Appendix A – Water Resources Study Report

Bad Creek Pumped Storage Project

Oconee County, South Carolina

January 2025

This page intentionally left blank.

1 Project Introduction and Background

Duke Energy Carolinas, LLC (Duke Energy or Licensee) is the owner and operator of the 1,400-megawatt Bad Creek Pumped Storage Project (Project) (FERC 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 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 expiration date of 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, 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 developed a Revised Study Plan (RSP) for the Project and proposed six studies for Project relicensing. The RSP was filed with the Commission and made available to stakeholders on December 5, 2022. FERC issued the Study Plan Determination on January 4, 2023, which included modifications to one of the six proposed studies. Duke Energy completed its first year of studies in 2023 with stakeholder consultation as required by the Commission's SPD. Duke Energy filed the Initial Study Report (ISR) on January 4, 2023, and per the Commission's regulations at 18 CFR §5.15(c), Duke Energy held an ISR meeting with participants and FERC staff within 15 days of filing the ISR on Wednesday, January 17, 2024. Duke Energy completed its second and final year of studies in 2024; this Updated Study Report [18 CFR §5.15(c)] describes the Licensee's methods and results of the studies conducted in support of preparing an application for a new license for the existing Project and construction of the proposed Bad Creek II Power Complex (Bad Creek II).

---

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

2 Water Resources Study

2.1 FERC Environmental Resource Issues

The Commission issued Scoping Document 2 on August 5, 2022, which identified the following environmental resource issues to be analyzed in the National Environmental Policy Act (NEPA) document for the Project relicensing related to water resources. These resource issues address the effects of continued Project operations as well as potential construction and operation of Bad Creek II during the new license term:

- 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.
- Effects of Project operation on water levels in Lake Jocassee.
- Effects of Project operation on water quality in Lake Jocassee, including water temperature, dissolved oxygen (DO) concentrations, and vertical mixing of DO.
- Effects of reservoir fluctuations associated with Project operation on aquatic habitat and biota in Lake Jocassee.
- Effects of vertical mixing of DO associated with Project operation on fish populations in Lake Jocassee.

The Water Resources Study focused on historical water quality data of Lake Jocassee, potential impacts to surface waters due to construction of Bad Creek II, and water resources affected by a second inlet/outlet structure in the Whitewater River arm of Lake Jocassee, while the Aquatic Resources Study (Appendix B) evaluated impacts associated with aquatic life and habitat. The Water Resources Study is complete, and this report presents methods and results of the individual study tasks.

2.2 Study Goals and Objectives

Tasks carried out for the Bad Creek Water Resources Study employ standard methodologies consistent with the scope and level of effort described in the RSP. The goal of the Water Resources Study is to evaluate the Project effects, as well as potential effects or impacts due to the construction and operation of the proposed facility using existing and new information; it is intended to provide sufficient information to support an analysis of the potential Project-related effects on water resources, as well as potential effects or impacts due to the construction and operation of Bad Creek II. The main objectives of this study are as follows:

- To evaluate water resources and water quality impacts of current Project operations using existing data.
- To evaluate water resources and water quality impacts potentially resulting from the construction and operation of Bad Creek II.
- To address stakeholder concerns regarding water resources in the Project Boundary with clear nexus to the Project and Bad Creek II.

Objectives of the Water Resources Study were met through five competed study tasks listed in Table 1 below.[2]

3 Report Layout

The Water Resources Study is complete and final task reports have been developed in consultation with the Water Resources Resource Committee; individual task reports are attached to this report as shown in Table 1. Task reports included as final in the Initial Study Report are not being filed again with this Updated Study Report[3]. Documentation of consultation with the Resource Committee is presented in Attachment 6.

Table 1. Water Resources Study Tasks and Attachments

Study Report Title	Attachment	Attachment Title
Appendix A – Water Resources Study Report	1	Summary of Existing Water Quality Standards Final Report *Not attached/Filed with the Initial Study Report*
	2	Whitewater River Cove Water Quality Field Study Final Report
	3	Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse Final Report
	4	Water Exchange Rates and Lake Jocassee Reservoir Levels Final Report
	5	Draft Water Quality Monitoring Plan
	6	Consultation Documentation

[2] The fifth study task is development of a draft Water Quality Monitoring Plan to address potential water quality effects associated with Bad Creek II construction. The draft monitoring plan was developed in consultation with the South Carolina Department of Environmental Services (SCDES) during the third quarter of 2024 and has been reviewed by the Water Resources and Aquatic Resources Resource Committees. The development of the draft monitoring plan has been completed consistent with the RSP, however, a Standard Operating Procedures (SOP) document will be developed and attached to the monitoring plan when it is finalized for inclusion in the final license application.

[3] The complete study report with all attachments will be included in the final license application.

This page intentionally left blank.

Attachment 1

Summary of Existing Water Quality Standards

<PLACEHOLDER; REFER TO ISR>

This page intentionally left blank.

Attachment 2

Whitewater River Cove Water Quality Field Study

WATER QUALITY MONITORING IN WHITEWATER RIVER ARM

FINAL REPORT

WATER RESOURCES STUDY

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

November 26, 2024

This page intentionally left blank.

WATER QUALITY MONITORING IN WHITEWATER RIVER ARM
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
TABLE OF CONTENTS

Section	Title	Page No.

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS
CONTINUED

Section	Title	Page No.

ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
Bad Creek (or Project)	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
Bad Creek Reservoir	upper reservoir
CFD	computational fluid dynamics
CFR	Code of Federal Regulations
cfs	cubic feet per second
DO	dissolved oxygen
Duke Energy or Licensee	Duke Energy Carolinas, LLC
ft	feet/foot
ft msl	feet above mean sea level
FERC	Federal Energy Regulatory Commission
ILP	Integrated Licensing Process
mg/L	milligrams per liter
miles per hour	miles per hour
RSP	Revised Study Plan
SCDHEC	South Carolina Department of Health and Environmental Control
USP	Updated Study Report
VuLink	In-Situ VuLink® CI datalogger and telemetry system

This page intentionally left blank.

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 Bad Creek Pumped Storage Project (Project) (FERC 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 Hydroelectric Project (KT 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 expiration date of 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, as described at 18 Code of Federal Regulations (CFR) Part 5. Given the need for additional significant 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 proposing to add pumping and generating capacity at the Project. Additional energy storage and generation capacity would 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-megawatt Bad Creek II Power Complex (Bad Creek II) is an alternative relicensing proposal presently being evaluated by Duke Energy.

In accordance with 18 CFR §5.11 of the Commission's regulations, Duke Energy developed a Revised Study Plan (RSP) for the Project and proposed six studies for Project relicensing. The RSP was filed with the Commission and made available to stakeholders on December 5, 2022. FERC issued the Study Plan Determination on January 4, 2023, which included modifications to one of the six proposed studies (Recreational Resources).

This report details the methodologies and findings from the first (2023) and second (2024) study seasons for Task 2 (Water Quality Monitoring in Whitewater River Arm) of the Water Resources Study. This study was conducted to support the application for a new license for the Project, in accordance with 18 CFR §5.15, as outlined in the RSP.

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

1.2 Study Goals and Objectives

Tasks carried out for the Bad Creek Water Resources Study employ standard methodologies that are consistent with the scope and level of effort described in the RSP filed with the Commission on December 5, 2022. This report was developed in support of the Water Resources Study and is intended to provide sufficient information to support an analysis of the potential Project-related effects on water resources in the Whitewater River Arm of Lake Jocassee.

The goal of Task 2 was to collect and analyze existing water quality data to evaluate the effect of the submerged weir on vertical mixing upstream and downstream of the weir and the influence of the exchange of water on stratification in the Whitewater River Arm. Objectives were met through continuous and biweekly monitoring of water temperature and dissolved oxygen (DO) at three historic monitoring stations in the Whitewater River Arm of Lake Jocassee. Data collection was carried out over two summers (2023 and 2024) from June 1 through September 30 when water temperatures are expected to be warmest and stratification is at its peak.[2] Data collected in 2023 represented conditions under three-unit operations at the Project while data collected in 2024 represented conditions under four-unit operations.[3]

Given the absence of water quality data or monitoring in Bad Creek Reservoir, water quality results from this study serve as a representative indication of conditions in the upper reservoir, as water is directly exchanged between the upper reservoir and the Whitewater River arm of Lake Jocasee.[4] Although Bad Creek II operations are not anticipated to adversely impact water quality, these baseline data can provide a critical benchmark for comparing existing conditions with those observed under future operational phases of the proposed project.

