power Facilities

DER follows the tiered approach provided by the USFWS's *Land-Based Wind Energy Guidelines* (WEG) that was finalized in March 2012 (USFWS 2012). To demonstrate adherence to the WEG, each wind site prepares a Bird and Bat Conservation Strategy (BBCS) that clearly outlines adherence to each Tier as a wind project progresses from an early development project, through construction and during the first several years of commercial operation.

The WEG includes five separate tiers. Each tier offers a set of questions to help the developer evaluate the potential risk associated with developing a project at the given location. The WEG tiers are as follows:

- Preliminary site evaluation
- Site characterization
- Field study to document site wildlife/habitat and predict project impacts
- Post-construction studies to estimate impact
- Other post-construction studies

DER also, where applicable, will prepare an Eagle Conservation Plan per the guidance of the *Eagle Conservation Plan Guidance, Module 1 – Land-based Wind Energy, Version 2* that was finalized in April 2013 (USFWS 2013) and apply for an eagle take permit. For both WEG and Eagle Conservation Plan Guidance, the cornerstone of adherence is communication and coordination with the USFWS and State wildlife resource agency throughout each Tier. Additional elements for an eagle take permit application's consideration were included in the BGEPA regulatory revisions completed in 2016

DER wind facilities use state-of-the-art, best available technology turbine and support structure design. These include the use of low rpm (18 rpm maximum) turbine generators and tubular steel support structures. Specifics of turbine design vary by site and details can be found in the respective BBCS.

Pre-construction Tier 3 studies include avian point-count surveys, eagle-use surveys, and other site-specific surveys (e.g., prairie grouse lek surveys), as appropriate. The Tier 3 studies also include raptor/eagle nest surveys. The raptor/eagle nest surveys are done to inform the micro-siting of the final turbine layouts and to ensure that appropriate non-disturbance buffers are employed during the construction phase. Construction crews are trained and restricted from working within the non-disturbance buffers of active raptor nests. Buffers, as determined by species, site conditions, and operational concerns, are developed for raptor nests located within and/or near the wind site boundary. Construction best management practices (BMPs) will also address other potential impacts to non-raptor migratory birds and/or nests.

Best management practices are instituted at all DER's construction sites. Depending on the particular wind site's wildlife profile, BMPs tailored to the site's wildlife issues may be instituted as provided in the site-specific BBCS. On-the-ground management of wildlife BMPs during construction is coordinated by an on-site EHS specialist that supports DER's construction projects. All of these management duties are overseen by the DER Environmental Director with support from the Environmental Services/Natural Resources group.

Where feasible, all collector lines are buried. Any overhead electrical collection, distribution, and transmission lines are constructed in accordance with Duke Energy's standards which are based on the suggested practices of APLIC for raptor protection on power lines (APLIC 2012).

Line marking devices can be installed, where feasible, where raptor or water bird use would be expected to occur at greater frequencies. These areas are evaluated on a case-by-case basis. If required at a wind site, permanent meteorological (Met) towers are constructed of free-standing lattice construction where possible. If guyed Met towers are necessary, line marking devices or other marking devices are installed to increase visibility of the guywires. Temporary Met towers which are used to collect wind, bat acoustical and other weather data in the pre-construction phase are removed after the site is built or if no longer required for site operation.

Speed limits are set for the duration of construction and also for operations if wildlife mortality concerns are present. Additional information can be found in Appendix J.

7.3.4.2 Solar Power Facilities

Solar power facilities do not have the same USFWS formal guidelines or guidance similar to the WEG. However, DER uses the tiered approach for siting and development (Tiers 1-3) for solar projects to avoid and minimize both direct and indirect impacts to avian resources. On a case-by-case basis, DER will use Tier 4 monitoring for fatalities. The Tier 4b approach for determining indirect impacts resulting from habitat loss or displacement is useful for assessing any potential impacts.

Pre-construction wildlife studies identify foreseen impacts to wildlife including migratory birds. These studies include surveys of migratory bird presence, habitat features, and nesting raptors and other birds to inform micro-siting of solar panels and ancillary facilities; this ensures disturbances during construction and placement of solar panels and infrastructure are reduced. Construction crews are restricted from working near active raptor nests using buffers (as determined by species and operational concerns) which are developed for nests located within the solar site boundary.

General BMPs are instituted at all DER's construction sites. Depending on the particular solar site's wildlife profile, BMPs tailored to the site's wildlife issues may be instituted. On-the-ground management of wildlife BMPs during construction is coordinated by the on-site EHS specialist that supports DER's construction projects. All of these management duties are overseen by the DER's Environmental Director with assistance from the Environmental Services/Natural Resources group.

Where feasible, all collector lines are buried. Any overhead electrical distribution and transmission lines are constructed or modified in accordance with Duke Energy's standards which are based on the recommendations of APLIC for raptor protection on power lines (APLIC 2006).

Where feasible the APLIC suggested practices for reducing avian collisions with power lines is referenced (APLIC 2012). Line marking devices are installed, where feasible, where raptor or water bird use would be expected to occur at greater frequencies. These areas are evaluated on a case-by-case basis. Additional information can be found in Appendix J.

7.3.5 Natural Gas Operations

7.3.5.1 Pipes

A variety of pipe and vent configurations with ends open to the atmosphere, both vertical and horizontal, have been documented to serve as nesting cavities and foraging areas for avian species (e.g., swallows, finches, wrens, bluebirds, English sparrows and European starlings). These pipes are aa source of mortality for bird species (e.g., birds become trapped in the pipe).

Birds have been documented using horizontal pipes with diameters as small as 1.5 inches and as large as 12.0 inches in diameter for nesting. Mortality has been typically associated with larger diameter vertical pipes (>3.0 inches in diameter) where the birds fall in and become trapped. Dead birds, bird nesting material, and other associated debris/waste material in discharge pipes and vents may render the associated equipment inoperable, jeopardize facility safety, cause air discharge problems and obstructions, induce fires, and induce labor intensive maintenance issues. PVC pipes are sometimes used as survey markers, sample point markers or other landscape markers. These pipes, when they are >1.5 inches in diameter can be a source of mortality. When such pipes are used in the field, they should be capped with a cover to prevent entry by birds.

1. Duke Energy has two risk groups for systems that contain piping open to the atmosphere:
   a. Blockage of the piping, due to wildlife related causes, could render the associated equipment (e.g., generator) unable to function or
   b. Blockage of the piping due to wildlife related causes, would not render the equipment unable to function but would result in wildlife mortality if the system is actuated (e.g., relief valves that are normally inactive)
2. Based on the risk groups stated above, Appendix O summarizes the various pipe configurations typically found at Duke Energy facilities, type of likely bird use, the risk of bird use (Unlikely, Low, High), and proposed mitigative measures.

8.0 Nest Management Procedures

8.1 General Guidance

Numerous bird species have been identified as nesting on or in Duke Energy utility structures. Bird nests, both for species covered and not covered under the MBTA, are responsible for the expenditure of tens of thousands of dollars yearly to protect birds from electrocutions and strikes, as well as protect Duke Energy customers from outages. Nests are often found on and in distribution and transmission poles, on substation equipment, and other facility structures. The most prolific species nesting on Duke Energy utility structures is the osprey. Other species such as bald eagles, great blue herons, great horned owls, American kestrels, monk parakeets, and various species of woodpeckers have been found nesting on and in facilities. Nesting on Duke Energy utility structures presents an increased risk to adult and fledgling birds for electrocution or collision with lines and equipment. These interactions are often caused by adults building nest, perching around the nest or bringing food to the nest, and fledglings learning to fly.

Additionally, bird nests on transmission and distribution structures present an increased risk to the reliability of Duke Energy's system resulting in customer outages. Table 8.1-1 identifies species known to nest on (stick nest) or in (cavity nest) Duke Energy utility structures. For nest management purposes, Table 8.1-1 provides detailed information by species on the approximate length of times for egg incubation and for fledging of young birds. A flowchart in Appendix E helps provides step-by-step guidance on handling a nest. It is important to note that nests are only protected under the MBTA when the nest is active; an active nest is one that has eggs or chicks in it or if there are young birds present that are still dependent on the nest for survival.

Nests of wrens and bluebirds in electric service panels and meter boxes of new homes are one of the most common bird issues encountered by Duke Energy. When Duke Energy employees arrive on site to provide electric service to these new homes they can encounter bird nests where the meter needs to be installed. When the meter box cannot be installed at a later date (after the young have fledged) our employees are trained to relocate these nests to an artificial nest box provided by Duke Energy's avian SMEs (Appendix H) and place the box as close to the original nest site as practical. Temporary nest boxes can be obtained through contacting the regional Migratory Bird Hotline (Section 10.2).

Woodpeckers also use Duke Energy power poles for nesting. Employees are trained to check for woodpecker nests prior to removing a pole. If an active woodpecker nest is discovered the crew leaves the pole until after the birds have fledged. If this is not possible, electric components and lines may be relocated to a new pole erected beside the old pole (Appendix H). The old pole is allowed to remain until after nesting season and even longer if it does not pose any operational threat or safety concern. The section of pole that contains the woodpecker nest may also be cut out and affixed to the new pole. The preferred approach is to leave the pole alone until after the birds have fledged and then take the necessary steps to repair/replace the pole.

Bald and golden eagle nests are always protected (both when active and inactive); additional information on eagle nests can be found in Appendix K. The nests that belong to certain species protected under the ESA may also have special provisions or restrictions; additional information for these species can be obtained through the regional Migratory Bird Hotline (Section 10.2) or by contacting the regional SME (Section 15).

Table 8.1-1. Birds known to nest on (stick nest) or in (cavity nest) Duke Energy utility structures along with approximate egg incubation time and approximate time to fledge.

ommon Name	Scientific Name	Nest Type	Incubate Eggs (days)	Hatching to Fledging (days)
American crow	*Corvus brachyrhynchos*	Stick Nest	19	35
Bald eagle	*Haliaeetus leucocephalus*	Stick Nest	35	77
Barn owl	*Tyto alba*	Cavity Nest	34	60
Barn swallow	*Hirundo rustica*	Cavity Nest	16	24
Barred owl	*Strix varia*	Cavity Nest	33	45
Carolina wren	*Thryothorus ludovicianus*	Cavity Nest	13	14
Chimney swift	*Chaetura pelagic*	Cavity Nest	19	25
Common Raven	*Corvus corax*	Stick Nest	21	28
Downy woodpecker	*Picoides pubescens*	Cavity Nest	12	22
Eastern bluebird	*Sialia sialis*	Cavity Nest	15	18
Eastern screech-owl	*Megascops asio*	Cavity Nest	26	32
English sparrow	*Passer domesticus*	Cavity Nest	14	15
European starling	*Sturnus vulgaris*	Cavity Nest	15	22
Fish crow	*Corvus ossifragus*	Stick Nest	18	21
Great blue heron	*Ardea herodias*	Stick Nest	29	60
Great crested flycatcher	*Myiarchus crinitus*	Cavity Nest	15	15
Great horned owl	*Bubo virginianus*	Stick Nest	35	35
House wren	*Troglodytes aedon*	Cavity Nest	13	14
Monk parakeet	*Myiopsitta monachus*	Stick Nest	25	42
Nanday conure	*Nandayus nenday*	Cavity Nest	26	42
Northern flicker	*Colaptes auratus*	Cavity Nest	13	28
Northern rough-winged swallow	*Stelgidopteryx serripennis*	Cavity Nest	16	21
Osprey	*Pandion haliaetus*	Stick Nest	33	60
Pileated woodpecker	*Dryocopus pileatus*	Cavity Nest	18	28
Purple martin	*Progne subis*	Cavity Nest	17	30
Red-bellied woodpecker	*Melanerpes carolinus*	Cavity Nest	13	26
Red-headed woodpecker	*Melanerpes erythrocephalus*	Cavity Nest	14	27
Red-shouldered hawk	*Buteo lineatus*	Stick Nest	25	42
Red-tailed hawk	*Buteo jamaicensis*	Stick Nest	32	42
Southeastern American kestrel	*Falco sparverius paulus*	Cavity Nest	30	30
Tree swallow	*Tachycineta bicolor*	Cavity Nest	16	24
Wood duck	*Aix sponsa*	Cavity Nest	32	1

8.1.1 Working Near Active Nests

8.1.1.1. Protocols

The presence of an active nest near a proposed work zone may affect the time and duration that work may be performed. Guidance for working near active nests may vary by state or region. Work activity shall not interfere with normal nesting behaviors. Eggs and chicks can be sensitive to temperature adjustments. Adult birds can become stressed by a perceived threat. The ES, regional SME, or Migratory Bird Hotline should be contacted for specific guidance (Section 15 or Section 10.2, respectively).

Actions aimed to eliminate risky nest building include: removing nest debris, installing nest or perch deterrents, and/or installing an alternate nest platform. Nests on electrical equipment should be identified and reported for nest relocation throughout the year. Proactively addressing new nests that are discovered out of nesting season (October – February for osprey) allows more time for scheduling mitigation. A nest left on an electrical structure may be active during the next nesting season.

8.1.1.2 Reporting

All work on structures containing active nests should be documented and reported to the Migratory Bird Hotline, or regional the SME; as described in Section 10.2.

8.1.1.3 Safety

When work near an active nest is unavoidable, precautions should be taken. Workers may need to defend themselves from a nesting bird, particularly osprey and bald eagles. Although rare, bald eagles or osprey may use these talons to defend their nests; the large talons of bald eagles and osprey can puncture human skin. Wear proper personal protective equipment (PPE) at all times.

8.1.1.4 Vegetation Management Activities

Personnel should schedule tree-trimming activities to avoid sensitive nesting areas during nesting season. Certain clearing and trimming activities are considered temporary activities. Contact an ES or regional SME (Section 15); or the Migratory Bird Hotline (Section 10.2) for more information.

8.1.1.5 General Maintenance Activities

Many maintenance activities are considered temporary in nature and are therefore permitted on or around nested structures. Precautions, as previously discussed, should be taken to avoid stressing the adult birds or causing exposure of eggs or chicks. Contact an ES or regional SME (Section 15); or the Migratory Bird Hotline (Section 10.2) for more information.

8.1.2 Relocating Active and Inactive Nests

Raptors, and some other avian species, benefit from the presence of power lines by utilizing distribution poles and transmission structures for nesting. Large osprey and other raptor nests built on energized lines can cause power outages and electrocution to birds. Relocation of inactive osprey nests (nests without eggs or young) between October and February is preferred, however, Duke Energy's federal and state permits allow relocation of active nests (Appendices A, B, and I) to nearby nesting platforms when they pose a threat to the birds or to system reliability. Relocated raptor nests are typically monitored monthly during the nesting season for success.

Ospreys and other raptors will also nest on the upper portions of transmission towers. However, the greater separation between conductors on transmission towers generally allows raptors room to nest without causing problems for electric operations or electrocution to the birds, provided the insulator strings are not subjected to contamination (e.g. streamers).

Due to the large size of some nests (i.e., ospreys) a Duke Energy bucket truck is typically used to relocate nests (Appendix H). Consult a regional SME prior to relocating any large, fully formed raptor nest, or active nests, and to obtain nesting platforms (see Migratory Bird Hotline Section 10.2 or Section 15.0 for SME contacts). All other small species' nest relocations should be reported to the Migratory Bird Hotline once the work is completed.

8.1.2.1 Protocols

Duke Energy's Migratory Bird Special Purpose Utility Permit (and the associated state permits) authorize us to relocate active (eggs or chicks present) migratory bird nests (except those of threatened/endangered species or bald and golden eagles) when necessary to alleviate a safety emergency or when the nest is preventing the ability to establish permanent electricity to structures.

The MBTA does not contain any prohibition that applies to the destruction of an inactive migratory bird nest alone, provided that no possession occurs during the destruction. This does not include nests of federally endangered/threatened species, bald and golden eagles, and certain colonial nesting birds. Thus, Duke employees and contractors can remove (i.e., destroy) inactive nests from facilities and structures (e.g., exhaust pipes, vents, facility entrance-ways, support beams) except for nests of those bird groups mentioned above. If the species of the nesting birds is unknown, the SME should be contacted for further instructions. Based on Duke Energy's MBTA and state permits, employees are also authorized to relocate active nests (i.e., with bird young and eggs) of non-endangered/non-threatened migratory birds (see Appendix B for MBTA permit conditions). In specific situations where it is necessary (e.g., public safety, fire hazards, crucial/emergency facility operations) to remove (destroy) a nest that is active, the USFWS can issue Duke Energy an additional permit to take individual birds. The removal of nests belonging to European starlings, English sparrows, Eurasian collared doves, rock doves (pigeons), Nanday conures, and monk parakeets may occur anytime since these species are not protected by the MBTA.

8.1.2.2 Reporting

If a nest is relocated, the person performing the task must have a copy of both the state and federal migratory bird permits (Appendices A and I). Once the task has been completed it must be reported to that person's environmental coordinator or the Migratory Bird Hotline immediately.

Please anticipate any problematic nests (e.g., inactive nests on distribution structures) or nest sites and contact the Migratory Bird Hotline as early in the nesting season as possible to alleviate potential issues with outages, customers, and bird mortality. Duke employees are encouraged to call the Migratory Bird Hotline for assistance on nest incidents, any technical questions, and proper documentation; contact information is in Section 10.2.