This report encompasses results from both study years and provides a comprehensive assessment of the water quality impacts (temperature and DO) associated with the Project.

1.3 Study Area

The Whitewater River arm (see Figure 1) is in the northwestern portion of Lake Jocassee and receives direct tributary flow from the Whitewater River. Lake Jocasee has a drainage area of approximately 145 square miles

---

[2] While the study period for each year is June 1-Sepember 30 as described in the RSP, continuous data are presented through equipment demobilization.

[3] Prior to unit upgrades (completed in March 2024), the maximum hydraulic capacity for the Project was 17,234 cubic feet per second (cfs). After the upgrades, the maximum hydraulic capacity is 19,760 cfs.

[4] Note that water quality monitoring in the Bad Creek Reservoir is not safe (due to rapid, large fluctuations in water level elevation and typically continuous Project operation) nor is it considered meaningful, given the short retention time in the upper reservoir. Due to pumping and generating cycles, retention time is approximately three days if only a single pump-turbine unit is operating. There are no existing water quality data in the upper reservoir; it is used only for Project operations and there is no public access.

(mi^2) and roughly 92 miles of shoreline at full pond (1,110 feet (ft) above mean sea level [msl]). Whitewater River arm also directly receives and exchanges water from the Bad Creek Reservoir through the Project's existing inlet/outlet (I/O) structure; the upper reservoir was formed by damming the Bad Creek and the West Bad Creek tributaries of Howard Creek (a tributary of Lake Jocasee). Bad Creek Reservoir has a drainage area of approximately 1.5 mi^2.

During construction of the original Project, excavated rockfill was transported to the western shore of the Whitewater River arm. From there, it was moved to the lake via barges and used to construct an underwater weir approximately 1,800 ft downstream of the Project's lower reservoir I/O structure (weir midpoint coordinates are 35.0015, -82.991509). The submerged weir, measuring approximately 567 feet in width and 455 feet in length, with a crest elevation of about 1,060 feet above msl, was constructed to mitigate (i.e., minimize) the effects of Project operations on thermal and DO stratification in Lake Jocassee by dissipating the energy of the water discharged from the Project's lower reservoir I/O structure, thereby preserving trout habitat and supporting Lake Jocassee's high quality fishery.

1.4 Water Quality Monitoring Stations

Duke Energy has conducted water quality monitoring throughout Lake Jocassee for over 40 years. To evaluate the influence of the existing submerged weir and Project operations on water temperature and DO stratification in the lake, continuous temperature data and bi-weekly temperature and DO profiles were collected near historical monitoring stations 564.1, 564.0, and 560.0 (Figure 1). The depth at Station 564.1, which is situated between the Project's I/O structure and the submerged weir, is approximately 140 ft. Station 564.0 is located on the downstream side of the submerged weir, 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 in Lake Jocassee downstream of the confluence of the Whitewater River arm and Thompson River arm and is approximately 260 ft deep. Normal maximum pond elevation is 1,110 ft msl and normal minimum pond elevation is 1,080 ft msl.

Detailed water quality data for all historic monitoring stations in Lake Jocassee was provided in the final Water Quality and Summary Standards report (provided in Attachment 1 of Appendix A of the ISR). The historic monitoring station locations differ slightly from the locations monitored during this study; however, the depths and locations are comparable.

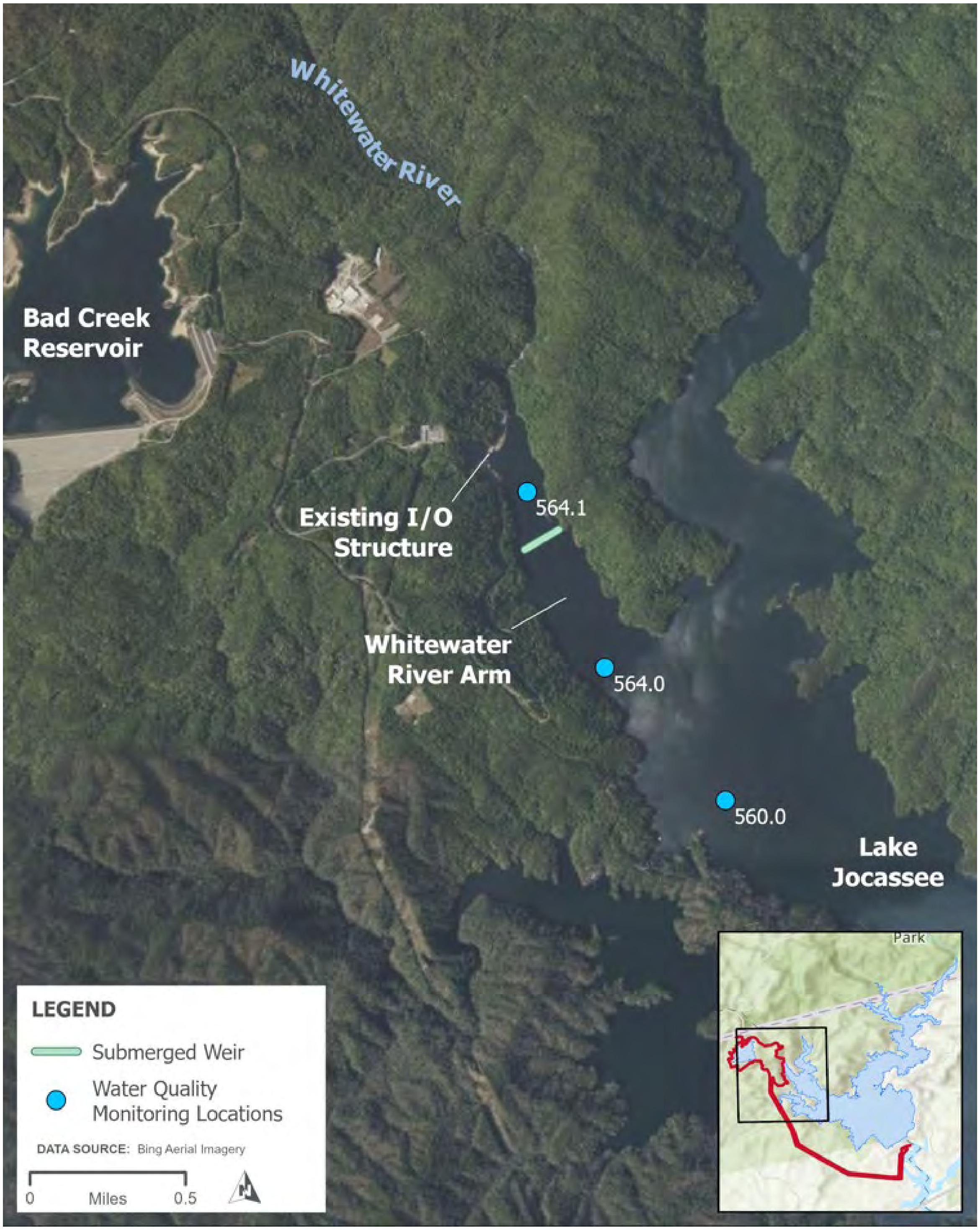


Figure 1. Water Quality Monitoring Stations Assessed in the Whitewater River Arm

2 Methods and Instrumentation

Five individual temperature dataloggers were deployed at each of the three monitoring locations during the 2023 field season (June 1 – October 11) and 2024 field season (May 21 – October 8) using an in-Situ VuLink® CI datalogger and telemetry system (VuLink). [5] The dataloggers (In-Situ Level Troll 400; range of 60 meters) were attached to a 3/16-inch stainless steel cable and strategically placed at specific depths (noted in Table 1) to continuously monitor changes in thermal and DO stratification throughout the 2023 and 2024 field seasons (Figure 2). The VuLink system features built-in venting and barometric compensation, configurable alarms based on instrument and device parameters, and the ability to log data at intervals from every minute to every seven days. It has a memory capacity of 512 megabytes and can simultaneously connect to eight instruments.

The VuLink device was enclosed within a telescoping aluminum protective cage and attached to a high-visibility buoy. The stainless-steel cables, with the attached dataloggers, were deployed at each monitoring location using a boat-mounted winch and anchored with a weight (Figure 3). The datalogger depths and corresponding Lake Jocassee Pond elevations are detailed in Table 1, noting that these depths and elevations are approximate, as they depend on the fluctuating water levels of Lake Jocassee. Pond elevations recorded during each field season are shown on Figure 4.

Although the VuLink system offers cellular coverage across multiple networks and bands (e.g., LTE Global, Verizon, 2G Quadband), the existing cellular transmission (i.e., cell towers) in the vicinity of the Whitewater River arm is insufficient which required manual data downloads (via boat) during bi-weekly field visits. Data from the VuLink system were downloaded to a secure laptop and discrete vertical profiles of water temperature and DO were measured using Hach© Hydrolab DS5 multiprobe[6] and an In-Situ Troll® 500 multiparameter sonde[7] from the water surface to the reservoir bottom, with bottom depth varying by location. The water column was sampled at approximately 0.3-meter and 1 meter from the surface, then at 2-meter intervals for the remaining profile at all three monitoring stations. Dates of all field visits are included in Table 2.

[5] https://in-situ.com/us/vulink
[6] ott.com/download/user-manual-hydrolab-ds5x-ds5-and-ms5-water-quality-multiprobes-1/
[7] Level TROLL 500 Data Logger - In-Situ

Figure 2. Water Quality Instrumentation: (A) VuLink device; (B) In-situ datalogger; (C) VuLink device and dataloggers on single continuous cable system; (D) Deploying stainless steel cable with dataloggers; (E) High visibility buoy with protective cage for VuLink device

Figure 3. Instrumentation Deployment with Boat-mounted Winch (left) and Deployed Water Quality Monitoring Buoy and Datalogger Chain at Station 564.0 (right)

Table 1. Datalogger Depth and Elevation*

Logger	Approximate Water Depth (ft)	Approximate Elevation (ft msl)	Notes
1	3	1,107	Near surface
2	30	1,080	Normal maximum Lake Jocassee drawdown elevation
3	50	1,060	Approximate crest of the submerged weir
4	70	1,040	Approximately 20 ft below the crest of the submerged weir
5	100	1,010	Approximate location of the thermocline

*Depths and elevations are dependent on Lake Jocassee elevations.

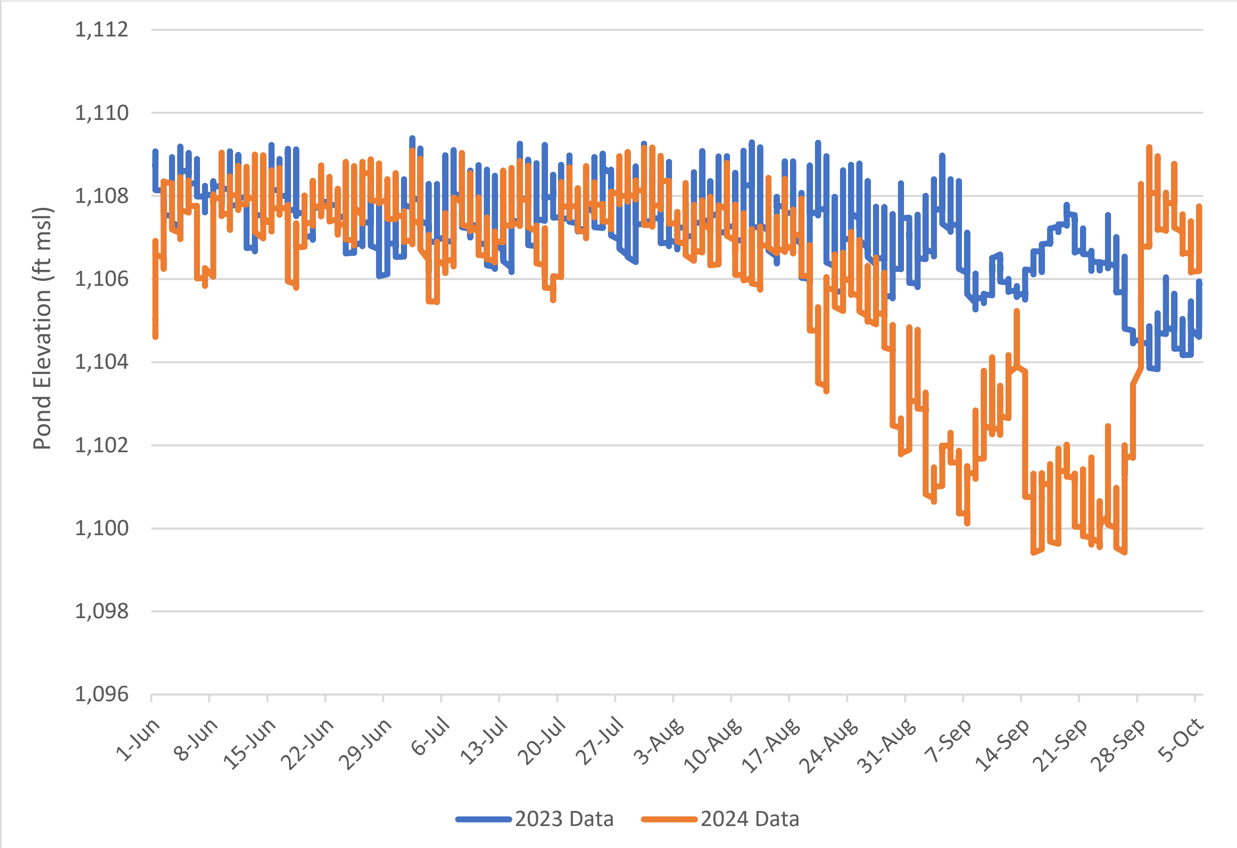


Figure 4. Lake Jocassee Pond Elevations - 2023 and 2024 Study Periods

Table 2. Field Dates for Water Quality Measurement and Data Collection

Study Period	Date	Details
2023	May 22	Deploy instrumentation
	May 31	Data download and vertical profile
	June 14	Data download and vertical profile
	June 27	Data download and vertical profile
	July 13, 14*	Data download and vertical profile
	July 24	Data download and vertical profile
	August 11*	Data download and vertical profile
	August 21	Data download and vertical profile
	September 7	Data download and vertical profile
	September 23*	Data download and vertical profile
	October 11	Data download; Remove instrumentation
2024	May 21	Deploy instrumentation
	June 11	Data download and vertical profile
	June 17	Data download and vertical profile
	July 1	Data download and vertical profile

Study Period	Date	Details
	July 16	Data download and vertical profile
	July 30	Data download and vertical profile
	August 14	Data download and vertical profile
	August 26	Data download and vertical profile
	September 9	Data download and vertical profile
	September 25	Data download and vertical profile
	October 7	Data download and vertical profile; Remove instrumentation

*ADCP flow measurements were conducted for computational fluid dynamics (CFD) model verification during this event in support of the Water Resources Study Task 3.

3 Results

3.1 Study Season 1 (Summer 2023)

3.1.1 Station 564.1

Station 564.1 is immediately downstream of the Project I/O structure and upstream of the submerged weir. From June to early September, epilimnetic water temperatures increased, peaking at 27.7 degrees Celsius (°C) in late July, while hypolimnetic water temperatures peaked in early September at 25.4°C (Figure 5). DO concentrations remained above 7.0 milligrams per liter (mg/L) all at datalogger depths throughout the entire monitoring period (Figure 6).

While there was some minor evidence of thermal stratification between 20 and 40 feet in the earliest part of summer, there was no indication of a stable thermocline, indicating vertical mixing occurred throughout the monitoring period. Vertical mixing is associated with the operation of the Project, which facilitates the direct exchange of water between Bad Creek Reservoir and Lake Jocassee. Vertical mixing at this location is further supported by historical water quality monitoring (Task 1 of the Water Resources Study) and computational fluid dynamics (CFD) modeling conducted for Task 3 of the Water Resources Study.