8.1.2.3 Safety

When relocating active nests caution must be used with respect to the energized lines, and with respect to the parent birds of the nest. Some species can become aggressive when their nest is being relocated

For temporary work conducted near raptor nests (e.g., tree trimming or vegetation management near an adjacent active red-tailed hawk or owl nest), it is recommended that the employee/contractor use the following guidance:

- The preferred approach is to leave the nest area alone until after the birds have fledged.
- If this is not possible, conduct the work as quickly and efficiently as possible.
- Eggs and young should be carefully removed during cool, not cold, periods of the day.
- Follow proper safety protocols including the use of an on-the-ground spotter, and use of PPE including a hard-hat, safety glasses, gloves, and a protective shirt or jacket. The adult birds will be agitated and will likely stay in the general area: they should return to the nest once the disturbance is gone. Certain species such as goshawks and great horned owls can be extremely aggressive around active nests and can cause personal injury.
- Do not trim any branches or limbs supporting or shading the nest. Branches or limbs shading the nest should be left unless they pose a threat to the electric system or are themselves a violation of regulation.

8.1.2.4 Relocation Techniques

In most cases, nests should be relocated to a suitable location, preferably at the same height, within the proximity of the current nest location. For large nests such as an osprey's, a new, non-energized, pole will be set with a nest platform attached to the top (Appendix H).

Specific nest relocation guidance includes:

- Relocation distances may be from 65 to 325 feet from the original nest site with direct line of sight.
- Any platforms should be placed where conductors and energized equipment will not be fouled by nest material, prey remains, or excrement.
- Nesting platform or nest relocation site should be as high or higher than the energized pole and provide an unobstructed view of the lake or river (if an osprey nest).
- Nesting platform may be installed on a taller non-energized pole or above power lines.
- A perch that extends above the nest or from the platform may increase its desirability.
- On poles (not energized) with platform nests, predator guards (i.e., five feet length of sheet metal wrapped tightly around the pole three to five feet above the ground) should be used to prevent predators such as raccoons from climbing into the nests.
- Incorporate proper safety protocols into the activity.
- Discourage future nesting on the energized pole by properly installing nest deterrents or perch discouragers in the appropriate locations.
- If in doubt, call the Migratory Bird Hotline for guidance.

8.1.3 Nest Deterrents

There are instances where nesting should be discouraged due to risks and hazards to people, equipment, the power system, and the nesting birds. A PVC pipe, corrugated drain pipe, or crossarm cover can be attached to the crossarms to prevent birds from nesting on H-frame transmission structures and double dead-end structures. The structure needs to be mounted close enough to the crossarms (i.e., no more than 10 inches) to prevent the birds from nesting under them. These structures are especially effective for species such as ospreys.

Deterrents used in the past such as triangles, small metal spikes, and plastic owls are often deemed unsuccessful in deterring nesting birds; they can nest between the open spaces between the triangles, can build nests over the metal spikes and are habituated to plastic owls. Large plastic spikes, have been effective as a nest and perch deterrent for species such as ospreys. However, the effectiveness of this measure has diminished with the increase of the overall osprey population; especially in the Carolinas (they actually provide nest building substrate).

Small metal and polycarbonate spikes and netting are effective in keeping birds such as European starlings and rock doves from nesting on facility structural beams, loading docks and garages, and administration building entryways. The installation of these deterrents requires careful planning and implementation due to the presence in active work zones.

9.0 Native and Exotic Avian Nuisance Species

9.1 Canada Goose

9.1.1 Biology Summary

The native Canada goose (*Branta canadensis*) can be found nearly throughout the entire North American continent. Their distribution varies based on season where they can be seen migrating in V-shaped flocks (Alderton 2008). Non-migratory resident Canada geese (*Branta canadensis maxima*) exhibit a high degree of adaptation and can be found in areas with a wide degree of human disturbance (e.g., wildlife refuges to golf courses). They normally graze on species of grasses but also cause considerable damage to agricultural crops (Alderton 2008). Canada geese nest in the spring where a large nest is constructed with down feathers used as lining (Alderton 2008). They are very protective of their nests and often hiss menacingly at perceived threats. This behavior typically causes many incidents of conflicts between geese and humans and may warrant nest management control activities at Duke Energy facilities.

9.1.2 Regulatory Classification

The Canada goose (including non-migratory resident birds) is protected by the MBTA. The species is very common throughout its range and is increasing. The proliferation of open grass areas such as lawns, public parks, golf courses, and greenways has caused a significant increase in available habitat. There are many communities throughout the U.S. that consider the Canada goose a nuisance species based on the hazards it causes (e.g., lawn fouling, airplane collisions, aggressive behavior during nesting season, and others).

9.1.3 Effects on Operations and Maintenance

Canada geese typically nest around wastewater treatment ponds, service water ponds, reservoirs, and other open grass areas at many Carolinas, Florida, and Midwest generation facilities. This can cause conflicts with station personnel in the form of geese attacks while protecting nests, traffic hazards, and the exposure to geese fouling in public places such as picnic areas, boating access areas, and Duke Energy Exploriums. Canada geese are also a risk to Carolinas, Florida, and Midwest Power Delivery operations as they cause significant amount of power outages due to electrocution on transmission and distribution structures.

9.1.4 Management and Control

Prevention of access (via a barrier) to equipment and property from Canada geese is the first alternative recommended by Duke Energy biologists. It is not always possible or practical to exclude geese from areas, so where applicable, Canada goose depredation permits are available for the management and control of Canada geese. These permits are available in the Carolinas, Florida, and the Midwest. For example, in Ohio, the Ohio Department of Natural Resources offers Canada Goose Egg Destruction permits that allow permittees to addle goose eggs by means of shaking, oiling, or puncturing. Duke Energy SMEs coordinate and implement these activities at the request of station personnel (see Section 15.0 for SME contacts by region). Other permits, such as trapping permits, are also available and should be handled by the SMEs on a case-by-case basis.

In the Carolinas, several facilities have had effective and efficient control of resident geese through the use of contracted and specially trained border collies (e.g., Goosebusters). The dog services humanely move the problematic birds off the property through the persistent herding and corralling instinct of the dog. Other Canada geese management and control alternatives would be evaluated on a site-by-site basis by SMEs through careful consideration of biological, public relation, and site-specific factors.

9.2 Turkey and Black Vulture

9.2.1 Biology Summary

The native turkey vulture (*Cathartes aura*) can be found throughout the entire continental U.S. depending on season. As common with other vultures, turkey vultures have a bald head, and get their name from the red coloration on their head which is reminiscent of the wild turkey (Alderton 2008). Turkey vultures can often be seen feeding on the carcasses of dead animals. Their keen sense of smell allows them to locate dead prey items. Turkey vultures will often lay their eggs in the cave of a cliff face, on the ground, and sometimes in a deserted building (Alderton 2008). Turkey vultures are fairly common in the Duke Energy service territory and tend to roost in large concentrations of up to 300 birds on transmission structures and communication towers.

Black Vultures (*Coragyps atratus*) are native can be found throughout the southeastern and eastern portions of the U.S. Black vultures also feed on dead prey items and have also been known to feed on garbage (Alderton 2008). Black vultures seem to be less able to smell dead prey items compared to other vulture species but are adept at tracking turkey vultures to the location of prey items (Alderton 2008). Their breeding habits are similar to turkey vultures where the young usually leave the nest between 70 and 80 days of age (Alderton 2008). Black vultures are also long lived and can have life expectancies measured in decades (Alderton 2008). Black vultures are also common in the entire Duke Energy service territory and will congregate with turkey vultures on transmission structures.

9.2.2 Regulatory Classification

Turkey and black vultures are protected by the MBTA. Although these two species have faced previous threats from DDT, trapping, poisoning, and shooting they have significantly increased their numbers throughout their range including the Duke Energy service territory. Their population trends continue to be positive and seem to have been benefitted by the increase in animal road kill in the U.S.

9.2.3 Effects on Operations and Maintenance

In the Carolinas, Florida and the Midwest, these species have presented themselves as a nuisance species at generation facilities. In particular, both vulture species will congregate around the stacks of generation facilities and cause conflicts with stack testing crews through fouling (feces and regurgitation) and bird fatalities. These birds have also been known to fall into the stacks.

Large concentrations of roosting birds also cause significant issues around Duke Energy hydroelectric facilities, communication towers, and transmission structures. Issues include equipment damage (including personal vehicles and company boats), noxious waste accumulation, and power outages through electrocutions and collisions.

9.2.4 Management and Control

Prevention of access (via a barrier) to equipment and property from vultures is the first alternative recommended by staff SMEs. If avoidance is not practicable, one management activity implemented across the service territory to mitigate vulture issues has been the use of effigies. Suspending a vulture carcass (permit required to kill a vulture) or effigy by its feet from a structure, beam or tower support is an effective means of ridding a structure of roosting vultures. Another control mechanism available is the use of perch discouragers such as large plastic spikes, small metal "teeth" strips, and horizontal stainless-steel wires. Such activities are and have been implemented by Carolina, Florida, and Midwest SMEs at the request of station personnel.

Other measures at Duke Energy facilities include the use of combustion cannons to disperse roosting birds. The key to the use of cannons is that the location and timing of the cannons needs to periodically be varied so the birds do not become habituated to the noise. Cannon use is also problematic, due to the intrusive noise, in areas of human use such as near office buildings.

A chemical compound called methyl anthranilate has also been used at several Duke Energy facilities to deter roosting and foraging vultures. While this is an effective vulture deterrent, the misting dispersal system (1) requires frequent maintenance (due to clogging), (2) is quite costly, and (3) is subject to vagaries in wind patterns. All other vulture management and control alternatives would be evaluated on a site-by-site basis by regional SMEs and require through and careful consideration of biological and site-specific factors. Duke Energy SMEs coordinate and implement these activities at the request of station personnel (see Section 15.0 for SME contacts by region).

To combat against the build-up of vulture and other avian waste (e.g., streamers) on transmission structures, several protection measures are available including polymeric and porcelain rigid guano shields and so called "buzzard guard" panels that keep birds from excreting on phase insulators and other critical equipment (see Appendix H).

In instances where all other deterrent efforts have failed, Duke Energy has, at the guidance of the United State Department of Agriculture Wildlife Services Division (USDA), has obtained a depredation permit under the MBTA. This permit allows for USDA to lethally remove vultures that have not responded to other efforts. The need for this permit is evaluated on a site-by-site basis by regional SMEs and require through and careful consideration of biological and site-specific factors. Duke Energy SMEs coordinate and implement these activities at the request of station personnel (see Section 15.0 for SME contacts by region). All lethal removal must be properly reported under the specific permit conditions.

9.3 Rock Dove

9.3.1 Biology Summary

The rock dove (*Columba livia*) or feral pigeon was introduced into the U.S. from Europe and has evolved from a domesticated stock into an independent species (Alderton 2008). This invasive species is usually found in heavily urbanized areas and is an effective scavenger that forages on a wide variety of food items including refuse (Alderton 2008). They often gather in public parks where they are fed by humans. Rock doves can breed during any month of the year and can build nests in shrubs, ledges of buildings, and in abandoned buildings (Alderton 2008). Both sexes take turns incubating the eggs for a period of approximately two weeks (Alderton 2008).

9.3.2 Regulatory Classification

Rock doves and their associated nests are not protected under the MBTA. Thus, it is not necessary to report any interaction (e.g., fatality and nest destruction) with this species. Its populations are stable and widespread.

9.3.3 Effects on Operations and Maintenance

This species has caused fouling issues at generation facilities throughout the Duke Energy system. Rock doves will congregate in large numbers and deposit large amounts of feces on station equipment and property, thus exposing station personnel to potential health and safety issues. Fouling issues can also lead to equipment damage and failure.

9.3.4 Management and Control

Prevention of access (via a barrier) to equipment and property from rock doves is the first alternative recommended by environmental SMEs. Baited live trapping of the birds can also be undertaken. If avoidance and trapping are not practicable, then the use of the chemical frightening agent 4-aminopyridine (i.e., Avitrol) is an acceptable and efficient control measure. Avitrol is mixed with bait such as corn. However, there are specific protocols that need to be followed including time of day, blend ratio, air temperature, location (e.g., not in the vicinity of high personnel traffic areas), and the potential presence of protected birds (e.g., songbirds, crows). Duke Energy has a SDS (16520) for Avitrol. Any decisions to implement these chemicals are made on a site-by-site basis by regional SMEs and require thorough and careful consideration of biological, health and safety, public relations, and site-specific factors. Duke Energy SMEs coordinate and implement these activities at the request of station personnel (see Section 15.0 for SME contacts by region).

9.4 European Starling

9.4.1 Biology Summary

The European starling (*Sturnus vulgaris*) is a species introduced into the U.S. from Europe (Alderton 2008). Its distribution ranges throughout a majority of North America. Like many successful exotic species, European starlings feed on a wide variety of prey items including: berries, insects, and grain/seeds (Alderton 2008). European starling nests are virtually always in a cavity, typically in a building or other structure (such as streetlights and traffic signal supports), old woodpecker holes, or nest boxes. European starlings also occasionally nest in burrows and cliffs (Alderton 2008). The male builds the nest and uses the location to attract females (Alderton 2008). The nesting period usually lasts 21 to 23 days (Alderton 2008).

9.4.2 Regulatory Classification

European starlings and their associated nests are not protected under the MBTA. Like many successful exotic species, they are fiercely competitive for resources and thus their populations are stable.

9.4.3 Effects on Operations and Maintenance

Within the Duke Energy service area, European starlings have historically presented significant challenges to operations and maintenance. The potential of fouling does exist and any such incidents or other related starling issues (e.g., nesting in out-buildings and pipes) would be handled by regional SMEs on a site-by-site basis. Duke Energy has had significant starling issues at several facilities (e.g., Gibson station) in the past including roosting by the thousands on or near the station.

9.4.4 Management and Control

Prevention of access (via a barrier) to equipment and property from European starlings, is the first alternative recommended by Duke Energy SMEs. Other measures at Duke Energy facilities include the use of combustion cannons to disperse roosting birds. The key to the use of cannons is that the location and timing of the cannons needs to be varied periodically so the birds do not become habituated to the noise. Cannon use is also problematic, due to the intrusive noise, in areas of human use such as near office buildings. A chemical compound called methyl anthranilate has also been used at several Duke Energy facilities to deter roosting starlings (see Section 9.2.4).

If avoidance is not practicable, then other alternatives would be evaluated on a site-by-site basis by SMEs through careful consideration of biological, health and safety, and site-specific factors. Control measures such as the use of Avitrol (see discussion in section 9.3.4) and nest deterrent netting are practicable control measures. Decisions to implement these chemicals are made on a site-by-site basis by regional SMEs and require through and careful consideration of biological, health and safety, public relations, and site-specific factors. Duke Energy SMEs coordinate and implement these activities at the request of station personnel (see Section 15.0 for SME contacts by region).

9.5 English Sparrow

9.5.1 Biology Summary

The English or house sparrow (*Passer domesticus*) is also an exotic species introduced into the U.S. from Europe (Alderton 2008). The first birds were believed to be released in Central Park in New York in 1850 (Alderton 2008). Since then the species has spread throughout much of North America. House sparrows feed on a wide variety of prey items including: grains and seeds, livestock feed, discarded food, ragweed, crabgrass and other grasses, and buckwheat (Alderton 2008). House sparrows nest in a variety of locations including: buildings, holes in trees, streetlights, gas station roofs, over hanging fixtures, signs, and a number of other places (Alderton 2008). They keep an untidy nest and nesting usually lasts 10 to 14 days (Alderton 2008).

9.5.2 Regulatory Classification

House sparrows and their associated nests are one of the few birds in North America not protected under the MBTA and like the other two exotic species described above, their populations are stable and widespread.

9.5.3 Effects on Operations and Maintenance

In the Duke Energy Service Area, house sparrows have not historically presented any significant challenges to operations and maintenance. The potential of fouling does exist and any such incidents or other related sparrow issues would be handled by regional SMEs on a site-by-site basis.

9.5.4 Management and Control

Prevention of access (via a barrier) to equipment and property from house sparrows is the first alternative recommended by Duke Energy SMEs. Baited live trapping can be undertaken for this species. If trapping and avoidance are not practicable, then other alternatives would be evaluated on a site-by-site basis by SMEs. Duke Energy SMEs coordinate and implement these activities at the request of station personnel (see Section 15.0 for SME contacts by region). Control measures such as the use of Avitrol (see discussion in section 9.3.4) and nest deterrent netting are practicable control measures. Decisions to implement these chemicals are made by regional SMEs require thorough and careful consideration of biological, health and safety, and site-specific factors.

9.6 Monk Parakeet

9.6.1 Biology Summary

The monk parakeet (*Myiopsitta monachus*), an introduced, exotic, communal nesting species that constructs large nests from sticks and twigs on trees, power poles, and substations in urban settings. This is a medium-sized parakeet that is green overall with a gray forehead, cheeks, lores, and throat. Monk parakeets build large nests, sometimes on utility poles, and nest together. Sexes are similar and they fly in loose flocks of 15 to 20 birds, but flocks of 100 birds are not uncommon.

Monk parakeets are native to subtropical and temperate South America. Their establishment in North America was the result of intentional and unintentional releases of captive individuals in the 1960s and 1970s (Lever 1987). Feral monk parakeets were widely established in many major urban areas by the early 1970s. Stable populations occur in at least 17 states. Florida has the largest population of monk parakeets in the United States.