Continuous temperature data generally indicated a gradual increase in water temperature throughout the summer months, which stabilized in September before experiencing a gradual decline into mid-October (Figure 7). The near surface datalogger recorded greater temperature variability, reflecting diurnal atmospheric temperature fluctuations. This observed variability aligns with the anticipated effects of solar heating and nighttime cooling on surface waters. In contrast, dataloggers positioned at depths between 30 ft and 100 ft recorded relatively stable temperatures, indicative of vertical mixing (due to Project operations) and minimal diurnal temperature variability. This stability displayed effective thermal stratification where deeper waters remain less susceptible to short-term atmospheric temperature changes.

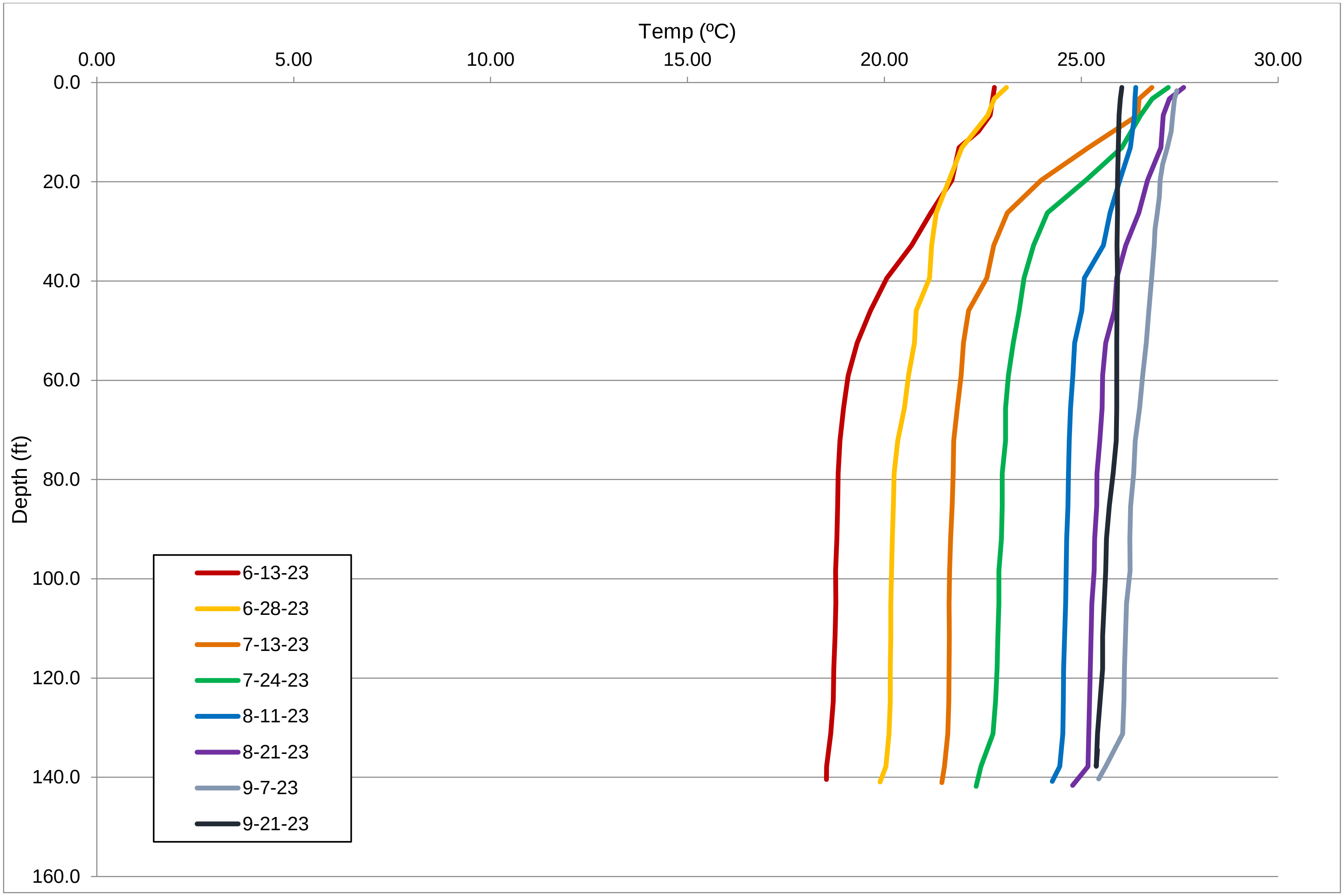


Figure 5. Water Temperature Profiles for Monitoring Station 564.1

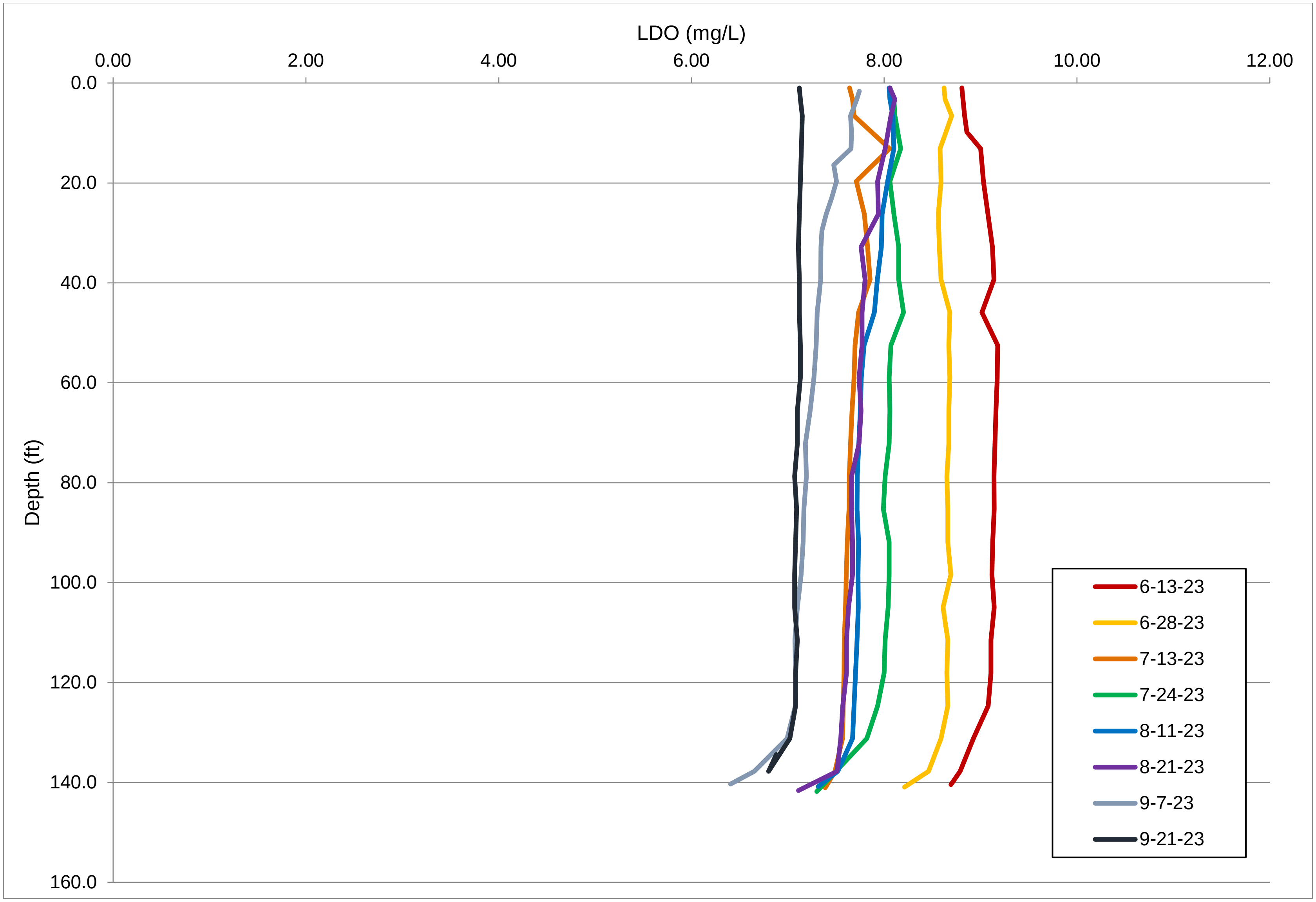


Figure 6. Dissolved Oxygen Concentrations for Monitoring Station 564.1

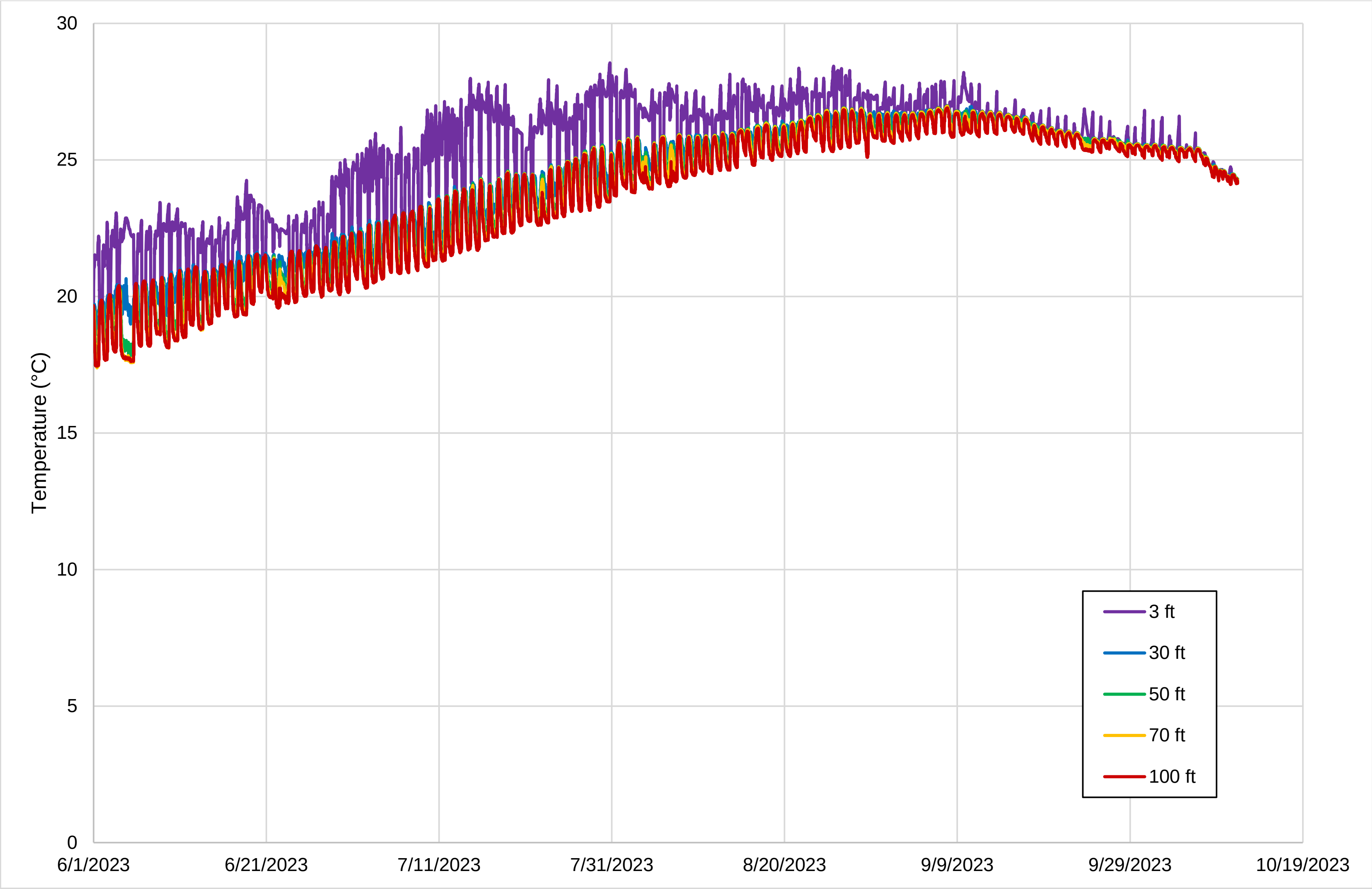


Figure 7. Continuous Water Temperature Profiles for Monitoring Station 564.1

3.1.2 Station 564.0

Station 564.0 is located on the downstream side of the submerged weir, upstream of the confluence of the Whitewater River arm and the Thompson River arm of Lake Jocassee. The recorded surface water temperature exhibited a seasonal trend, characterized by a steady increase throughout the summer months, with a peak temperature of 27.8°C in early September, followed by a gradual decline towards the end of the month (Figure 8). Thermal stratification shows a well-defined thermocline observed at a depth of approximately 100 ft, separating the epilimnion from the hypolimnion. DO concentrations exhibited a consistent decline over the monitoring period from June through September. Surface DO concentrations ranged from 7.3 to 8.8 mg/L, while concentrations at a depth of approximately 200 ft ranged from 0.0 to 2.3 mg/L (Figure 9).