The diet of monk parakeets is variable, depending on local availability of seeds, fruits, berries, nuts, flowers, and leaf buds. On occasion, monk parakeets will prey on insects and other small invertebrates. Throughout their introduced range, monk parakeets obtain much of their food from bird feeders. They will sometimes forage in flocks, while sentinels perch high on vantage points to keep lookout for predators. Monk parakeets nest in natural or man-made sites, including radio towers, light poles, and other electrical utility structures.

Monk parakeets are unique among parrots in that they build nests out of sticks from whatever is readily available instead of nesting in cavities. The monk parakeet is a highly social species and can either nest singly or in groups of varying size. Nesting structures can get very large, with dozens of pairs nesting within a single structure. Monk parakeets often build their bulky stick nests in electric utility substations and on support structures for distribution and transmission lines.

9.6.2 Regulatory Classification

Monk parakeets and their nests are not protected under the MBTA. Certain states have regulations concerning the sale, possession, and importation of monk parakeets. The Animal Damage Control Act (1931) authorizes the Animal and Plant Health Inspection Service (APHIS) to protect crops and agricultural interests from introduced pests, including monk parakeets. It is illegal to own or sell monk parakeets in several states (California, Georgia, Kansas, Kentucky, Hawaii, New Jersey, Pennsylvania, Tennessee, and Wyoming).

9.6.3 Effects on Operations and Maintenance

Damage to utility structures has been reported from a number of the states in which monk parakeets occur. The nesting of monk parakeets on utility structures in Florida (and other states including Georgia and South Carolina) has increased dramatically in the last 10 years, causing significant amounts of damage to the utility structures and substantial subsequent power outages. Increasing amounts of time and money are being spent to repair damage and remove nests from substations, transmission lines, and distribution lines. The increase in the amount of utility damages, outages, and costs for controlling monk parakeets has been associated with the dramatic increase in monk parakeet populations.

Direct economic damage caused by monk parakeets includes:

- Loss of electric power sales during outages,
- Costs for restoration of power after outages and repair of equipment damaged during outages,
- Costs for removal of nests and other control and mitigation measures,
- Indirect costs for utility management time and effort in attending to problems,
- Costs to electric customers for loss of service or reduced electrical system reliability.

9.6.4 Management and Control

Control and eradication programs are generally controversial, labor intensive, and expensive. In the early 1970s, the USFWS initiated a control and removal program based on the species' reputation as an agricultural pest in South America. This program ended in 1975 and reduced the existing population at that time by approximately 50 percent. Since 1975, however, the species has dramatically increased its population size and distribution in the U.S., and new populations have become established in many urban centers.

The only effective technique for managing monk parakeet nest problem, used to date, is nest removal. Because birds will readily rebuild their nest, an effective nest removal program requires that the birds be removed with the nest. The short-term solution of nest removal is labor intensive and can compound the nesting problem if the birds are not captured, because individual pairs of a colony will disperse to start new nesting colonies.

Possible management options under investigation include: visual deterrence, trapping and removal, ROW and substation habitat management, and biological control. Ultimately, overall control strategies consisting of a variety of flexible approaches will have to be developed. Additional research will be needed to evaluate the effectiveness and costs associated with various management strategies. The Duke Energy SMEs coordinate and implement these activities at the request of station personnel (see Section 15.0 for SME contacts by region).

In addition, any strategy needs to account for public acceptance of the control methods. Since the monk parakeet is also an attractive pet species, it will be important to understand various stakeholders' interests when developing a public communications program. Public communications should emphasize the economic impacts and utility reliability problems associated with the monk parakeet.

9.7 Nanday Conure

9.7.1. Biology Summary

The Nanday conure (*Aratinga nenday*), is a neotropical parakeet that has established a self-sustaining population in the United States. It is a cavity nester that will form rather large communal roosts. This parakeet is mostly green in color with a black facial mask and beak. This species nests in cavities in palm trees and sometimes utility poles.

The Nanday conure is native to South America including areas of southeast Bolivia to southwest Brazil, central Paraguay, and northern Argentina, from the region known as the Pantanal. Caged birds have been released in some areas of the U.S., and have established self-sustaining populations in Los Angeles, California and several areas of Florida. The Nanday conure feeds on seeds, fruit, palm nuts, berries, flowers, and leaf buds. Feral birds also feed at bird feeders.

Nanday conures usually find cavity holes in trees or power line poles in which to nest. It has been found in both developed areas and native pinelands. After raising its young, all birds will form large communal roosts until the next breeding season.

9.7.2 Regulatory Classification

The Nanday conure and its nests are not protected under the MBTA. Certain states have regulations concerning the sale, possession, and importation of exotic birds. The Animal Damage Control Act (1931) authorizes APHIS to protect crops and agricultural interests from introduced pests, including Nanday conures.

9.7.3 Effects on Operations and Maintenance

Cavity nesters in utility poles are typically not at risk unless the cavities are adjacent to energized parts (APLIC 2006). However, nest cavities in power poles, in substation structures, or in transformers can increase the risk of fire or other structural damage.

9.7.4 Management and Control

Physical deterrents are the most effective for managing the Nanday conure nesting problem. Reports of nests and nesting behaviors on utility infrastructure will result in the installation and maintenance of physical barriers to prevent entrance to cavities and other spaces where nests can be established. Trapping and removal may be necessary for established nests that are considered a risk. Duke Energy SMEs coordinate and implement these activities at the request of station personnel (see Section 15.0 for SME contacts by region).

10.0 Avian Reporting Procedures

This section contains procedures that all Duke Energy personnel and/or contractors shall follow in regard to reporting a bird fatality, bird injury, or required nest management on Duke utility structures, other equipment (i.e., substations and switchyards), projects (e.g. vegetation management), or facilities. The following factors determine the appropriate procedures to follow in order to comply with Duke Energy's USFWS Special Purpose Utility Permit, specific state permit requirements, corporate APP, and the corporate Environmental Compliance Manual:

- *Determine significance of incident; is the incident an emergency (e.g., significant outage, fire, immediate threat to birds) or non-emergency situation?*

    - The significance of an incident primarily applies to safety hazards to human health and life, nest management, or eminent bird risk on utility structures or other energized equipment; this can occur at facilities, or during projects such as vegetation management. There are two levels of significance: (1) emergency situation and (2) non-emergency situation.

        1. Emergency situations are defined as those situations in which birds, eggs, or nests, pose a safety hazard to human health and life, or situations when bird life is at immediate risk. In the event of an emergency situation, which requires immediate action or nest management, the SME (see section 15.0) or the Migratory Bird Hotline (Section 10.2) shall be contacted to provide recommendations on the situation, or coordinate the proper procedures and protocol for the removal and/or relocation of an active nest or an inactive protected nest.

        2. Non-emergency situations consist of all other situations in which human health and life or bird life are not in immediate or eminent jeopardy (e.g., nest removal can occur at a later time after the birds have fledged). The SME can be contacted for recommendations, procedures, and protocols.

- *Identification of bird species involved in the incident. Is the bird species a federal or state protected species (e.g., bald eagle, golden eagle, wood stork)?*

    - Correctly identifying the species of bird will determine appropriate procedures for responding to avian incidents and ensures that Duke Energy employees and contractors remain in compliance with the federal and state laws summarized in Section 5.0. For compliance reporting (including in the federal annual reports), the goal is to avoid the entry of "unknown bird" as the species. Avian incidents, associated with federal and state protected species (i.e., Endangered and Threatened), have specific reporting requirements that may be state specific (e.g., ospreys in Florida). An Avian Resource Guide will be available to field employees for species identification. A copy of the Florida guide can be found in Appendix L (the majority of birds found in Florida are found throughout the Duke Energy service area). Photos of the bird can also be sent to the SME via email or text message.

- *Respond appropriately based on the type of incident. The incident will generally consist of the following three types or combination of the three types:*
  - Bird fatality;
  - Bird injury; and/or
  - Nest management

10.1 Avian Incident Reporting

Duke Energy is using an avian-specific data management system for tracking all avian incidents company wide.

The recommended process for reporting avian incidents is to have the incident reporter call the Migratory Bird Hotline number listed in Section 10.2 and provide the necessary information to the SME. A designated avian SME will then enter the information into the avian reporting system. The incident reporter does not have to physically enter the data into the system.

10.2 Migratory Bird Hotline

A key aspect of Duke Energy's avian reporting system is the establishment of in-house Migratory Bird Hotline. The hotline is manned 24-hours per day, 7-days per week. Anytime an employee or contractor encounters a bird issue (i.e., incident or question), regardless of magnitude, they are encouraged to call the hotline for documentation and guidance.

DUKE ENERGY MIGRATORY BIRD HOTLINE PHONE NUMBERS

Migratory Bird Hotline (Carolinas): 1-800-573-3853
Migratory Bird Hotline (Midwest): 1-317-430-4497
Migratory Bird Hotline (Florida): 1-727-386-3084

When an employee or contractor encounters a bird (dead or live) or bird nest (active or inactive) that poses a risk to the bird or Duke's electric system reliability, they should follow the appropriate regulatory reporting pathway for a bird incident (i.e., injury and fatality) or nest management issue. If dealing with a bird incident or nest management issue, employees are advised to call the Migratory Bird Hotline so that a SME can provide specific guidance. Employees and contractors always have the option to call the hotline for guidance on any bird issue. See Appendix E for the associated migratory bird and nest management compliance flowcharts.

When calling the Migratory Bird Hotline with an incident such as an electrocution, collision injury or fatality, or nest management issue, please provide the following information to assist in completing required documentation:

- Bird species or photograph, if possible
- Date of incident
- Location including nearest road, town, county, line/structure name/number, or GPS coordinate

- Incident cause such as bird electrocution or collision or nest issue
- Configuration of the structure (e.g., single phase, three phase, transformer bank, switch pole), if pertinent
- Estimated ground distance and direction of carcass to pole, line, or other structure
- General habitat surrounding the carcass (e.g., forest, grassland, agricultural lands)
- Description of carcass (entire, partial, scavenged, severed wing, burned)
- Estimated date of mortality of carcass (<1 day, 1 day, 2 days, >2 days), if known
- Weather conditions at time of death, if known (temperature, wind direction and speed, cloud cover, and precipitation)
- Any nearby food sources (e.g., fish hatchery, landfill, chicken houses)
- Final disposition of the bird (i.e., buried, incinerated, taken to rehabilitator) is required
- Name and phone number of incident reporter or caller

Avian SMEs who receive calls on the Migratory Bird Hotline or incident reports, records this information in the avian reporting system initial incident data form; when a field crew records a bird incident on their work ticket, they must use an outage code for animal and also describe the incident in the comments field. All outage work tickets are entered into the Outage Link database. SMEs query the Outage Link database for any reference to birds or their nests. It is important to note in the Outage Link entry if the Migratory Bird Hotline was contacted for this response and if the bird was previously reported. This helps to avoid a double reporting of the same incident. This information is combined with information from the avian reporting system Migratory Bird databases and annual reports are generated for state and federal agencies. Based on Duke's Special Purpose Utility permits conditions, reports are maintained for a minimum of five years in a central location.

Duke Energy's reporting process is documented in the migratory bird and nest management flowcharts (Appendix E). Each employee receives detailed instruction on the process when trained and receives a copy of the flowchart.

10.3 Incident and Nest Management Form

As discussed in section 10.1, avian incident and nest management actions are entered into the avian reporting system using specifically designed software. This avian reporting system has multiple tools to separate, organize, and analyze avian interactions with all asset types. The system has a robust integrated quality control mechanism and a quality assurance process is included through an SME validation of all record entries. This system will be updated and revised periodically to reflect changes in requirements and procedures.

10.4 Annual Report

Duke Energy is required to provide year-end annual reports (i.e., annual activity summaries) to the USFWS (i.e., 50 CFR parts 13, 21, & 22), NCWRC, SCDNR, and the FWC documenting avian incidents including the number of species-specific injuries and fatalities, as well as nest management and relocation activities. These reports are based primarily on the incidents reported in the avian reporting system.

10.5 Centralized Records Keeping

Based on the conditions of the MBTA Special Purpose Utility Permit, Duke Energy is required to keep all records associated with the MBTA in a centralized location. Acceptance of the Special Purpose Utility Permit, authorizes the USFWS to audit and/or copy any MBTA related permits, books, or records required to be kept. The avian reporting system provides an ideal central electronic depository for Duke Energy's MBTA related documents and reports.

11.0 Avian Risk Assessment

Avian risk assessment is crucial to the success of Duke Energy's APP. Assessing system assets for avian friendly design allows for the identification of electric utility structures at risk for avian collision or electrocution. As of this APP revision date, Florida and Carolina Regions risk assessments are complete, with the Midwest Region assessment nearing completion.

11.1 Background

Duke Energy owns and operates thousands of miles of power lines some of which already meet our avian-friendly standards and some that pose little risk to birds. Assessing risk includes identifying and prioritizing areas of high risk for bird/power line interaction. These risk factors include the line's proximity to wetland areas, lakes, rivers, national wildlife refuges, established migration corridors, state and local wildlife management areas and other areas that provide good habitat to migratory birds.

Electric lines that traverse these areas and present a collision or electrocution risk are identified and prioritized based on the risk present. Problem poles are also identified where bald eagles or other raptors might perch or where ospreys might build a nest. An example would be a pole immediately adjacent to a large river that provides a good nesting and feeding vantage point for an eagle. High-risk lines and/or poles are identified for retrofitting to our avian friendly standards. Focusing on areas of greatest risk is a cost-effective way of reducing avian mortalities. These projects in high-risk avian areas are then designed to prevent collision and electrocution fatalities.

11.2 Species Included in Risk Assessment

Species analyzed in the risk assessment included: (1) bird species identified at highest risk of probable electrocution or collision, due to size, species population density and known activity in the area; (2) all bird species known to occur within Duke Energy territories that are listed as endangered or threatened, by the USFWS under 50 CFR part 17, informally identified by the USFWS as a species of special concern, or are state-listed species; (3) species that are known to commonly utilize structures for foraging, perching, or nesting; and (4) species identified by state wildlife agencies known to occur within various Duke Energy Regions. Bald eagles, ospreys, raptors and shore birds are considered among the species at risk due to their affinity to perch and nest on utility structures. Birds that are poor flyers, flock formers, water birds with conductive wet feathers, and coastal species influenced by high winds and fog were included in the risk assessment as collision-risk species. See Section 4 for additional information on the dynamics of avian risk.

11.3 Risk Assessment Method

The intent of the risk assessment is to accurately identify the areas of high avian use in an effort to prioritize avian-friendly protocols in the most warranted areas. Overall, the risk assessment integrates biological data (habitat use and other species-specific data) with Duke Energy's service territory. A Geographic Information System (GIS) spatial model was created by combining biological and utility data to predict areas of risk for avian interaction with utility structures. The avian risk areas were established using a spatially explicit habitat suitability index model with available information from local, state, and federal resource agencies, local expertise on bird use and movements, field efforts, and DE Environmental Services.

The process for conducting the Risk Assessment involved three main components: (1) determining and obtaining the most biologically meaningful spatial data for high-risk avian species within Duke Energy's service area; (2) obtaining spatial data for the transmission and distribution networks; and (3) creating a spatial model that predicts avian risk categories (De minimis Risk, Low Risk, Medium Risk, High Risk, and Very High Risk) through the integration of these two distinct data sets.

The first step was to obtain all the relevant biological GIS data, including aerial imagery, land use, soils data, topography, wildlife preserves, public lands, water bodies, coastline, landfills, species-specific data (nest locations, nesting colony locations, flyways, observations, etc.), Important Bird Areas (IBA), and the transmission and distribution system. These spatial data were overlaid onto the Duke's Service Territory within a Section based grid system. A typical section is one square mile containing 640 acres.

Model variables were selected based on the regional discussed above. Species-specific and habitat variables were included in the risk model. These variables were selected with emphasis on specific species and habitat data available at the statewide level. As example, a list of variables used in the Florida Region risk assessment is found in Table 11.3-1.

Table 11.3-1. Risk Assessment Variables and Weights.

Variable	Weight
Important Bird Area	1
500 FLUCCS over 50 acres	3
Coastline	3
Bald Eagle Nests	5
Eagle Nest Territory Area (3,000 foot buffer)	3
Whopping Crane Migration Routes (2 miles)	1
Whooping Crane Observations*	1
Wading Bird Colony	2
Wading Bird Colony Foraging Buffer (5 miles)	1
Wood Stork Colony	2
Wood Stork Foraging Area (CFA)	1
Shorebird and Colonial Water Bird Colony	1
Landfill (Class I)	5
Landfill Buffer (5 miles)	1
* Non-additive variable)	

Weights were assigned to each of the model variables (referred to as Avian Use Components or AUCs) included in the risk assessment. The weights ranged from one (1) to five (5) and were determined based on the importance for each AUC in the risk model. The greater number of AUC within a section, particularly those with greater weight, the higher the risk score.

Each section was then assigned a level of risk (risk category) based on its score. The five levels of risk range from de minimis to very high risk. Table 11.3-2 shows the relationship between the risk category and the assigned risk score, as well as the associated color with the risk category. More specific details regarding the specific region AUC's and weights are available from the Natural Resource unit upon request.

Table 11.3-2. Risk Category, Score & Color.

Risk Category	Risk Score	Color
De Minimis Risk	0-1	Green
Low Risk	2-4	Blue
Medium Risk	5-7	Yellow
High Risk	8-11	Orange
Very High Risk	greater than 11	Red

11.3 Model Results and Validation

Assessment results vary by region; however, the high and very high risk areas matched to those areas known operationally as having the most bird interactions and activity. The accuracy of the risk assessment was examined by comparing the risk categories with the reported electrical outage data and the bird incident reports. In order to conduct the comparison, avian related power outage data and bird incident reports were examined for accuracy and mapped within Duke Energy's service area along with the avian risk categories.

11.3 Summary

The risk assessment identifies the relative avian electrocution and collision risk in all sections that have Duke Energy transmission and distribution structures. This approach focuses remedial and proactive avian friendly actions to the high avian use areas with the greatest likelihood for avian incidents. Duke Energy has implemented avian construction standards in these sections (High and Very High). The risk assessment has been integrated into the construction design process to ensure target assets found within these sections will be built to avian friendly standards. Region specific risk assessments will be evaluated on a minimum three-year basis to make certain the latest species and habitat criteria are included.

12.0 Structure Retrofitting Process and Reporting

Structure retrofitting, including those implemented for avian incidents, is conducted throughout the Duke Energy service areas, and typically recorded by department. It is the objective of the avian protection program to implement a centralized process for tracking avian-induced retrofits on distribution, transmission, and substation facilities. The risk assessment identification provided a launching point for Duke Energy to take action in building a response plan for avian incidents, as well as development of a proactive plan. New construction and rebuilt structures within the identified High and Very High Risk Areas will automatically be built to Duke avian-friendly standards. Duke Energy continues to immediately evaluate and address any structure involved in a bird fatality.

Environmental Services together with Power Quality, Reliability and Innovation, Engineering and Future State Project Management have initiated a Pilot Avian Retrofit Program in Florida in which four distribution feeders were identified as being the highest risk for avian interactions. As a result, 1,600 individual structures were evaluated for avian safety, and were either redesigned or retrofitted with barriers to make them safer. Additional efforts are under way or in the planning stages for the Carolinas and the Midwest.

13.0 Quality Control Measures

A quality control mechanism has been incorporated into this APP to evaluate the overall effectiveness of the company's avian protection processes and the avian permit compliance program including avian awareness training. Compliance with Duke Energy's APP is part of routine site EHS Compliance Audits. Generation facilities, including renewable energy sites, are audited on a rotational basis at least every three to five years. Reports are issued to station managers and deficiencies are tracked to resolution in the avian reporting system.

Additionally, avian subject-matter experts periodically host workshops with customer groups to provide the latest information in avian protection and Duke Energy's overall APP. This is a time for three-way communication and clarification, and a time that customer groups can provide feedback and make suggestions for ongoing improvements.

The quality control component of the APP is an ongoing process. Information gathered during assessments and workshops will be used to improve the effectiveness and timeliness of avian protection efforts as well as reduce costs associated with such efforts.

14.0 Avian Enhancement and Public Awareness Measures

Duke Energy has, and will continue to, promote natural resource protection and actions that benefit local and regional bird populations and other wildlife. Duke Energy commits to a continuing partnership with local agencies and state and federal resource agencies to explore and participate in activities that enhance and restore habitat. Avian and wildlife enhancement activities implemented by Duke Energy include:

- Vegetation Management - Vegetation planting programs focused on natural landscapes, wildlife habitat, energy consumption reduction, and power line ROW will include restoring and enhancing habitat for native birds.

- Installation of artificial nest platforms and perches - Artificial nesting platforms and perches can be installed on utility poles, tower structures, and buildings where nesting sites are limited or where necessary to protect birds, nests, and/or company infrastructure.

- Protection, enhancement, and restoration of riparian and wetland vegetation – Duke Energy will continue to coordinate with local jurisdictions, agencies, and organizations in efforts to protect, maintain, create, and enhance habitat of wildlife and associated public access, and partner with local, state, and federal resource agencies regarding bird protection issues and habitat enhancement opportunities.

As the general public becomes more environmentally aware it is continually important that Duke Energy operates its facilities in an environmentally responsible manner. This includes siting, engineering, constructing and operating its electric generation system in a manner that minimizes its impact on wildlife. Fatalities or injuries to high-profile bird species such as osprey, bald eagles and whooping cranes or public displays of indifference toward wildlife by Duke Energy employees will be not be tolerated by Duke Energy. Successful implementation of an APP will require a thorough understanding of the issues and corresponding protocols. During migratory bird training sessions instructors discuss public awareness issues with Duke Energy employees. Examples of how to effectively handle high-profile bird problems are presented and discussed.

Duke Energy will include avian protection in its ongoing public awareness campaigns. The APP will be highlighted as a formalized program designed to reduce avian mortality and will describe the management efforts taken to reduce avian interactions; this includes the effectiveness of new avian-safe construction, retrofitting actions, ongoing monitoring to detect problem areas, and habitat enhancement activities. Opportunities to increase public awareness of the APP via the internet and social media will also be explored. In addition, Duke Energy will continue to work closely with resource agencies, conservation organizations, the media and the general public on bird conservation projects.

14.1 Florida

Duke Energy Florida continues to explore partnerships with local agencies and state and federal resource agencies that benefit local and regional bird populations and other wildlife. Examples include:

- Kestrel Nest Box Program - The southeastern American kestrel is a cavity nesting raptor that commonly uses power poles as a surrogate to nesting in dead trees. Duke Energy Florida has prepared a Kestrel Habitat Management Plan (Kestrel HMP) in an effort to enhance the success of nesting southeastern American kestrels within the service area. The Kestrel HMP includes components to promote and increase nesting through a nest box installation program, properly managing kestrel nest removals, maintaining kestrel habitats and perch sites, providing personnel training, and establishing routine monitoring and reporting guidelines.

- Nest platform installation - Nest platforms are erected where necessary on poles for large birds such as osprey, eagles, hawks, and herons. The recommendation is to encourage birds to re-nest on natural substrate by excluding nesting opportunities on nearby infrastructure or equipment. These efforts present an opportunity to partner with the public and wildlife conservation agencies and organizations to find and promote suitable nesting substrate nearby.

- Duke Energy Florida provides continued support and participation in various Florida Audubon Society and National Wildlife Federation groups and functions.

14.2 Carolinas

Duke Energy Carolinas continues to explore partnerships with local agencies and state and federal resource agencies that benefit local and regional bird populations and other wildlife. Examples include:

- Generation facilities in North and South Carolina participate in the Wildlife and Industry Together (WAIT) program to enhance wildlife at our stations and the surrounding communities. One project involved the construction and installation of bluebird and tree swallow boxes at various Duke Energy facilities.

- In 1985, Duke Energy partnered with the Carolina Raptor Center to reintroduce ospreys to Lake Norman, North Carolina. Hacking sites were erected with two young ospreys at each site. The birds were fed by Duke Energy employees until they fledged. The population has grown to approximately 125 nesting pairs in 2012 and today Duke Energy generation facilities proactively consult with biologists to erect osprey nesting platforms on their sites in places that will not interfere with operations or harm nesting birds.

- Nest platform and box installation - Nest platforms are erected where necessary on poles for large birds such as osprey, eagles, hawks, and great blue herons, as well as wood ducks. The recommendation is to encourage birds to re-nest on natural substrate by excluding nesting opportunities on nearby infrastructure or equipment. These efforts present an opportunity to partner with the public and wildlife conservation agencies and organizations such as the North Carolina Wildlife Federation.

- Duke Energy Carolinas provides continued support and participation in various North and South Carolina Wildlife Federation groups and functions including wildlife habitat enhancement partnerships.

14.3 Midwest

Midwest generation facilities proactively consult with biologists on these issues and have participated in several avian enhancement projects:

- In 1993, employees at the Miami Fort Station in Ohio built and installed a peregrine falcon nesting box. Peregrine falcons were still on the endangered species list in 1993. From 1997 to 2012, 38 eggs were laid and 27 successfully hatched by three different pairs of falcons.

- In 1997, the decision was made to convert the lands adjacent to Indiana's Gibson Generating Station cooling ponds into a wildlife habitat known as the Cane Ridge Wildlife Area. Duke Energy helped fund this effort and today the area is the home of the largest nesting colony of the endangered least tern east of the Mississippi River. In addition to the terns, more than 300 other species of birds have been documented in this area.

- In Kentucky, the East Bend Generating Station partners each year with the Kentucky Department of Fish and Wildlife to band wood ducks. Banding wood ducks is one of many methods used to monitor and improve waterfowl populations across the country.

- Duke Energy assisted the IDNR in reintroducing the bald eagle to the state. An active bald eagle nest is located at the Gibson Generating Station in Gibson County, Indiana and near the Wabash River Generating Station in Vigo County, Indiana. In addition, there are two active bald eagle nests near the Cayuga Generating Station in Vermillion County, Indiana. Duke Energy personnel work in collaboration with the IDNR to monitor and evaluate endangered avian species found on or near its properties.

In addition, the Midwest region will continue to work closely with resource agencies, conservation organizations, the media, and the general public on bird conservation projects. These include:

- Operation Migration (whooping crane reintroduction) support
- Eagle Viewing Days at Cayuga Generating Station with the American Eagle Foundation
- Wood duck banding at East Bend Station with the Kentucky Department of Fish & Game
- Interior least tern management at Gibson Station
- Peregrine falcon nest box installation and monitoring at various generating stations and company lands
- Installation of bald eagle nesting platforms

14.4 Renewable Energy Facilities

It is continually important that DER operate its facilities in an environmentally responsible manner. This includes siting, engineering, constructing, and operating its electric generation system in a manner that minimizes its impact on wildlife. Public displays of indifference toward wildlife by DER employees, will not be tolerated by DER or the public, and could result in negative media coverage and/or regulatory action by the agencies. This is particularly true with high-profile raptors, such as bald and golden eagles, and hawk and owl species. During migratory bird training sessions, instructors discuss public awareness issues with DER employees. Examples of how to effectively handle high-profile bird problems are discussed.

DER will continue to strive to educate the public on the environmental benefits of renewable wind energy. This includes partnerships with non-government organizations, local educational institutes, or academia to develop educational programs related to wind energy facilities. DER may allow tours or field trips with local schools, host open houses, and/or invite the public for visits to our facilities. In addition, DER will strive to continue working closely with resource agencies, conservation organizations, the media, and the general public on avian conservation projects.

Summary

Duke Energy management and employees are committed to the tenants of the APP. Duke Energy will strive to:

- Ensure that operations comply with migratory bird laws, regulations, permits, and guidelines through training and active participation.
- Document bird mortalities, bird injuries, and disturbances of active nests.
- Provide information, resources, and training to improve employee and contractor awareness of the responsibilities under bird protection laws.
- Identify bird habitats and bird species that may be impacted by proposed transmission and distribution corridors.
- Where necessary, use raptor-friendly standards in construction of new and retrofitting of existing transmission and distribution lines.
- Assess areas of high bird interactions and implement raptor-friendly improvements on existing facilities.
- Conduct applied research and participate in industry trade groups to reduce the detrimental effects of bird interactions with power lines and corporate operations.

15.0 Key Avian Resources

Duke Energy Avian Program SME:

- Misti Sporer
  Lead Environmental Scientist – Natural Resources
  980-875-5204

15.1 Florida

- Duke Energy Florida
  Migratory Bird Hotline
  727-386-3084

Duke Energy SME and Department Contacts:

- Tonya Corder
  Environmental Specialist II – Natural Resources
  727-820-5607

- David Bruzek
  Lead Environmental Specialist – Water Resources
  727-820-5410

- Betty Carter
  Lead EHS Professional – Environmental Field Support
  407-353-8473

- Wayne Richardson
  Lead Transmission Permitting Specialist – Transmission Siting & Permitting
  727-820-5148

Federal Agency Contacts:

USFWS Contacts

- Special Agent- U.S. Fish and Wildlife Service – Law Enforcement
  20501 Independence Blvd.
  Groveland, Florida 34736
  (352) 429-1037

- Ulgonda Kirkpatrick
  USFWS Region 4 Migratory Bird Program- Regional Eagle Biologist
  Regional Office
  1875 Century Blvd
  Atlanta, GA 30345
  Office (352) 972-9089

State Agency (FWC) Contacts:

- Wildlife Alert Hotline
  Call 1-888-404-3922

- Northwest Region – Law Enforcement
  850-265-3676
  Regional Office
  3911 Highway 2321
  Panama City, FL 32409

- Carrabelle Field Office
  287 Graham Drive
  Carrabelle, FL 32322

- Pensacola Field Office
  1101 East Gregory Street
  Pensacola, FL 32502

- North Central Region – Law Enforcement
  386-758-0525
  Regional Office
  3377 East US Highway 90
  Lake City, FL 32055

- Crystal River Field Office
  140247 North Suncoast Blvd.
  Crystal River, FL 34428-6715

- Jacksonville Beach Field Office
  Naval Air Station
  Bldg 118, Albemarie Ave.
  Jacksonville, FL 32212

- Northeast Region
  352-732-1225
  Regional Office
  1239 S.W. 10th Street
  Ocala, FL 34471

- Titusville Field Office
  1-A Max Brewer Memorial Parkway
  Titusville, FL 32796

- Southwest Region
  863-648-3200
  Regional Office
  3900 Drane Field Road
  Lakeland, FL 33811

- Tampa Field Office
  5110 Gandy Blvd.
  Tampa, FL 33611

- Michelle van Deventer
  Florida Fish and Wildlife Conservation Commission
  Bald Eagle Plan Coordinator
  1239 SW 10th Street
  Ocala, FL 34471
  Office (941) 894-6675

Pertinent Conservation Organizations
Avian Rehabilitation Contacts:

- Clearwater Audubon
  Pinellas Eagle Watch (not just eagles)
  Barbara Walker
  727-798-2385

- Lake Region Eagle Watch (not just eagles)
  Reinier Munguia
  863-797-7374

- St. Francis Wildlife Association
  5580 Salem Road
  Quincy, FL 32352
  Sandy Beck
  850-627-4151 (only 8:30 am to 5:00 pm)
  850-933-2735 (after hours)

- Seaside Seabird Sanctuary
  Eddie Gayton-Operations Manager
  18328 Gulf Boulevard
  Indian Shores, FL 33785
  Barb Suto
  727-391-6211

- Audubon Center for Birds of Prey
  1101 Audubon Way
  Maitland, FL
  Dianna Flynt
  407-644-0190 ext. 115

- Owl's Nest Sanctuary
  Kris Porter
  Tampa Bay Area
  813-598-5926

- Homosassa Animal and Bird Hospital
  8177 W. Grover Cleveland Blvd.
  Homosassa, FL
  352-628-4200

- Wrede's Wildlife Rehabilitation Center, Inc
  4820 Wilderness Trail
  Sebring FL 33875
  David& Karen Wrede
  863-385-2770

Avian Resource Consultants:

- Flatwoods Consulting Group, Inc.
  8306 Laurel Fair Circle, Suite 120
  Tampa, FL 33610
  813-600-5747
  Lee Walton, Senior Ecologist/Principal

- Normandeau Associates, Inc.
  102 NE 10th Ave
  Gainesville, FL 32601
  Christine Denny 353-372-4747

- USDA/APHIS/WS/NWRC
  Florida Field Station
  2820 E. University Ave.
  Gainesville, FL 32641
  Dr. Michael Avery
  352-375-2229

15.2 Carolinas and Renewables

- Duke Energy Carolinas
  Migratory Bird Hotline
  800-573-3853

Duke Energy SME and Department Contacts:

- Mark Auten
  Senior Environmental Science Technician – Natural Resources
  980-875-9390

- Wilson Ricks
  Environmental Specialist I – Natural Resources

- Sherry Reid
  Senior Scientist – Natural Resources
  980-875-5457

- Greg Aldrich
  Lead Scientist – Natural Resources (Renewable Energy)
  704-430-7946

Federal Agency Contacts:

USFWS Contacts:

- USFWS (Region 4, Atlanta, GA)
  404-679-7070

- USFWS- Region 4 Law Enforcement
  Phone: 404-763-7959 and for SC call 843-727-4707 (Rebecca Roca-USFWS Special Agent)

USDA Contacts:

- Andrew Moore
  District Supervisor
  USDA-Wildlife Services
  444 Bristol Drive Room 158
  Statesville, NC 28677
  919- 621-7843

State Agency Contacts:

North Carolina

- NCWRC Nongame Wildlife Office
  919-707-0060

- NCWRC Wildlife Enforcement Communications
  919-707-0040

South Carolina

- SCDNR
  Rembert C. Dennis Building
  1000 Assembly St.
  Columbia, SC 29201
  Phone: 803-734-3886

Pertinent Conservation Organizations
Avian Rehabilitation Contacts:

- Carolina Raptor Center
  6000 Sample Rd.
  Huntersville, NC 28078
  Phone: 704-875-6521

- Carolina Veterinary Specialists
  12117 Statesville Rd.
  Huntersville, NC 28078
  Phone: 704-949-1100

- North Carolina licensed wildlife rehabilitators
  http://www.ncwildlife.org/fs_index_06_coexist.htm

- South Carolina licensed wildlife rehabilitators
  http://www.dnr.sc.gov/wildlife/rehab.html

Avian Resource Consultants:

- Andrew Moore
  District Supervisor
  USDA-Wildlife Services
  444 Bristol Drive Room 158
  Statesville, NC 28677
  919- 621-7843

15.3 Midwest

- Duke Energy Midwest
  Migratory Bird Hotline
  317-430-4497

Duke Energy SME and Department Contacts:

- Dan Arndt
  Environmental Scientist II
  317-838-1112

- Stephen Beard
  Environmental Scientist I
  317-838-1315

Federal Agency Contacts:

- USFWS (Region 4, Atlanta, GA)
  404-679-7070

- USFWS- Region 4 Law Enforcement
  Phone: 404-763-7959

- USFWS (Region 3, Ft. Snelling, MN)
  Phone: 612-713-5449

- USFWS- Region 3 Law Enforcement (Indiana)
  Phone: 317-368-7014

State Agency Contacts:

Kentucky

- Kentucky Department of Fish and Wildlife Resources
  #1 Sportsman's Lane
  Frankfort, KY 40601
  800-858-1549

Indiana

- Indiana Department of Natural Resources
  402 West Washington Street
  Indianapolis, IN 46204
  Phone: 317-232-4200
  Toll Free: 1-877-463-6367

Ohio

- ODNR
  Division of Wildlife
  2045 Morse Rd.
  Bldg. G
  Columbus, OH 43229-6693
  Phone: 614-265-6565

Avian Rehabilitation Contacts:

- Kentucky licensed rehabilitators
  http://fw.ky.gov/rehablist.aspx

- Indiana licensed rehabilitators
  http://www.southeasternoutdoors.com/wildlife/rehabilitators/indiana-rehabilitators.html

- Ohio licensed rehabilitators
  http://www.dnr.state.oh.us/wildlife/Home/resources/orphans/rehabilitators/tabid/6013/Default.aspx

15.4 Legal

Duke Energy SME and Department Contacts:

- Garry Rice
  Deputy General Counsel
  704-382-8111
  Garry.Rice@duke-energy.com

15.5 Avian Protection Equipment Vendors

Nesting platforms:

- Zena designs
  P O Box 137
  Odenville , AL 35120
  Phone: 970-663-3980
  http://www.zenadesign.com/index.htm

Perch discouragers:

- National Transformer Sales, Inc.
  2613 B Discovery Dr
  Raleigh, NC 27616
  Phone: 919-850-3222

- Power Line Sentry, LLC
  432 wcr 66
  Fort Collins, CO 80524
  Phone: 970-599-1050
  info@powerlinesentry.com
  http://www.powerlinesentry.com/index.html

Vulture effigies:

- The Propper Source
  12401 Kittridge St.
  North Hollywood, CA 91606
  Phone: 404-918-9091
  http://www.proppersource.com/

- Scary Decorations
  Phone: 800-690-4425
  http://www.scarydecorations.com/

- Display It!
  P.O. Box 1749
  Cave Creek, AZ 85327
  Phone: 480-461-9333
  http://www.displayit-info.com/

Line marking devices:

- Tyco Electronics Energy Division
  Customer Service
  Phone 800 327 6996
  Fax 800 527 8350
  http://www.energy.tycoelectronics.com

Other avian protection products:

- Wildlife Outage Protectors
  37 Appletree Lane, P.O. Box 450
  Plumsteadville, PA 18949
  Phone: 888-414-2398
  http://www.wildlifeoutageprotectors.com/

- Kaddas Enterprises, Inc.
  Brad Nelson, East Coast Sales Manager
  Phone: 801-972-5400
  Fax: 801-972-3200
  Cell: 801-631-2634
  Email: bradn@kaddas.com
  http://www.kaddas.com/index.php

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APLIC. 2012. Reducing Avian Collisions with Power Lines: The State of the Art in 2012. Edison Electric Institute, and APLIC. Washington, D.C. 159 pp.

Bald and Golden Eagle Protection Act (BGEPA). 1940. 16 United States Code § 668-668d. June 8, 1940.

Endangered Species Act (ESA). 1973. 16 United States Code § 1531-1544. December 28, 1973.

Evans, L.J. 1996. Collision course: The hazards of lighted structures and windows to migrating birds. World Wildlife Fund and Fatal Light Awareness Program.

Gehring, J., Kerlinger, P., and Manville, A.M. 2004. Avian collisions with communication towers: A quantification of some associated tower variables. Presentation at American Ornithologists Union meeting, August 2004.

Harness, R.E. 2005. Pers. Comm. EDM International.

Klem, D., Jr. 1990. Collisions between birds and windows: mortality and prevention. J. Field Ornithol. 61:120-128.

Lever, C. 1987. Naturalized Birds of the World. Longman Scientific & Technical, London, UK.

Loss, S.R., Will, T. , Loss, S.S., and Marra, P.P. 2014. Bird-building collisions in the United States: estimates of annual mortality and species vulnerability. Condor 116: 8-23.

Migratory Bird Treaty Act (MBTA). 1918. 16 United States Code § 703-712. July 13, 1918.

Shire, G. G., Brown, K., and Winegrad, G. 2000. Communication towers: a deadly hazard to birds. Report Documents. A Report Compiled by American Bird Conservancy, June 2000.

U.S. Fish and Wildlife Service (USFWS). 2012. Land-based Wind Turbine Guidelines, March 23, 2012. http://www.fws.gov/windenergy/docs/WEG_final.pdf

U.S. Fish and Wildlife Service (USFWS). 2013. Eagle Conservation Plan Guidance, Module 1 - Land-based Wind Energy, Version 2. April 2013 .

Williams, R.D. and Colson, E.W. 1989. Raptor associations with linear rights-of-way. Pages 173-192 *in* B.G. Pendleton, ed. Proc.Western Raptor Management Symp. Natl. Wildl. Fed. Scientific and Tech. Series No. 12, Washington, D.C.

APPENDICES

APPENDIX A. MBTA Special Purpose Utility Permits for Duke Energy

APPENDIX B. USFWS MBTA Permit Conditions

Special Purpose–Utility Permit Conditions and Authorizations

Duke Energy has several Special Purpose-Utility Permit which are renewed with the USFWS every three years. In association with these permits are several conditions and authorizations that are as follows:

- Duke Energy is authorized to collect, transport, and temporarily possess carcasses and partial remains of migratory birds on company/utility property or rights-of-ways. This permit does not authorize the take and collection of live, non-injured migratory birds, eggs, or nests, except as related to emergency situations.
- Duke Energy's is authorized, in emergency situations, to relocate active migratory bird nests, including eggs or nestlings found on the utility structures when (1) the safety of the migratory birds, nests, or eggs is at risk, or (2) the migratory birds, nests, or eggs pose a threat of serious bodily injury or risk to human life, including a threat of fire hazard, mechanical failure, or power outage. This authorization may not be used for situations where migratory birds are merely causing a nuisance or inconvenience. Nests must be relocated to a site and structure appropriate to the species. In extenuating circumstances, the nest may be destroyed ONLY by first contacting the permit issuing office to seek additional authorization. This nest clause does not apply to any eagles or threatened or endangered species.
- Carcasses or partial remains of migratory birds, other than eagles or federally listed threatened or endangered species may be disposed of burial or incineration.
- In the event that migratory birds are found that are injured or orphaned, the Migratory Bird Hotline operator will immediately contact a federally permitted migratory bird rehabilitator or licensed veterinarian for instructions.
- Any person who is employed by or under contract to Duke Energy for the activities specific in the permit or otherwise designated a subpermittee by Duke Energy in writing may exercise the authority of the permit.
- Duke Energy and the subpermittees must carry a legible copy of the permit and display it upon request when exercised its authority. Subpermittees must also carry a written designation letter.
- The permit does not authorize personal use of any migratory birds salvaged under the authority of this permit.
- If you encounter a migratory bird with a Federal band issued by the U.S. Geological Survey Bird Banding Laboratory, report the band number to 1-800-327-2263 or www.reportband.gov.
- The permit does not authorize salvage of specimens on federal or state lands without prior written authorization from the applicable Federal/state agency.

- Duke Energy must maintain records as required by 50 CFR 13.46 and 50 CFR 21.27. All records relating to the permittee activities must be kept at the location indicated in writing by Duke Energy to the migratory bird permit issuing office.

- Acceptance of this permit authorized the USFWS to inspect any wildlife held, and to audit or copy any permits, books, or records required to be kept by the permit and governing regulations.

- Duke Energy may not conduct the activities authorized by this permit if doing so would violate the laws of the Applicable State, county, municipal or tribal government or any other applicable law.

References

1. 50 CFR 21.41 (permit)
2. 50 CFR 13.46 (record keeping statute)
3. 50 CFR 13.47 (authorizes federal inspection of records)
4. Migratory Bird Treaty Act of 1918 (as amended in 1936, 1974, 1978, 1989) (16 U.S.C. 703-712)

Annual Procedure review

These conditions are summarized for brevity. The current SPUT permit issued by the Regional Migratory Bird Office should be consulted for supreme authority regarding specific conditions. If questions arise regarding the applicability of certain conditions, please contact the Avian Program SME.

APPENDIX C. Pertinent Excerpts of the USFWS MBTA

16 USC § 703 - TAKING, KILLING, OR POSSESSING MIGRATORY BIRDS UNLAWFUL

(a) In general

Unless and except as permitted by regulations made as hereinafter provided in this subchapter, it shall be unlawful at any time, by any means or in any manner, to pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer to barter, barter, offer to purchase, purchase, deliver for shipment, ship, export, import, cause to be shipped, exported, or imported, deliver for transportation, transport or cause to be transported, carry or cause to be carried, or receive for shipment, transportation, carriage, or export, any migratory bird, any part, nest, or egg of any such bird, or any product, whether or not manufactured, which consists, or is composed in whole or part, of any such bird or any part, nest, or egg thereof, included in the terms of the conventions between the United States and Great Britain for the protection of migratory birds concluded August 16, 1916 (39 Stat. 1702), the United States and the United Mexican States for the protection of migratory birds and game mammals concluded February 7, 1936, the United States and the Government of Japan for the protection of migratory birds and birds in danger of extinction, and their environment concluded March 4, 1972, and the convention between the United States and the Union of Soviet Socialist Republics for the conservation of migratory birds and their environments concluded November 19, 1976.

(b) Limitation on application to introduced species

(1) In general

This subchapter applies only to migratory bird species that are native to the United States or its territories.

(2) Native to the United States defined

(A) In general

Subject to subparagraph (B), in this subsection the term "native to the United States or its territories" means occurring in the United States or its territories as the result of natural biological or ecological processes.

(B) Treatment of introduced species

For purposes of paragraph (1), a migratory bird species that occurs in the United States or its territories solely as a result of intentional or unintentional human-assisted introduction shall not be considered native to the United States or its territories unless—

(i) it was native to the United States or its territories and extant in 1918;

(ii) it was extirpated after 1918 throughout its range in the United States and its territories; and

(iii) after such extirpation, it was reintroduced in the United States or its territories as a part of a program carried out by a Federal agency.

16 USC § 705 - TRANSPORTATION OR IMPORTATION OF MIGRATORY BIRDS; WHEN UNLAWFUL

It shall be unlawful to ship, transport, or carry, by any means whatever, from one State, Territory, or district to or through another State, Territory, or district, or to or through a foreign country, any bird, or any part, nest, or egg thereof, captured, killed, taken, shipped, transported, or carried at any time contrary to the laws of the State, Territory, or district in which it was captured, killed, or taken, or from which it was shipped, transported, or carried. It shall be unlawful to import any bird, or any part, nest, or egg thereof, captured, killed, taken, shipped, transported, or carried contrary to the laws of any Province of the Dominion of Canada in which the same was captured, killed, or taken, or from which it was shipped, transported, or carried.

16 USC § 706 - ARRESTS; SEARCH WARRANTS

Any employee of the Department of the Interior authorized by the Secretary of the Interior to enforce the provisions of this subchapter shall have power, without warrant, to arrest any person committing a violation of this subchapter in his presence or view and to take such person immediately for examination or trial before an officer or court of competent jurisdiction; shall have power to execute any warrant or other process issued by an officer or court of competent jurisdiction for the enforcement of the provisions of this subchapter; and shall have authority, with a search warrant, to search any place. The several judges of the courts established under the laws of the United States, and United States magistrate judges may, within their respective jurisdictions, upon proper oath or affirmation showing probable cause, issue warrants in all such cases. All birds, or parts, nests, or eggs thereof, captured, killed, taken, sold or offered for sale, bartered or offered for barter, purchased, shipped, transported, carried, imported, exported, or possessed contrary to the provisions of this subchapter or of any regulation prescribed thereunder shall, when found, be seized and, upon conviction of the offender or upon judgment of a court of the United States that the same were captured, killed, taken, sold or offered for sale, bartered or offered for barter, purchased, shipped, transported, carried, imported, exported, or possessed contrary to the provisions of this subchapter or of any regulation prescribed thereunder, shall be forfeited to the United States and disposed of by the Secretary of the Interior in such manner as he deems appropriate.

16 USC § 707 - VIOLATIONS AND PENALTIES; FORFEITURES

(a) Except as otherwise provided in this section, any person, association, partnership, or corporation who shall violate any provisions of said conventions or of this subchapter, or who shall violate or fail to comply with any regulation made pursuant to this subchapter shall be deemed guilty of a misdemeanor and upon conviction thereof shall be fined not more than $15,000 or be imprisoned not more than six months, or both.

(b) Whoever, in violation of this subchapter, shall knowingly—

(1) take by any manner whatsoever any migratory bird with intent to sell, offer to sell, barter or offer to barter such bird, or

(2) sell, offer for sale, barter or offer to barter, any migratory bird shall be guilty of a felony and shall be fined not more than $2,000 or imprisoned not more than two years, or both.

(c) Whoever violates section 704 (b)(2) of this title shall be fined under title 18, imprisoned not more than 1 year, or both.

(d) All guns, traps, nets and other equipment, vessels, vehicles, and other means of transportation used by any person when engaged in pursuing, hunting, taking, trapping, ensnaring, capturing, killing, or attempting to take, capture, or kill any migratory bird in violation of this subchapter with the intent to offer for sale, or sell, or offer for barter, or barter such bird in violation of this subchapter shall be forfeited to the United States and may be seized and held pending the prosecution of any person arrested for violating this subchapter and upon conviction for such violation, such forfeiture shall be adjudicated as a penalty in addition to any other provided for violation of this subchapter. Such forfeited property shall be disposed of and accounted for by, and under the authority of, the Secretary of the Interior.

APPENDIX D. USFWS Bald and Golden Eagle Protection Act

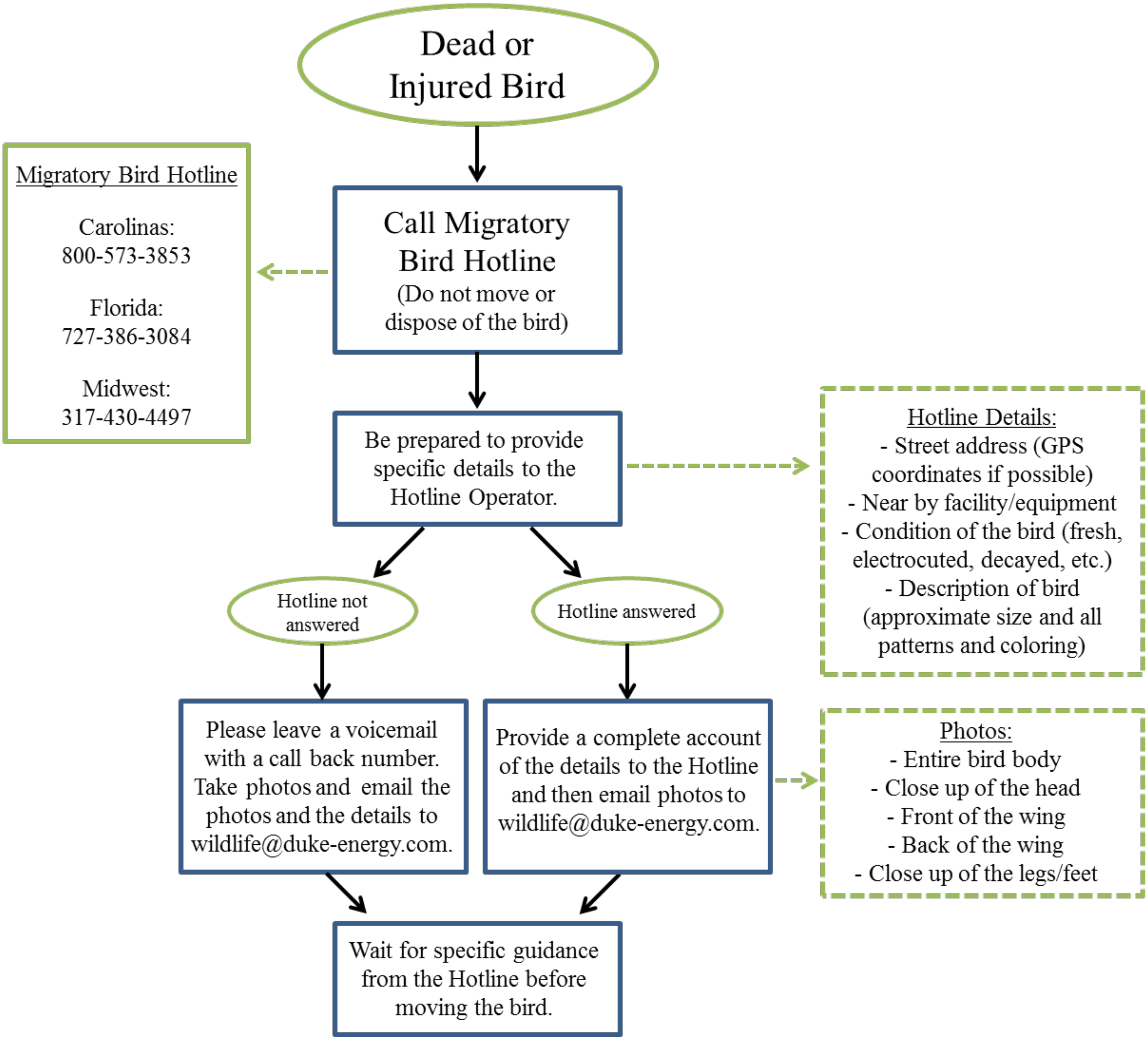
The Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c), enacted in 1940, and amended several times since then, prohibits anyone, without a permit issued by the Secretary of the Interior, from "taking" bald eagles, including their parts, nests, or eggs. The Act provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part, nest, or egg thereof." The Act defines "take" as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb."