Temperature and DO profiles at Station 564.0 indicate that the presence of the submerged weir minimizes vertical mixing on the downstream side of the weir, as evidenced by the presence of a stable thermocline. This stratification limits the mixing of oxygenated surface waters at depths greater than 100 ft.

Continuous water temperature monitoring data show distinct thermal dynamics at varying depths. Surface water temperatures (at the 3-ft-depth datalogger) reached a maximum of approximately 28.4°C in late July, while temperatures at greater depths (≥ 30 ft) displayed a delayed peak in early September and continued to decline until the end of data collection on October 11, 2023 (Figure 10). As anticipated, the surface water temperatures showed diurnal fluctuations, reflecting the influence of direct solar heating and atmospheric interactions. In contrast, depths at 30, 50, and 70 ft exhibited more stable profiles, with reduced diurnal variability, which are buffered from rapid surface driven temperature changes.

Daily water temperature fluctuations at a depth of 100 ft were larger than fluctuations at depths above 100 ft (Figure 10), likely due to flow circulation patterns immediately downstream of the submerged weir (also shown in the CFD modeling results near this location) and thermal density gradients associated with the thermocline, which were most pronounced at this depth. The submerged weir significantly reduces vertical mixing on the downstream side of the weir which is why thermal and DO stratification is more pronounced compared to Station 564.1 on the upstream side of the weir.