For purposes of these guidelines, "disturb" means: "to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior."

In addition to immediate impacts, this definition also covers impacts that result from human-induced alterations initiated around a previously used nest site during a time when eagles are not present, if, upon the eagle's return, such alterations agitate or bother an eagle to a degree that interferes with or interrupts normal breeding, feeding, or sheltering habits, and causes injury, death or nest abandonment.

A violation of the Act can result in a fine of $100,000 ($200,000 for organizations), imprisonment for one year, or both, for a first offense. Penalties increase substantially for additional offenses, and a second violation of this Act is a felony.

APPENDIX E. Migratory Bird Process Flow Charts.



NEST MANAGEMENT COMPLIANCE FLOW CHART

Migratory Bird Hotline

Carolinas:
800-573-3853

Florida:
727-386-3084

Midwest:
317-430-4497

Bird Nest in Work Zone

Is the nest active* or inactive?
(*Is it nesting season or are there adults or eggs or young present?)

Active

Inactive

A or C

B

Call Migratory Bird Hotline

Be prepared to provide a description of work activities, the location of the nest, and be able to describe the nest.

Active nests and nests of certain species require a permit to work around or remove. To assist the Hotline Operator please email photos of the nest, adults, or eggs to wildlife@duke-energy.com The Hotline Operator will advise you of the next steps. Do not disturb, remove, or destroy the nest.

Remove or relocate the nest to a platform or nest box based on species. Questions? Call the Migratory Bird Hotline.

Does the nest look like A or B or C?

A

B

C

APPENDIX F. Migratory Bird Treaty Act Information Sheet and FAQ

Migratory Bird Treaty Act of 1918:
Under this Federal law, commonly referred to as MBTA, taking, killing or possessing migratory birds (or any of their parts or active nests) is unlawful. The law uses the phrase "take" to describe the actions that are prohibited.

"Take" is defined as:

- to pursue, hunt, shoot,
- wound, kill,
- trap, capture, or collect birds, bird nests, eggs, parts or young

There are over 1,000 protected species of birds. It is easier to list the birds that are NOT protected under the law. These species include:

- Rock dove (commonly called a pigeon),
- English sparrow,
- European starling,
- Eurasian collared-dove,
- Monk parakeet,
- Nanday conure,
- Upland game birds (ring-necked pheasant, etc.)

The law applies all Duke Employees and contractors. According to the Act, a person, association, partnership or corporation which violates the Act or its regulations is guilty of a misdemeanor and subject to a fine of up to $15,000, jail up to six months, or both, for each instance of take. Proof of intent is not required to be prosecuted or to be found guilty.

Duke Energy maintains a Federal Migratory Bird Special Purpose Utility permit (SPUT) that authorizes Duke Employees (and contractors) to collect, transport and temporarily possess migratory birds found dead on utility property, structures, and rights-of-way for avian mortality monitoring or disposal purposes. The permit also allows for the handling of nests under certain circumstances. The permit requires that Duke Energy maintain records of all mortalities and injuries, and that Duke Energy reports the information to the US Fish and Wildlife Service. This permit does not authorize take of migratory birds or eagles, nor does it absolve the Duke Energy from liability for take. The SPUT specifically states, as a condition, that Duke Energy is legally responsible for ensuring adequate training of employees on the permit conditions and associated responsibilities. Duke Energy employees and contractors, who could realistically encounter birds or bird-related incidents during the course of their everyday work activities, should receive Migratory Bird Training (EN0070 or EN0071).

<u>How to comply with the Migratory Bird Treaty Act:</u>

If you find a live bird, a nest, an injured bird, or even a dead bird in or around the work area call ASAP to Duke Energy's 24 hour Migratory Bird Hotline for guidance on how to comply with our permit:

- Carolinas: 800-573-3853
- Florida: 727-386-3084
- Midwest: 317-430-4497

Before planning or beginning any project ask:

- Are there birds or nesting birds in the area?
- Is there the proper habitat for birds or nests?
- Will this action impact important bird habitat?
- Will this action unintentionally injure or kill any birds?

If you need more information - call Duke Energy's Migratory Bird Hotline or contact the local Environmental Professional.

APPENDIX G. Examples of the Duke Energy Migratory Bird Poster and Migratory Bird Wallet Card

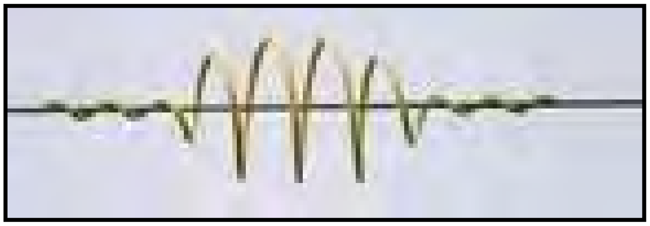
APPENDIX H. Examples of Avian Protection Materials

Duke Energy uses artificial nest boxes similar to the one pictured below when relocating small nests. Nest boxes are available through contacting 1-800-573-3853.

Duke Energy checks for active woodpecker nests prior to removing poles and leaves the pole until after the birds have fledged.

Duke Energy installs nesting platforms similar to the one pictured below when nests are found on electrical poles. Raptor nesting platforms are available through contacting 1-800-573-3853.

Swan Flight Diverter for Installation on Transmission Lines to Reduce Avian Collisions



Anti-Collision Devices (i.e., "flappers") for Installation on Transmission and Distribution Lines to Reduce Avian Collisions

Avian Protection Covers for Installation on Substations to Reduce Avian Electrocutions

Overhead Distribution Line Insulator Covers to Reduce Avian Electrocutions

Overhead Transmission Guano/Debris Shields **Buzzard Shield Panels for Transmission**

Vulture Effigy Use on Transmission and Communication Towers

APPENDIX I. State Avian Permits

APPENDIX J. Regional or Facility Avian Specifics

1.0 Florida

Numerous bird species have been identified as nesting on or in Duke Energy Florida (DEF) utility facilities and structures; including substations, transmission and distribution poles, buildings, and towers. The most prolific species nesting on DEF utility facilities and structures is the osprey. Other species such as bald eagles, great horned owls, southeastern American kestrels, and various species of woodpeckers have been found nesting on or in DEF facilities**.** The table below identifies species known to nest on (stick nest) or in (cavity nest) DEF utility structures.

1.1 Species covered under the Endangered Species Act

Federally listed endangered species or Florida state protected species most likely to be seen nesting within DEF territory are shown in the table below.

Federally and State Listed Birds Within the DEF Service Area.

Common Name	Scientific Name	Status[1]	
		FWS[2]	FWC[3]
American oystercatcher	*Haematopus palliatus*	---	SSC
Bald eagle	*Haliaeetus leucocephalus*	---*	T
Black skimmer	*Rynchops niger*	---	SSC
Brown pelican	*Pelecanus occidentalis*	---	SSC
Crested caracara	*Caracara cheriway*	T	T
Florida burrowing owl	*Athene cunicularia floridana*	---	SSC
Florida grasshopper sparrow	*Ammodramus savannarum floridanus*	E	E
Florida sandhill crane	*Grus canadensis pratensis*	---	T
Florida scrub-jay	*Aphelocoma coerulescens*	T	T
Least tern	*Sterna antillarum*	---	T
Limpkin	*Aramus guarauna*	---	SSC
Little blue heron	*Egretta caerulea*	---	SSC
Piping plover	*Charadrius melodus*	T	T
Red-cockaded woodpecker	*Picoides borealis*	T	SSC
Reddish egret	*Egretta rufescens*		SSC
Roseate spoonbill	*Platalea ajaja*	---	SSC
Roseate tern	*Sterna dougalli*	T	T
Snail kite	*Rostrhamus sociabilis plumbeus*	T	T
Snowy egret	*Egretta thula*	---	SSC
Snowy plover	*Charadrius alexandrinus*	---	T
Southeastern American kestrel	*Falco sparverius paulus*	---	T

Common Name	Scientific Name	Status[1]	
		FWS[2]	FWC[3]
Tricolored heron	*Egretta tricolor*	---	SSC
White ibis	*Eudocimus albus*	---	SSC
Whooping crane**	*Grus americana*	---	SSC
Wood stork	*Mycteria americana*	E	E

1 E= Endangered; T=Threatened; SSC= Species of Special Concern
2 FWS = U.S. Fish and Wildlife Service
3 FWC = Florida Fish and Wildlife Conservation Commission
* Bald eagle is protected under BGEPA.
** Classified as "non-essential experimental population" and not covered under ESA.

1.2 Bald Eagle

As indicated in Section 5.0, bald eagles and their nests are protected under the BGEPA and MBTA. State and federal guidelines allow only certain activities during nesting season (October 1st – May 15th) within the 330' primary protection zone and the 660' secondary protection zone. For aviation activities the buffer is 1,000' from the nest. The table below describes the disturbance distance and time of year restrictions for potential activities.

FWC and FWS Bald Eagle Nest Disturbance Guidelines for Duke Energy

Activity	Distance to an Active or Alternative Bald Eagle Nest		
	Inside 330 feet	Between 330 - 660 feet	Beyond 660 feet
	Setback	Time-of-Year Restriction	Setback
Right-of-Way Vegetation Management	None	None[5]	None
Electrical Maintenance	None[1]	None[2]	None
Utility Structure Replacement	None[1]	Non-nesting season only	None
New Transmission and Distribution Projects	330 feet if visual buffer exists or as close as similar activity[3]	Non-nesting season only	660 feet without visual buffer or as close as similar activity[3]
New Substation or Substation Expansion Projects	660 feet or as close as similar activity[3]	Non-nesting season only[3]	660 feet or as close as similar activity[3]

1. Not allowed to work on a structure with an active eagle nest if the maintenance activity will remove or substantially alter the nest to the extent that further use for nesting is affected.
2. Not allowed to work on a structure with an active eagle nest during the nesting season (1 October – 15 May).
3. Construction activities allowed as close as existing activity of similar scope occur.
4. Monitoring in accordance with the Bald Eagle Monitoring Guidelines (FWS 2007b) must be followed.
5. Duke Energy should consider conducting nest monitoring if any tree trimming activities occur within 660 feet of an active eagle nest during the nesting season (1 October – 15 May).

1.3 American Kestrel

The kestrel is a cavity nester that utilizes woodpecker holes and nests on wooden utility poles. Following the removal of inactive kestrel nests, DEF will install two kestrel nest boxes at a ratio of 2:1 for every nest removed. Please refer to Appendix H for Kestrel Nest Box Specifications and Installation Procedures. From the first kestrel nesting box installed during the winter of 2010 through Spring of 2013, DEF has successfully installed over 80 boxes.

1.4 Osprey

Osprey are protected under the MBTA. They are responsible for the most system interactions in multiple regions, but especially in Florida. Maintenance or construction activities shall be limited when near an active nest. Work shall be performed as far away from the nest as possible to avoid being seen by the osprey chicks that are not fledged. All work on a nested tower/pole shall be conducted prior to 8:30 a.m. and is limited to two, 45-minute intervals. A minimum 45-minute break should be taken to allow the adult birds to return to the nest.

Osprey nest building activity can be divided into several stages: Nest Start/Debris, Inactive Nest, and Active Nest. It is the responsibility of DEF employees to report all nests on transmission and distribution lines and equipment. The stages of nesting with descriptions and actions are summarized in the table below.

Nest Stage Summary for Florida Ospreys and Non-Listed Species Nests.

Stage	Description	Actions
Nest Start/Debris	A few sticks or multiple unorganized sticks; may be taking the shape of a nest	• Contact the regional SME • Remove nest start • Install perch/nest deterrents
Inactive Nest	Nest that does not contain eggs or flightless young	• Contact the regional SME • **Nest should not be relocated*** • Trim nest under the guidance of the regional SME and install temporary measures such as line hose/cover/jumpers • Enter avian condition for nest relocation and deterrents, insert comments that this is an *active* nest and will need to coordinate with the regional SME when nest becomes inactive • Monitor nest to determine when chicks fledge and the nest becomes inactive • Relocate nest upon verification by the regional SME that nest has become inactive. SME and appropriately permitted rehabber must be present for relocation. **
Active Nest	Nest contains eggs and/or flightless young	• Contact SME* • Trim nest under the guidance of the SME and install temporary measures such as line hose/cover/jumpers • Monitor nest to determine when chicks fledge and the nest becomes inactive • Relocate nest upon verification by SME that nest has become inactive

* Relocation of active nests can be accomplished only with specialized personnel and agency involvement for non-listed migratory birds.

** Appropriately permitted rehabber shall direct relocation transfer of eggs and chicks. In the event transfer to a new natural location is not possible, rehabber shall take custody of eggs or chicks.

1.5 Other MBTA Covered Species

Woodpeckers and owls are additional species that use power poles for nesting. Linemen must check for active nests prior to removing a pole. If an active nest is discovered, the preferred option is for the crew to leave the pole until after the birds have fledged. If this is not possible, electric components and lines may be relocated to a new pole erected beside the old pole. The old pole may be topped, but must remain in place until after nesting season. Notify an ES or Natural Resource SME when an active nest is discovered. Only these individuals can authorize the relocation of the active nest section.

Nests of small birds, such as wrens and bluebirds in electric service panels and meter boxes of new homes are the most common bird issues encountered by Duke Energy. When Duke Energy technicians arrive on site to provide electric service to these new homes they commonly encounter bird nests where the meter needs to be installed. When the meter box cannot be installed at a later date (after the young have fledged) our technicians are trained to relocate these nests to an artificial nest box (Appendix H) and place the nest box as close to the original nest site as practical.

2.0 Carolinas and Midwest

2.1 Species Covered under the Endangered Species Act

As in the other areas of Duke Energy's service territory, nest of eagles and endangered and threatened species cannot be altered, moved or destroyed at any time without proper authorization from the federal and state agencies such as the USFWS, NCWRC, SCDNR, INDNR, Kentucky Department of Fish and Wildlife Resources (KDFWR), and Ohio Department of Natural Resources, Division of Wildlife (ODNR). Listed species in the Carolinas include the piping plover (*Charadrius melodus*), red-cockaded woodpecker (*Picoides borealis*), and wood stork (*Mycteria americana*). Listed species in the Midwest include the red-cockaded woodpecker, interior least tern (*Sterna antillarum athalassos*), Kirtland's Warbler (*Dendroica kirtlandii*), and piping plover.

An eastern experimental flock of whooping crane has been established that migrates from Wisconsin to Florida. Its annual migration, in many cases, goes through Indiana and may occasionally pass through Ohio and Kentucky. This experimental flock has been classified as "non-essential experimental population" and are not included as a listed endangered species. Members of this flock have historically used Duke generating station properties during migration stopovers.

2.2 Bald Eagle

Bald and Golden Eagles, the two species of eagles that are native to the United States, have additional protection under the Bald and Golden Eagle Protection Act (BGEPA). Under BGEPA, the USFWS issues permits to take, possess, and transport bald and golden eagles for scientific, educational, and Indian religious purposes, depredation, and falconry (golden eagles). More recently, through regulation (2016 Eagle Permit Rule Revisions), the USFWS can issue a permit to take Bald and/or Golden Eagles.

If a deceased eagle is found on or near company property or ROW it must immediately be reported to the appropriate SME or environmental coordinator. The eagle fatality should then be reported to USFWS. Also, any eagle nests discovered on company property or ROW must be reported to the environmental coordinators (to facilitate preparation of a management plan, if needed and reporting to the agencies) and are not allowed to be relocated without a permit from the USFWS. Please see Appendix K for more information.

2.3 Ospreys

Ospreys will often build nests on the crossarms of distribution poles near fresh or brackish water and are now quite common in Duke Energy's service territory. The company has had success with relocating osprey nests to pole mounted nest platforms in a nearby location (as mentioned in Section 8.1.2). Nest deterrents can also be used on poles near fresh water habitat to prohibit ospreys building nest in the first place. Osprey nests (active and inactive) in Duke territory (besides Florida- see Section 8.2.2.4) can be relocated based on our USFWS Special Purpose Utility permit.

3.0 Renewable Energy Facilities

3.1 Species Covered under the Endangered Species Act

Endangered and threatened avian species (e.g., whooping crane) and any nest management issues, associated with Duke Energy's renewable projects, are covered under site-specific BBCS documents. Contact the DER SME for species-specific guidance (see Section 15.0 for the contact).

3.2 Bald Eagle and Golden Eagle

Bald and golden eagles and any nest management issues, associated with Duke Energy's renewable projects, are covered under site-specific BBCS documents, specific facility conditions, and any Eagle Conservation Plans prepared for the project. Contact the DER SME for eagle-specific guidance (see Section 15.0 for the contact).

APPENDIX K. Bald Eagle Nest Information

Excerpted from Duke Energy's Bald Eagle Nest Disturbance Guidelines, January 2017

Bald eagles are protected under the U.S. Fish and Wildlife Service (USFWS) Bald and Golden Eagle Protection Act (BGEPA; 16 U.S.C. 668–668d under 50 CFR 22.27) and any "take" requires a permit under this law. "Take" is defined under the federal law as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." Here "disturb" means: "to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior."

Many state laws that protect bald eagles also require a permit for certain activities; these states include: the Florida Fish and Wildlife Conservation Commission (FWC) Bald Eagle Management Plan and F.A.C. 68A-16.002, North Carolina General Statutes § 113-274, South Carolina Section 50-15: Nongame and Endangered Species Conservation Act. Bald eagles are protected under the state law but no permits are required in Indiana (Nongame and Endangered Species Conservation Act (IC 14-22-34)), Kentucky (KRS 150.320), and Ohio (Administrative Code 1501:31-19-01).

The following information is provided as guidance for Duke Energy to address bald eagle nest disturbance during right-of-way vegetation management, utility maintenance activities, utility structure rebuild projects, new transmission, distribution, and substation projects, and all other regulated utility site activities.

<u>Bald Eagle Natural History</u>

The bald eagle was historically found throughout the North American continent from western Alaska to the Maritime Provinces of Canada and south to the Florida Keys, the Gulf Coast, and Baja California (Curnutt 1996). Today eagle population numbers are highest in Florida, along the Chesapeake Bay, the Great Lakes, and in Washington state (USFWS 2007a). In the southeast, eagles historically existed throughout the region, although they were probably most abundant along large rivers and lakes. Today, bald eagle nesting is prevalent in the state of Florida along the south coast, the Gulf Coast from Pinellas County north to the Suwannee River, the St. Johns and Ocklawaha River basins, and the Kissimmee River valley including Polk and Osceola Counties (Curnutt 1996). Bald eagles are increasing in numbers in the Carolinas, as well as along the Ohio, Wabash, and White rivers in the Midwest (USFWS 2007a).

Bald eagles are considered a water-dependent species predictably found near estuaries, large lakes, reservoirs, major rivers and some seacoast habitats (USFWS 1999). Their distribution is influenced by the availability of suitable nest and perch sites near large, open water-bodies, usually with high amounts of water-to-land edge. Nesting habitat includes the nest tree, perch sites, roost sites, and adjacent high use areas, but it does not include the entire foraging area. The size and shape of a defended nesting territory varies greatly depending on the terrain, vegetation, food availability, and eagle density in the area (USFWS 1999). Nest sites must provide good overall visibility, with a clear flight path to the nest.

Bald eagles nest in mature or old-growth trees, snags (dead trees), cliffs, and rock promontories. In forested areas, bald eagles often select the tallest trees with limbs strong enough to support a nest that can weigh more than 1,000 pounds. Nest sites typically include at least one perch with a clear view of the water, where they forage. Eagle nests are constructed with large sticks, and may be lined with fresh evergreen clippings, moss, grass, plant stalks, lichens, seaweed, or sod. Nests are usually about 4-6 feet in diameter and 3 feet deep, although larger nests exist (USFWS 2007a). Most breeding eagles construct nests within several hundred yards of open water (Mojica and Meyers 2006). In Florida, nests can be found up to two miles away from open water (McEwan and Hirth 1979, Wood et al. 1989); the nests are often in the ecotone between forest and marsh or water and are constructed in living pines (Pinus spp.) or bald cypress (Taxodium distichum) (McEwan and Hirth 1979). A small number of nests are located in dead pine trees or other species such as Australian pine (Casuarina equisetzfolia) and live oak (Quercus virginiana). Recently, eagles have increased nesting on human-engineered structures. Utility structures may provide a benefit to bald eagles by providing enhanced nesting and roosting sites in areas that may not naturally be suitable, such as pastures and other areas without large mature trees (Kochert and Olendorff 1999).

Figure 1. Examples of bald eagles nests.

In the southeastern United States, bald eagles nest once a year. A mated pair returns to its nest area beginning in early September or October, refurbishes its nest during November and December, and lays eggs in December or January; the eggs hatch as early as February and as late as May. In the Midwest, the process starts 2-3 months later, with the pair returning to the nest site in early January, refurbishing the nesting materials through March, laying and incubating eggs between March and May, with the earliest hatching occurring in April.

Depending on the geographic area, incubation may begin as early as November or as late as March, with the eggs requiring approximately 35 days for incubation. Clutches usually consist of one or two eggs, but occasionally three are laid. The eaglets will grow to the size of the adult birds within 10 to 12 weeks, at which time they typically fledge (Wood and Collopy 1995). Parental care may continue 4 to 6 weeks after fledging even though young eaglets are fully developed and may not remain at the nest. The immature bald eagle has a dark bill and dark eyes but lacks the white head, neck, and tail. The overall color of young eaglets is dark to light brown with light-colored base feathers that give a blotchy appearance. White head and tail plumage may not appear complete until the eagle is 4 to 5 years of age.

Adult Bald Eagle **Juvenile Bald Eagle**

Figure 2. Side-by-side comparison of adult and juvenile bald eagles.

The bald eagle is an opportunistic feeder. Accordingly, its diet varies tremendously, depending on the time of year and habitat. Most studies indicate that fish are the largest component of the eagle's diet, followed by birds and mammals (Johnsgard 1990). Carrion is taken by many eagles and is also a substantial portion of the diet, especially for coastal eagles dependent on post-spawning salmonids. Non-coastal populations may also rely heavily on carrion particularly during the late winter and early spring. In the southeastern United States, the bulk of the diet is fish. Broley (1947) found catfish (Ictalurus spp.), mullet, and turtles to be the most common food items found at nests in Florida. He also found that the variety of prey items differ among individual pairs. McEwan (1977) found that 79 percent of the prey remains found in nest were fish and 17 percent were bird, based on a sample size of 788 remains. Of these, the dominant items were catfish and the American coot (Fulica americana). In the Midwest, bald eagles also eat waterfowl, shorebirds, colonial waterbirds, small mammals, turtles, and carrion (often along roads or at landfills) (USFWS 2015).

Bald Eagles and Duke Energy

Within the last several years Duke Energy has observed an increasing trend in bald eagles nesting on or near Duke Energy utility structures in Florida. According a 2011 query to the FWC Eagle Nest Locator, there are 85 known bald eagle nests (active and inactive) within 0.25-mile of the Duke Energy transmission utility structures in Florida. A total of 59 of these nests were active during the 2008-2009 nesting season, and of these, nine active bald eagle nests are known to occur on Duke Energy utility structures. In addition, the likelihood of eagles nesting on or near Duke Energy lands may rise as the Florida nesting population continues to increase annually. A 2009 survey conducted by the Florida Fish and Wildlife Research Institute reports 1,340 active nesting territories. This correlates to a greater than 20 percent increase from the 1,102 occupied nesting territories reported in 2001 (Brush et al. 2009).

In the Carolinas and the Midwest, population numbers are not tracked as routinely as the Florida population so these estimates are unavailable; however, general observations by resource agencies have seen an increase in the number of nesting territories along major river corridors (USFWS 2015). Duke Energy is working with various state agencies to increase the data collection efforts near Duke Energy facilities to better understand these populations.

Bald Eagle Nest Disturbance Guidelines

The following sections discuss guidance and regulations concerning activities that may disturb nesting bald eagles. All information is based on the National Bald Eagle Management Guidelines (FWS 2007a) and the online activity planner tools provided by both the Southeast and the Midwest Regions of the USFWS (USFWS 2016a; 2016b); as well as the Florida Bald Eagle Management Plan (FWC 2008).

One of the key elements to these management plans is a buffer zone around nesting locations. Bald eagle nests are protected under the federal law all year long, not just during breeding season. Since bald eagles can have variable home range sizes and can nest in multiple locations in subsequent breeding seasons the buffer is applied to both active and alternate nests. An exclusion buffer helps to shield the nest from activities that may result in detrimental impacts to breeding and successful production of chicks. The standard buffer distance applied to all bald eagle nests during the nesting season (generally January to July, but is variable based on latitude) is a 660 foot radius measured out from the base of the nest. This means that all Duke Energy activities are to take place greater than 660 feet from the nest, if at all possible. If it is not possible to keep activities outside of this buffer zone, during nesting season, a consultation with the state and with the USFWS is recommended to determine if a take permit is needed. During the non-nesting season a standard buffer radius of 330 feet is maintained for the three years following an active nesting season.

Activities that do not require a permit include those conducted at any time more than 660 feet from a bald eagle nest or any temporary activity conducted at any distance from a nest outside of the nesting season (generally July through December, but is variable based on latitude). For the purpose of these guidelines a temporary activity is defined as any activity that will leave no permanent structure or have any permanent effect (outside the nesting season).

For bald eagle nests Duke Energy's basic guidelines include:

A. During the nesting season, maintain a buffer of at least 660 feet between all activities and the nest (including active and alternate nests), or if a similar extant activity is closer than 660 feet, then maintain a distance buffer at least as far from the nest as the existing tolerated activity.

B. Within the 660 foot buffer of the nest (including active and alternate nests), restrict all clearing, external construction, and landscaping activities to outside the nesting season.

C. Maintain any established landscape buffers , and if possible, create additional landscape buffers to screen the new activity from active and alternate nests.

D. During the non-nesting season maintain a buffer of at least 330 feet between all activities and the nest.

E. All aerial activities, including helicopter surveys or drone surveys, need to maintain a buffer distance of 1,00 feet from the nest during the nesting season. During the non-nesting season aerial activities will need to maintain the minimum 330 foot buffer.

F. Where nests are blown from trees during storms or are otherwise destroyed by the elements, continue to protect the site in the absence of the nest for up to three complete breeding seasons or until a qualified biologist directs otherwise. Many eagles will rebuild the nest and reoccupy the site.

G. Where bald eagles are likely to nest in human-made structures (i.e. power line structures) and such use could impede operation or maintenance of the structures or jeopardize the safety of the eagles, the structures should be equipped with either devices engineered to discourage bald eagles from building nests, or nesting platforms that will safely accommodate bald eagle nests without interfering with structure performance.

Below we present five common activities undertaken by Duke Energy. Each activity assumes Duke Energy's basic guidelines are followed and any additional recommendations are provided for each activity type.

Right-of-Way Vegetation Management

Vegetation management is a broad term that may be defined as an unavoidable requirement. Eagles are not likely to be disturbed by routine vegetation management, such as minor tree trimming or noxious or invasive weed control, occurring outside of the 660 foot buffer of an active or alternate bald eagle nest. Therefore, these types of routine activities on existing right of ways can continue outside of the buffer of an eagle nest during any season without a permit.

Extensive tree trimming or tree clearing within the right-of-way may not be viewed as routine vegetation maintenance and may be considered an intermittent, occasional, or irregular activity that may disrupt nesting eagles. At no time during the nesting season should these activities take place within the 660 foot nest buffer. Tree trimming or tree clearing may take place outside of the nesting season, within the 660 foot buffer so long as the activities observe the following guidelines:

A. Avoid clear-cutting or removal of overstory trees within 330 feet of nests at any time of the year.
   a. Protect and preserve potential roost and nest sites by retaining mature trees and old growth stands, particularly within ½ mile from water to the extent practicable.
B. Selective thinning and other silviculture management practices designed to conserve or enhance habitat, including prescribed burning close to the nest tree, should be selected over clear cutting.
   a. If chemical control is selected, use pesticides, herbicides, fertilizers, and other chemicals only in accordance with Federal and state laws.
C. If burning is necessary, do the following:
   a. Conduct burns only when adult eagles and young are absent from the nest tree (i.e., at the beginning of, or end of, the nesting season, either before the particular nest is active or after the young have fledged from that nest).
   b. Take precautions such as raking leaves and woody debris from around the nest tree to prevent crown fire or fire climbing the nest tree.
D. Avoid construction of vegetation stockpiles, staging, or transfer facilities within 330 feet of nest locations.
E. If during a nesting season, tree trimming or clearing needs to take place near alternate nests within a particular territory (including nests that were attended during the current nesting season but were not used to raise young) then the vegetation may be managed within 330 feet of the alternate nest, provided that the eggs laid in another nest within the territory have hatched.

Any questions regarding these guidelines or specific project related needs should be directed to the SME for the region, these contacts can be found in Section 15 of Duke Energy's Avian Protection Plan.

Utility Structure or Electrical Maintenance

The maintenance of existing utility structures is defined as temporary in nature and falls within existing operations; eagles are not likely to be disturbed by routine and necessary electrical structure maintenance activities occurring outside of the 660 foot buffer of an active or alternate bald eagle nest. Therefore, structure or electrical maintenance of existing structures can occur outside of the 660 foot buffer of an of an eagle nest year round without a permit. A permit may be required if the maintenance activity is proposed to occur within the 660 foot buffer (i.e. on a utility structure with an active eagle nest).

Electrical maintenance on any utility structure that is inside the 660 foot buffer that contains a bald eagle nest may be maintained, repaired, or upgraded when:

A. the work will not remove or substantially alter the nest to the extent that further use for nesting is affected; and
B. the work is conducted outside the nesting season (variable, depending on the latitude) or if a qualified biologist confirms that the eagles have left the nest (e.g., eaglets fledged, nesting season has concluded).

If structure or electrical maintenance on any utility structure that is inside the 660 foot buffer that contains a bald eagle nest must be maintained, repaired, or upgraded during the nesting season consultation with the USFWS and the state agencies must be completed prior to initiating work. Obtaining a permit has a variable time line and depends on the nature of the work, the timing within the nesting season, and the regional office of the USFWS. Please allow adequate time for the permit process. The requirement for a permit does not apply to emergency situations (storm repair, critical outages, or threats to human health and safety, or imminent failure or danger to the nest or power line). Any questions regarding these guidelines or specific project related needs should be directed to the avian SME for the region; these contacts can be found in Section 15 of Duke Energy's Avian Protection Plan.

Utility Structure Replacement

Utility structure replacement projects can vary in scope and can be defined as temporary or permanent and can be similar to either maintenance or new construction. Since the nature of the action is variable it is best to coordinate with the avian SME for the region; these contacts can be found in Section 15 of Duke Energy's Avian Protection Plan.

Bald eagles are not likely to be disturbed by replacement activities occurring outside of the 660 foot buffer of an active or alternate bald eagle nest; therefore, replacement of existing structures can occur outside of the 660 foot buffer of an of an eagle nest year round without a permit. A permit may be required if the replacement activity is proposed to occur within the 660 foot buffer (i.e. on a utility structure with an active eagle nest). Bald eagles may not be disturbed if the proper landscape screening is in place even if the activity is within the 660 foot buffer, a qualified biologist can provide guidance in these situations. The basic Duke Energy guideline apply, as do the following guidelines if the action is temporary and similar in scope to maintenance:

A. the work will not remove or substantially alter the nest to the extent that further use for nesting is affected; and
B. the work is conducted outside the nesting season (variable, depending on the latitude) or if a qualified biologist confirms that the eagles have left the nest (e.g., eaglets fledged, nesting season has concluded).

If the action is similar in scope and nature to a new transmission project, the guidelines provided in the section below, *New Transmission…*, apply. Since the nature of the action is variable it is best to coordinate with the avian SME for the region; these contacts can be found in Section 15 of Duke Energy's Avian Protection Plan.

New Transmission and Distribution Projects or New Substation or Substation Expansion Projects

New utility transmission and distribution projects are treated like brand new construction, containing both temporary and permanent structures and activities. During the siting phase of the project the following guidelines are recommended:

A. To avoid collisions, site power lines and substations at least ¼ of a mile from nests, foraging areas, and communal roost sites, if practicable.
B. Employ industry-accepted best management practices to prevent birds from colliding with or being electrocuted by utility lines, towers and poles. If possible, bury utility lines in important eagle areas.

During the construction phase the following guidelines are recommended:

A. Maintain a buffer of at least 660 feet between all construction activities and the nest (including active and alternate nests) regardless of the season. If a similar activity is closer than 660 feet, then a distance buffer must be maintained as close to the nest as the existing tolerated activity, but no closer than 330 feet; a qualified biologist can provide guidance in this situation.
    a. If the construction activity is closer than the 660 foot buffer due to a similar activity existing closer than 660 feet, then restrict all clearing, external construction, and landscaping activities inside of the 660 foot buffer to outside the nesting season.
B. Maintain established landscape buffers that screen the activity from the nest.
C. Avoid clear-cutting or removal of overstory trees within the 660 foot buffer of nests at during the nesting season, and within the 330 foot buffer during the non-nesting season.
    a. Protect and preserve potential roost and nest sites by retaining mature trees and old growth stands, particularly within ½ mile from water to the extent practicable.
D. Avoid blasting and other activities that produce extremely loud noises within 1/2 mile of active nests (or within 1 mile in open areas), unless greater tolerance to the activity (or similar activity) has been tolerated by the eagles in the nesting area, a qualified biologist can provide guidance in this situation.

Bald Eagle Permitting Guidelines

Under the BGEPA a permit is not required to conduct any particular activity, but the permit is necessary to avoid liability for take or disturbance caused by the activity. Therefore, any land-altering activity within the 660 foot buffer of an active or alternate bald eagle nest that cannot be undertaken consistent with these guidelines may require an eagle take permit. Activities beyond the 660 foot nest buffer do not generally require an eagle take permit; however, it is best to contact the regional avian SME for the region; these contacts can be found in Section 15 of Duke Energy's Avian Protection Plan.