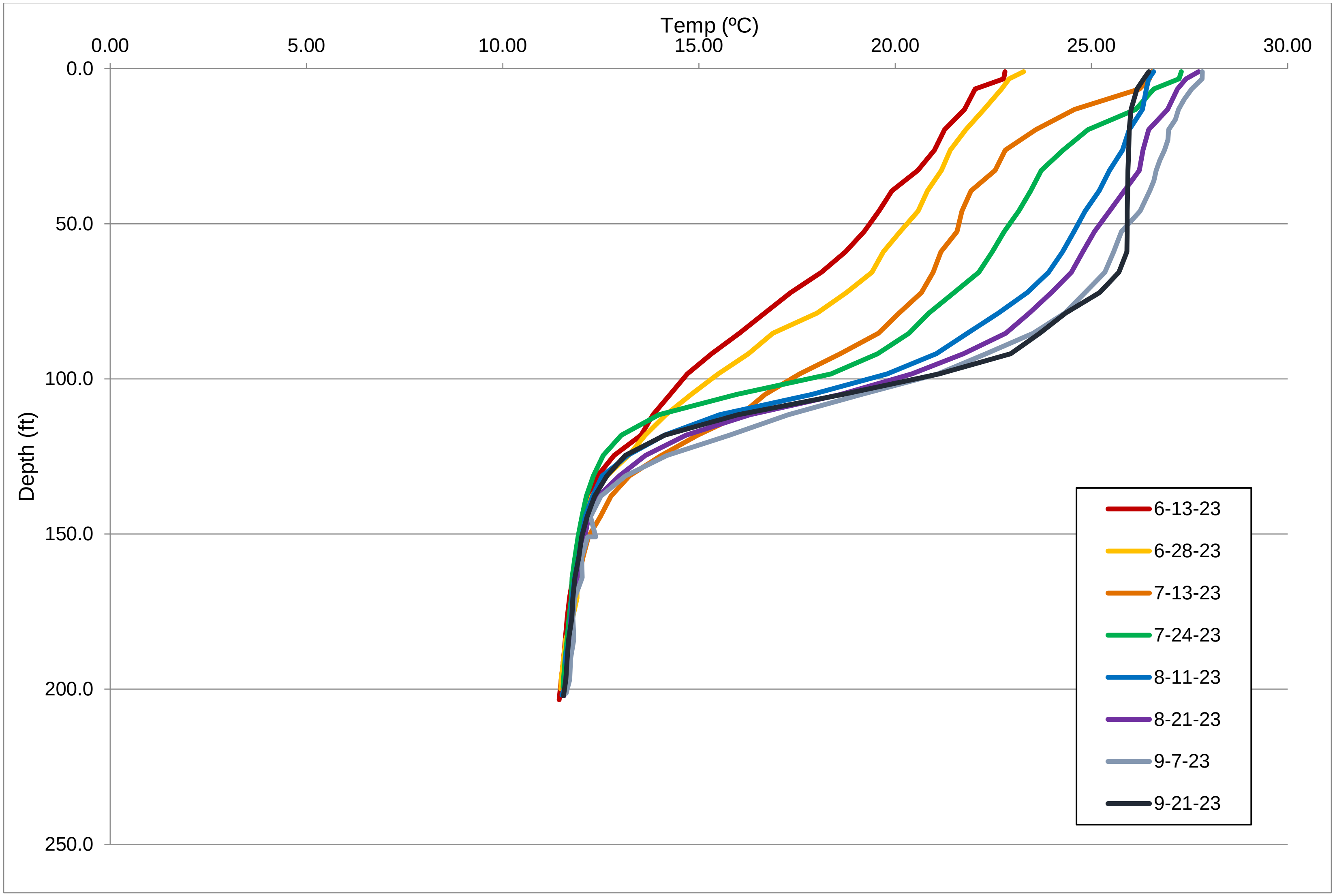


Figure 8. Water Temperature Profiles for Monitoring Station 564.0

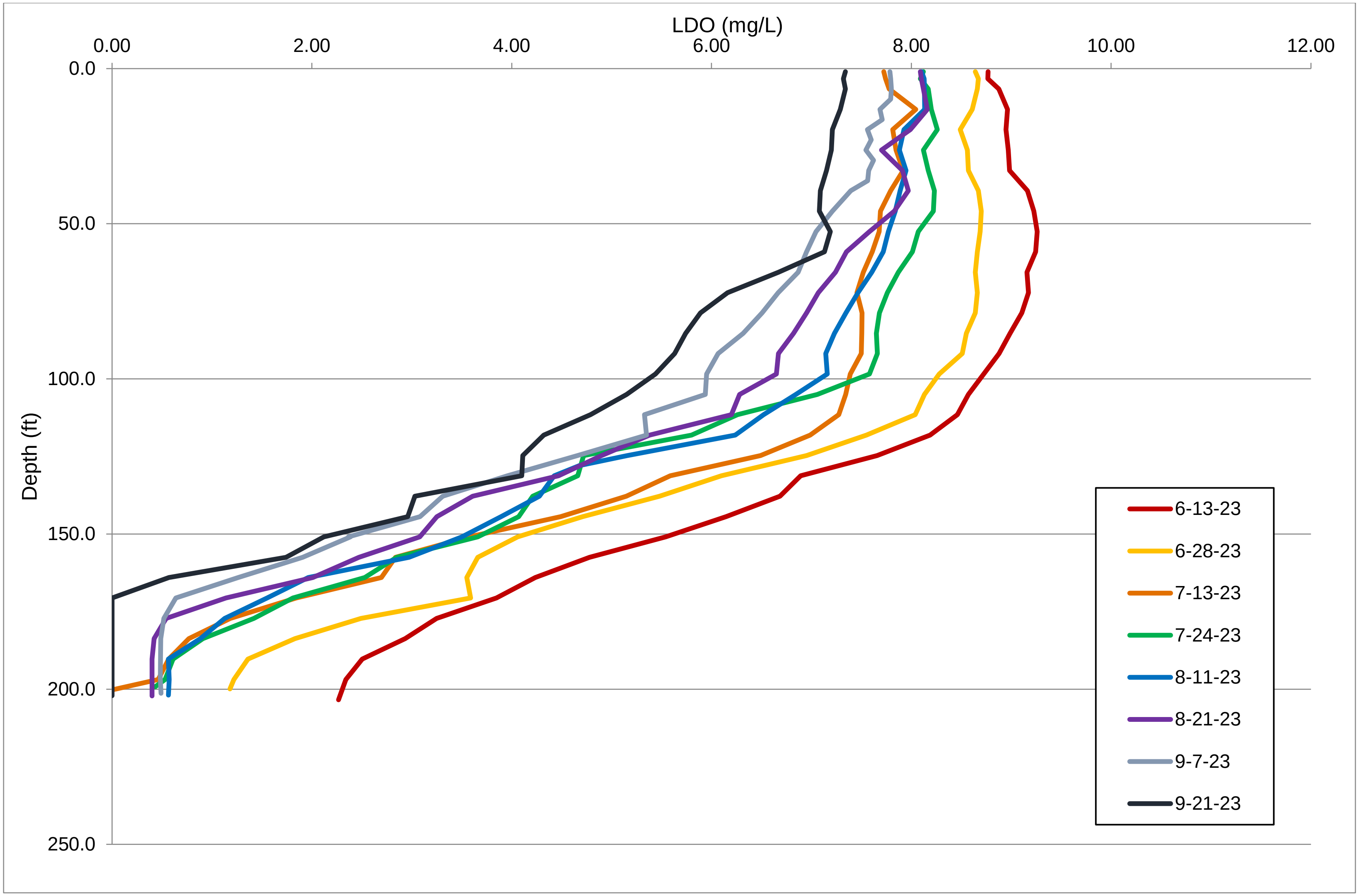


Figure 9. Dissolved Oxygen Concentrations for Monitoring Station 564.0

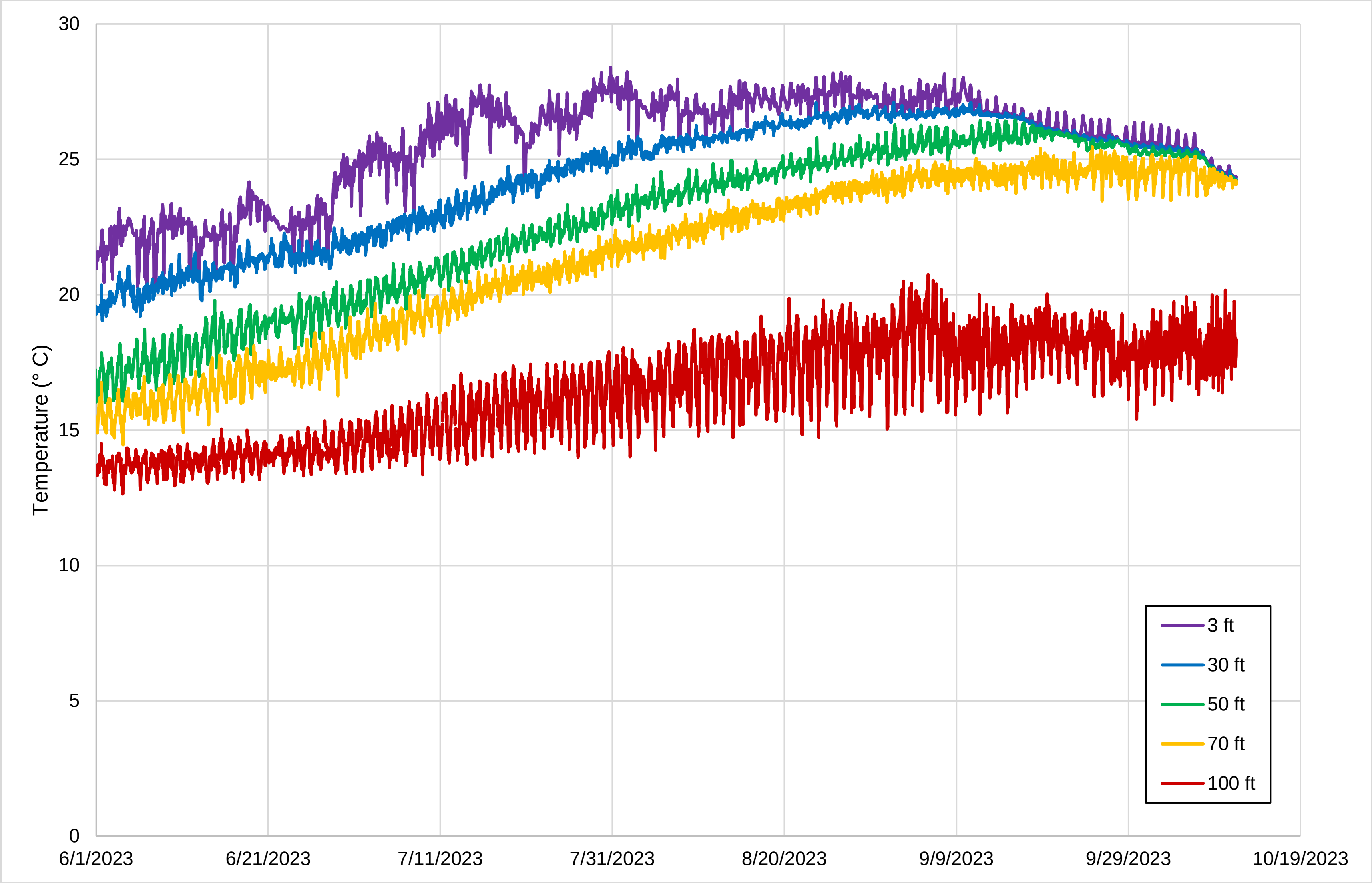


Figure 10. Continuous Water Temperature Profiles for Monitoring Station 564.0

3.1.3 Station 560.0

Thermal and DO profiles at Station 560.0 exhibited stratification patterns similar to those observed at Station 564.0. Throughout the monitoring period, surface water temperatures increased, reaching a peak of 28.1°C, while DO concentrations ranged from 7.8 to 8.9 mg/L (Figure 11 and Figure 12). A thermocline was observed at approximately 100 ft, separating the warmer epilimnion from the cooler hypolimnion.

At Station 560.0, which has a depth of approximately 260 ft, temperatures below the thermocline were approximately 11°C, with DO concentrations ranging from 0.9 to 2.2 mg/L. The deeper and wider channel at this location exhibits less vertical mixing (confirmed by the CFD modeling results) resulting in pronounced thermal and DO stratification.

Continuous water temperature monitoring data are shown on Figure 13. Surface water temperatures reached a maximum of approximately 28.7°C in late August, while temperatures at greater depths (≥ 30 ft) peaked in early September before gradually declining through the end of the study period. Similar to observations at Station 564.0, surface temperatures exhibited diurnal fluctuations.

At 100 ft, water temperature fluctuations were also observed, but the magnitude of the fluctuations were reduced compared to those observed at Station 564.0. This can be attributed to the decreasing influence of flows in the Whitewater River arm as the channel deepens and broadens resulting in a more stable thermal environment.

Pond elevations in Lake Jocassee, as shown on Figure 4, remained within the upper 4 ft of the reservoir’s 30-ft operating band from early June through early September. However, during the latter part of the study period, drought conditions resulted in decreased pond elevations (as low as 1,103.3 ft msl, or 6.7 ft below full pond) in early October. Despite this decrease, there was no observable impact on water temperature or DO trends in the recorded data.