The an eagle take permit will only be issued where the applicant provides minimization and/or conservation measures that will advance the goal and objectives of the USFWS and state management plans. Obtaining a permit has a variable time line and depends on the nature of the work, the timing within the nesting season, and the regional office of the USFWS. Please allow adequate time for the permit process.

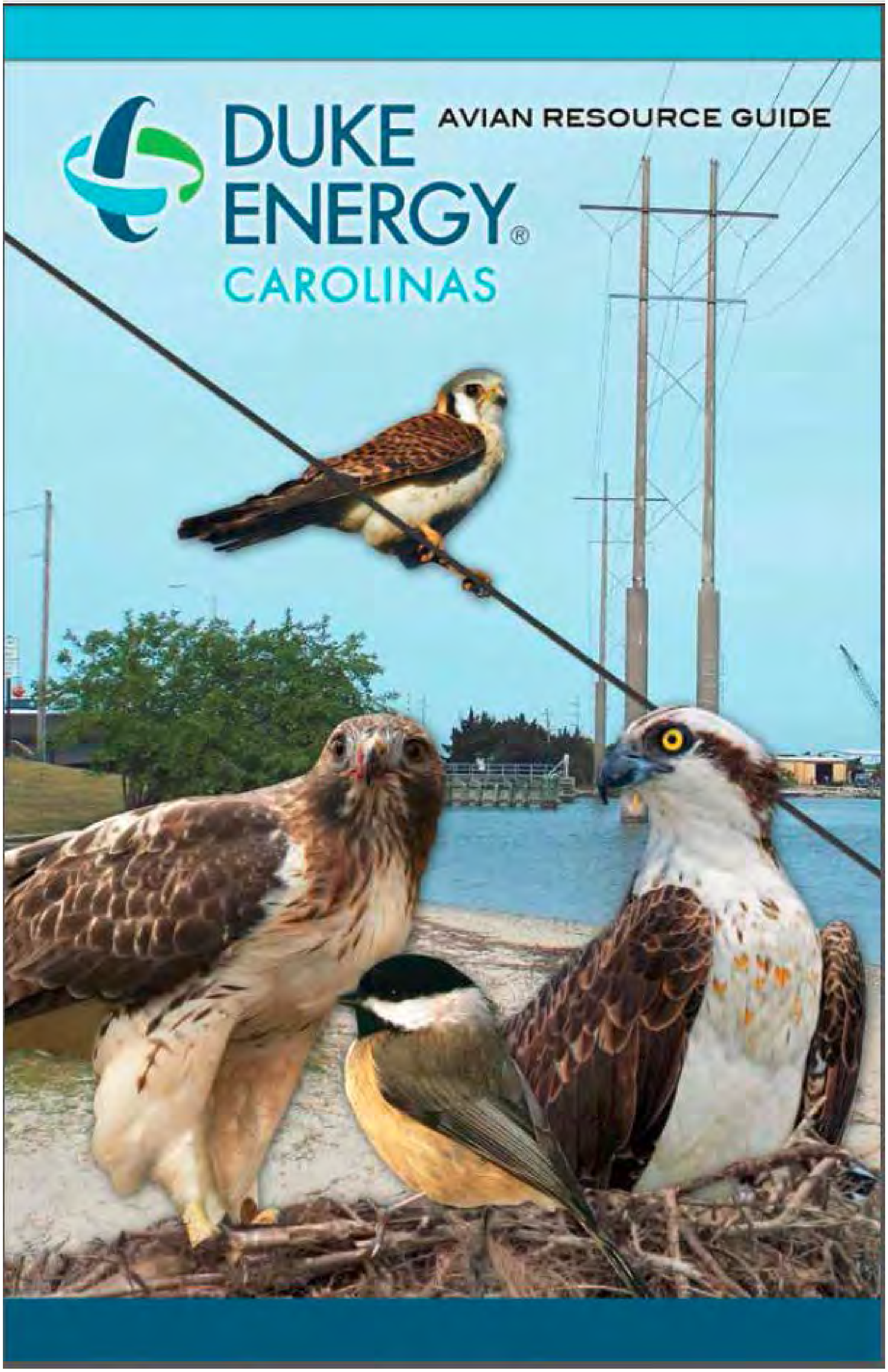
Summary

Assuming the basic Duke Energy guidelines are followed, site work outside of the 660 foot buffer of an eagle nest does not require a permit and can be conducted year-round. Vegetation management and other temporary activities may be conducted outside of the nesting season outside of the 330 foot buffer of the nest, if the additional guidelines (for the specific action) are followed. Once inside the 330 foot buffer of an eagle nest, all work needs to be coordinated through the avian SME for the region; these contacts can be found in Section 15 of Duke Energy's Avian Protection Plan.

It is important to note that a permit may be required for activities that may have impacts to bald eagles that rise to the level of disturbance under the BGEPA, regardless of the guidance provided in this document. The ultimate goal of Duke Energy's bald eagle nesting guidelines is to reduce the risk of "take" of a bald eagle and to proactively consider the bald eagles in our work planning efforts.

APPENDIX L. Example Avian Resource Guide

Full Avian Resource Guides are available for the both Florida and the Carolinas through the Migratory Bird Hotline or from Duke Energy's Natural Resources.



APPENDIX M. Duke Energy Avian Protection Peer Group Members

Avian Protection Peer Group Members

Peer Group Member	Region/Area	Contact Information	Note
Greg Aldrich	Natural Resources-Duke Energy Renewables Charlotte, NC	Greg.Aldrich@Duke-Energy.com 704-382-7656	Departmental Expertise
Dan Arndt	Midwest-Plainfield, IN	Daniel.Arndt@Duke-Energy.com 317-838-1112	Regional Expertise
Mark Auten	Carolina West-Huntersville, NC	Mark.Auten@duke-Energy.com 704-875-5459	Regional Expertise
David Bruzek	Florida-St. Petersburg, FL	David.Bruzek@pgnmail.com 727-820-5410	Regional Expertise
Tonya Corder	Florida-St. Petersburg, FL	Tonya.Corder@Duke-Energy.com 727-820-5607	Regional Expertise
Nathan Craig	Envir Policy & Strategy Director	Nathan.Craig@Duke-Energy.com 704-382-9622	Departmental Expertise/Support
Amy Dierolf	Siting and Licensing-St. Petersburg, FL	Amy.Dierolf@Duke-Energy.com 727-820-5657	Regional Expertise/Support
Scott Fletcher	Natural Resources Manager -Huntersville, NC	Scott.Fletcher@Duke-Energy.com 980-875-6014	Departmental Expertise
Tim Hayes	Environmental Director Duke Energy Renewables-Charlotte, NC	Tim.Hayes@Duke-Energy.com 704-382-9820	Departmental Expertise/Renewable Support
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Sherry Reid	Natural Resources-Huntersville, NC	Sherry.Reid@Duke-Energy.com 980-875-5657	Regional Expertise/Support
Garry Rice	Legal, Charlotte, NC	Garry.Rice@Duke-Energy.com 704-382-8111	Departmental Expertise/Legal Support
Wilson Ricks	Carolinas East- Raleigh, NC	Wilson.ricks@Duke-Energy.com 919-546-4396	Regional Expertise
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APPENDIX N.   Guidelines for Transporting Injured Birds

General Guidelines

- Be sure the bird needs to be rescued. In many cases, it may be normal behavior for the bird to be on the ground.
- **Call Migratory Bird Hotline at 1-800-573-3853 (Carolinas); or 1-317-430-4497 (Midwest); or 1-727-386-3084 (Florida)** for assistance concerning birds associated with Duke Energy facilities and assets.
- The SME associated with the Migratory Bird Hotline will provide you with a local wildlife rehabilitator contact or see the "Key Resources" section of this APP for state-specific links.
- Before handling the bird make sure you have proper PPE including safety glasses, thick gloves, towels and sheets (see specifics below).

Raptors

- NEVER attempt to handle an injured raptor without using extreme caution and without first consulting with the Migratory Bird Hotline. Raptors can cause severe injuries-even when they are hurt or sick.
- If an injured bald or golden eagle is found- DO NOT MOVE IT AND CALL THE REGIONAL MIGRATORY BIRD HOTLINE IMMEDIATELY.
- Follow the first rule of wildlife handling – Keep yourself safe! The raptor you are attempting to rescue will not understand that you are trying to help it; it will try to protect itself and may attack you.
- Approach with extreme caution. Most injured raptors will use their primary weapon, their strong feet and talons, to protect themselves; they can also bite with an extremely sharp beak.
- Before capture, prepare a box by making ventilation holes in the top and placing an absorbent material on the bottom of the box (paper towels, newspaper, etc.). The box should be large enough for the bird to stand in, but small enough to keep it from flapping or flying around.
- Gather the materials needed to safely capture the raptor. This includes safety glasses, heavy gloves (such as leather welder's gloves), and a large piece of lightweight material large enough to cover the bird (towel, blanket, old sheet, etc.).
- Approach the bird from the tail if possible. Carefully place the sheet or blanket over the entire bird. The raptor may try to grab the blanket, sheet or you with its feet. AVOID THE FEET AND TALONS by getting a firm grip from behind, being sure to press/hold the wings to the bird's body. Keep in mind any injured wings when holding them to the bird's body and try not to bend or press injured areas. Keep the talons away from you and others.
- Pick the bird up. Hold the covered bird away from your body, and place it in the prepared box. Make sure the lid or cover of the box is secured or restrained so the bird cannot escape during transport. The bird could get loose and cause an accident or injury.
- Gently try to remove the covering before closing the box. If the bird is firmly attached to the blanket or sheet, try to expose the bird's head.
- Transport to licensed wildlife rehabilitator ASAP. Secure the lid firmly and secure the box to the vehicle. Placing a sheet or towel over the box to block light maybe helpful to keep the bird calm, but be sure there is adequate air flow into the box to prevent suffocation.
- Do not handle the bird any more than necessary.
- Do not attempt to feed or force the bird to drink. Each species has specific dietary requirements. You can provide water in a small container.
- If you are transporting the raptor it is important to remember: speak quietly and do not play your car radio. Never transport a raptor held in a person's lap. Never transport a raptor unboxed or unrestrained. The bird could get loose and cause an accident or injury.

<u>Other Species</u>

- You will need safety glasses and a large piece of lightweight material large enough to cover the bird (towel, blanket, old sheet, etc.). The use of gloves (e.g., leather welder's gloves, latex gloves) is necessary.
- The best way to contain and transport an injured wild bird is in a cardboard box. The box needs to be large enough so that the bird fits comfortably in it without being cramped but not too large as to encourage wing flapping or flailing. Punch a few air holes in the sides and put a towel or an absorbent material on the bottom so the bird is not on a slippery surface, and tape the top closed. Small birds may be safely transported in a paper bag, again with absorbent material on the bottom. Airline sky kennels and other pet carriers can also be used. Placing the bird in a *closed, secure, darkened* environment is very important. It will help keep it calm, reduce additional stress and prevent it from causing further injury to itself.
- Make sure the lid or cover of the box is secured or restrained so the bird cannot escape during transport. The bird could get loose and cause an accident or injury.
- The best way to capture water birds and wading birds (e.g., Canada geese, great blue herons) birds is with a long-handled, large fishing net or a throwing net. If a net is not available, use a blanket or coat and cover the entire bird before picking it up. If you must carry the bird in your arms, be sure to keep its beak and wings away from your face and body. Place it in a box suitable for the bird's size, and keep it warm, dark and quiet until you can get it to a wildlife rehabilitator.

APPENDIX O. Summary of Duke Energy Pipe Configurations.

Summary **of Duke Energy pipe configurations, potential bird use and risk, and mitigative measures.**

Pipe Configuration	Type of Potential Bird Use	Relative Risk of Bird Use*	Proposed Mitigative Measure	Notes
Small bore, vertical piping, no normal flow, no candy cane vent	<1.5 inches in diameter: nesting not likely; no general use and mortality unlikely (e.g., trapping) 1.5 to 3.0 inches in diameter: nesting not likely; no general use and low mortality (e.g., trapping)	Unlikely	No mitigative measure recommended due to lack of operational impacts and/or avian impacts	Pipe diameter generally too small for avian use. Nesting unlikely due to vertical nature of system
Small bore, vertical piping, no normal flow, candy cane vent	1.5 to 3.0 inches in diameter: nesting not likely; no general use	Unlikely	No mitigative measure recommended due to lack of operational impacts and/or avian impacts	Small bore, candy cane vent configurations render the system difficult for any bird use (i.e., difficult to fly into the pipe)
Small bore, horizontal piping, no normal flow, no candy cane vent	<1.5 inches in diameter: nesting not likely; no general use and mortality unlikely (e.g., trapping) 1.5 to 3.0 inches in diameter: nesting not likely; general use and low mortality (e.g., trapping)	Unlikely High	No mitigative measure recommended due to lack of operational impacts and/or avian impacts Recommend 0.25 to 0.5 inch square mesh hardware cloth over opening and secured by galvanized stainless steel hose clamp or similar device. Periodic monitoring for debris build-up	Pipe diameter at <1.5 inches generally too small for avian use such as nesting However, pipe diameters >1.5 inches have a high risk for general avian use and nesting

Small bore, vertical piping, normal flow, no candy cane vent	<1.5 inches in diameter: nesting not likely; no general use and mortality unlikely (e.g., trapping) 1.5 to 3.0 inches in diameter: nesting not likely; no general use and low mortality (e.g., trapping)	Unlikely	No mitigative measure recommended due to lack of operational impacts and/or avian impacts	Pipe diameter generally too small for avian use. Nesting is not likely due to vertical nature of system. Air flow a deterrent for nesting and general use
Small bore, vertical piping, normal flow, candy cane vent	<1.5 inches in diameter: nesting not likely ; no general use and mortality unlikely (e.g., trapping) 1.5 to 3.0 inches in diameter: nesting not likely ; no general use and low mortality (e.g., trapping)	Unlikely	No mitigative measure recommended due to lack of operational impacts and/or avian impacts	Pipe diameter generally too small for avian use. Nesting is not likely due to vertical nature of system. Air flow a deterrent for nesting and general use
Small bore, horizontal piping, normal flow, no candy cane vent	1.5 to 3.0 inches in diameter: nesting not likely ; no general use.	Unlikely	No mitigative measure recommended due to lack of operational impacts and/or avian impacts	Air flow a deterrent for nesting and general use
Large bore, vertical piping, no normal flow, no candy cane vent	>3.0 inches in diameter: nesting not likely; general use and mortality (e.g., trapping)	High	Recommend 0.25 to 0.5 inch square mesh hardware cloth over opening and secured by galvanized stainless steel hose clamp or similar device. Periodic monitoring for debris build-up	High risk for general bird use and avian trapping
Large bore, vertical piping, no normal flow, candy cane vent	>3.0 inches in diameter: nesting likely; general use and mortality (e.g., trapping)	High	Recommend 0.25 to 0.5 inch square mesh hardware cloth over opening and secured by galvanized	High risk for general avian use and avian trapping

			stainless steel hose clamp or similar device. Periodic monitoring for debris build-up	
Large bore, horizontal piping, no normal flow, no candy cane vent	>3.0 inches in diameter: high nesting and general use likelihood	High	Recommend 0.25 to 0.5 inch square mesh hardware cloth over opening and secured by galvanized stainless steel hose clamp or similar device. Periodic monitoring for debris build-up	High Risk for general bird use and avian nesting
Large bore, vertical piping, normal flow, no candy cane vent	>3.0 inches in diameter: nesting not likely low general use and mortality (e.g., trapping)	Low	No mitigative measure recommended due to lack of operational impacts and/or avian impacts. Hardware cloth deterrent system (mentioned above) can be installed as a precaution	Low risk for general avian use and avian trapping. Air flow a deterrent for nesting and general use
Large bore, vertical piping, normal flow, candy cane vent	>3.0 inches in diameter: nesting not likely; low general use and mortality (e.g., trapping)	Low	No mitigative measure recommended due to lack of operational impacts and/or avian impacts. Hardware cloth deterrent system (mentioned above) can be installed as a precaution	Low risk for general bird use and avian trapping. Air flow a deterrent for nesting and general use
Large bore, horizontal piping, normal flow, no candy cane vent	>3.0 inches in diameter: nesting likely; low general use and mortality (e.g., trapping)	Low	No mitigative measure recommended due to lack of operational impacts and/or avian impacts. Hardware cloth deterrent system (mentioned above)	Low risk for general bird use and avian trapping. Air flow a deterrent for nesting and general use

			can be installed as a precaution	
Roof vents and hoods	Nesting likely, low use and low mortality (e.g., trapping)	Low	No mitigative measure recommended due to lack of operational impacts and/or avian impacts. Make sure all vents and hoods are closed, especially during facility outages	Low risk for general bird use and avian trapping. Air flow a deterrent for nesting and general use
Large bore horizontal piping with flapper deterrent and rain shield installed	No nesting, no use and no mortality (e.g., trapping)	Unlikely	No additional mitigative measure recommended due to lack of operational impacts and/or avian impacts	The pipe flapper is a good avian deterrent. The associated rain shield, as designed, should not provide additional nest substrate and opportunity (SSF DG diesel generator exhaust pipes)

* **Note:** (1) There are no 100% guarantees that birds will not use a particular unprotected piping situation for some reason (e.g., foraging, security, and nesting). However, the relative risk of bird use (i.e., Unlikely, Low, High) can be applied to most piping systems due to their configuration, presence of air flow, and location. (2) The risk assessment assumes that the opening of a candy cane vent is directed towards the substrate below the system. An opening at <90º can increase the probability of avian use (direct flight into pipe opening).