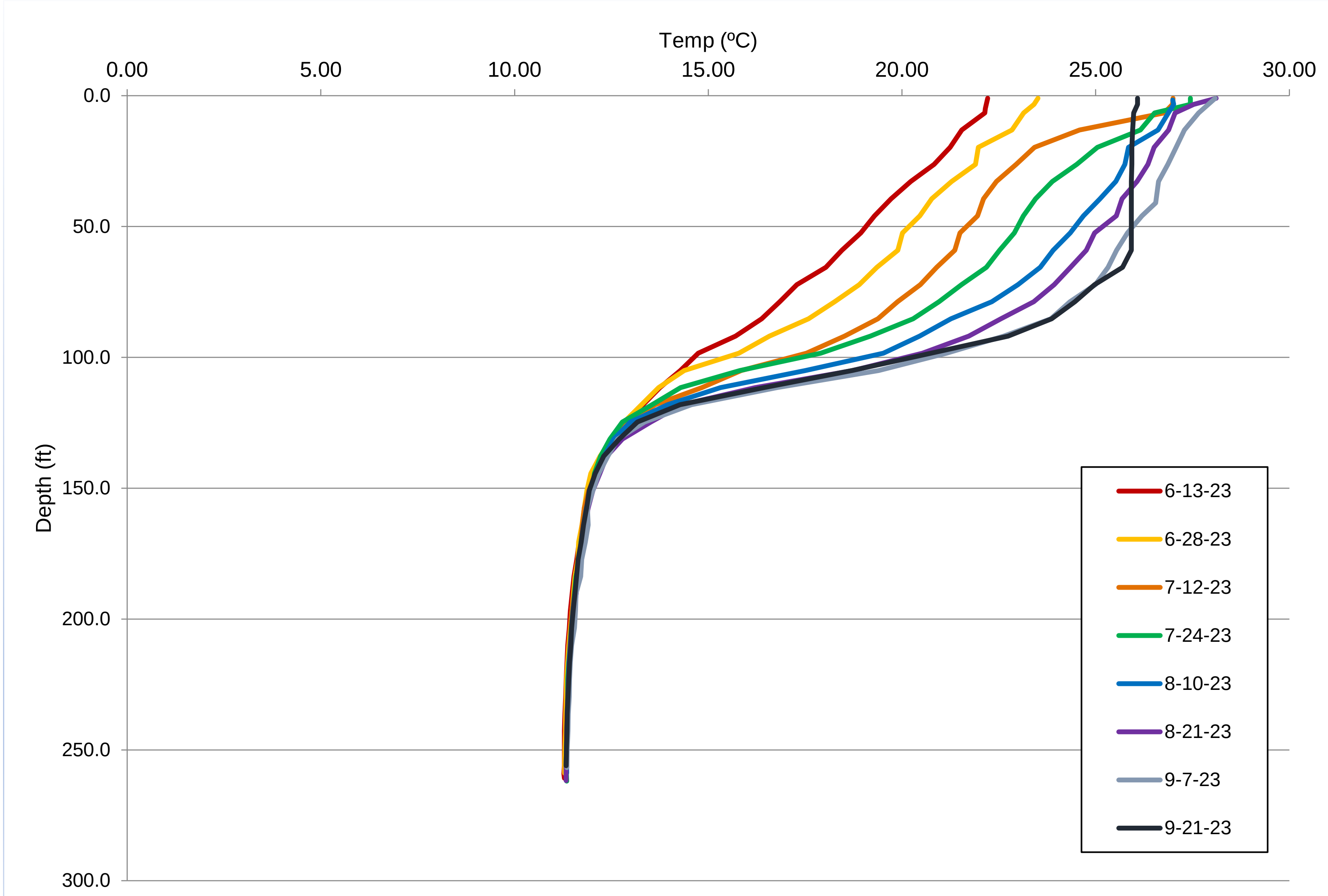


Figure 11. Water Temperature Profiles for Monitoring Station 560.0

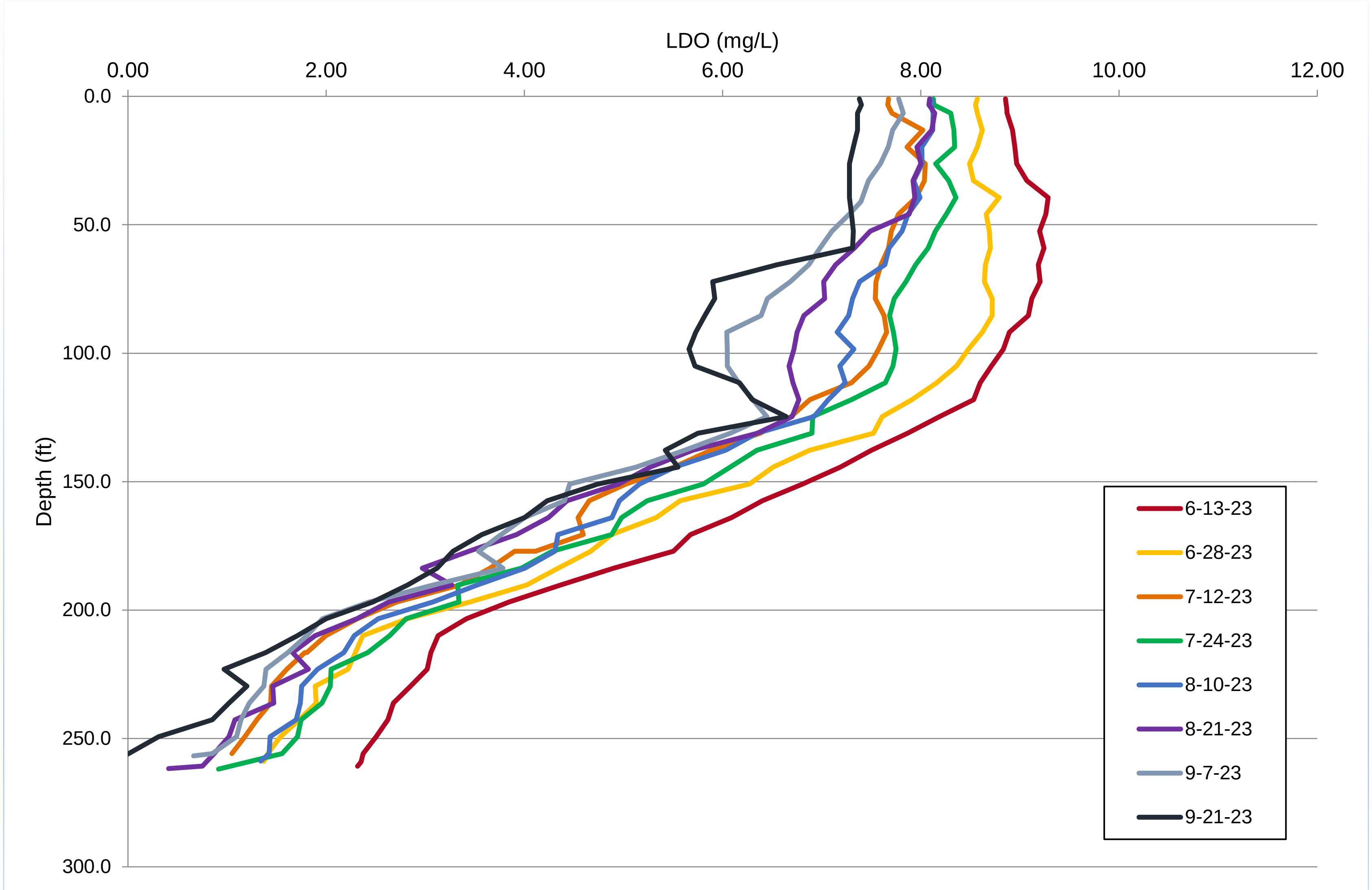


Figure 12. Dissolved Oxygen Concentrations for Monitoring Station 560.0

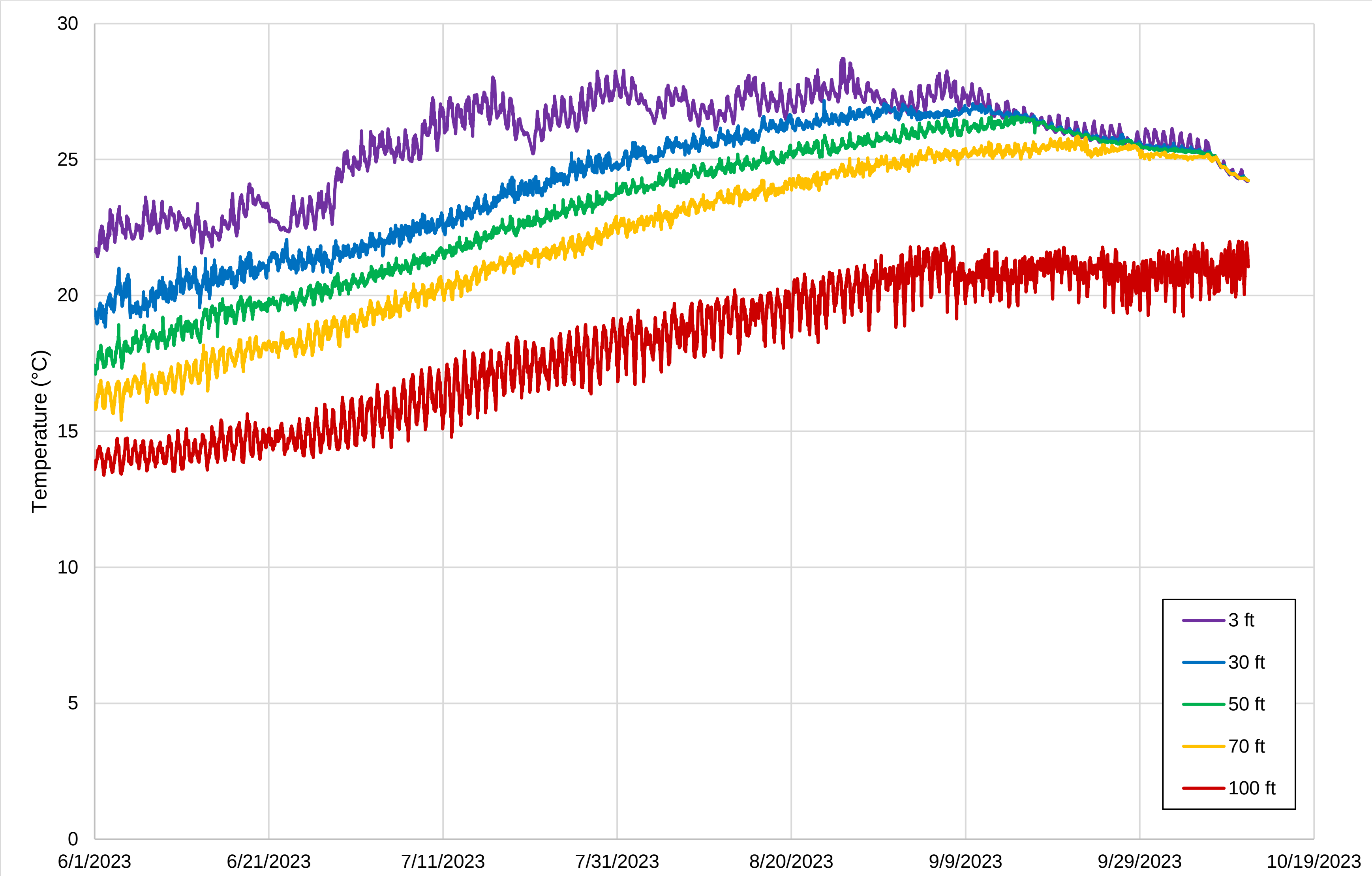


Figure 13. Continuous Water Temperature Profiles for Monitoring Station 560

3.2 Study Season 2 (Summer 2024)

3.2.1 Station 564.1

In the early summer months (June – mid-July) of 2024, similar to the previous year, there was some evidence of thermal stratification between 20 and 40 feet. Epilimnetic temperatures peaked at approximately 28.5°C in mid-July, while deeper hypolimnetic waters reached a maximum temperature around 21.0°C (Figure 14). By August, thermal stratification was less evident in the upper water column (likely due to mixing/Project operations) and relatively isothermal conditions persisted through the end of the study period in early October. DO concentrations remained consistently above 6.0 mg/L across all depths, indicating well-oxygenated conditions during the study period (Figure 15).

Continuous temperature monitoring data showed a gradual increase in water temperatures throughout the summer, plateauing in early September before experiencing a gradual decline into mid-October (Figure 16). The surface datalogger (3 ft) recorded greater temperature variability, likely driven by diurnal fluctuations in atmospheric temperatures, corresponding to solar heating during the day and cooling at night. In contrast, temperature loggers positioned at depths of 30 to 100 feet recorded relatively similar thermal conditions, indicative of effective vertical mixing and minimal influence from diurnal atmosphere variability.

The landfall of Hurricane Helene in the Upstate of South Carolina on September 26-27 directly impacted temperatures in the Whitewater River arm (Figure 16); this is discussed in Section 3.2.4.

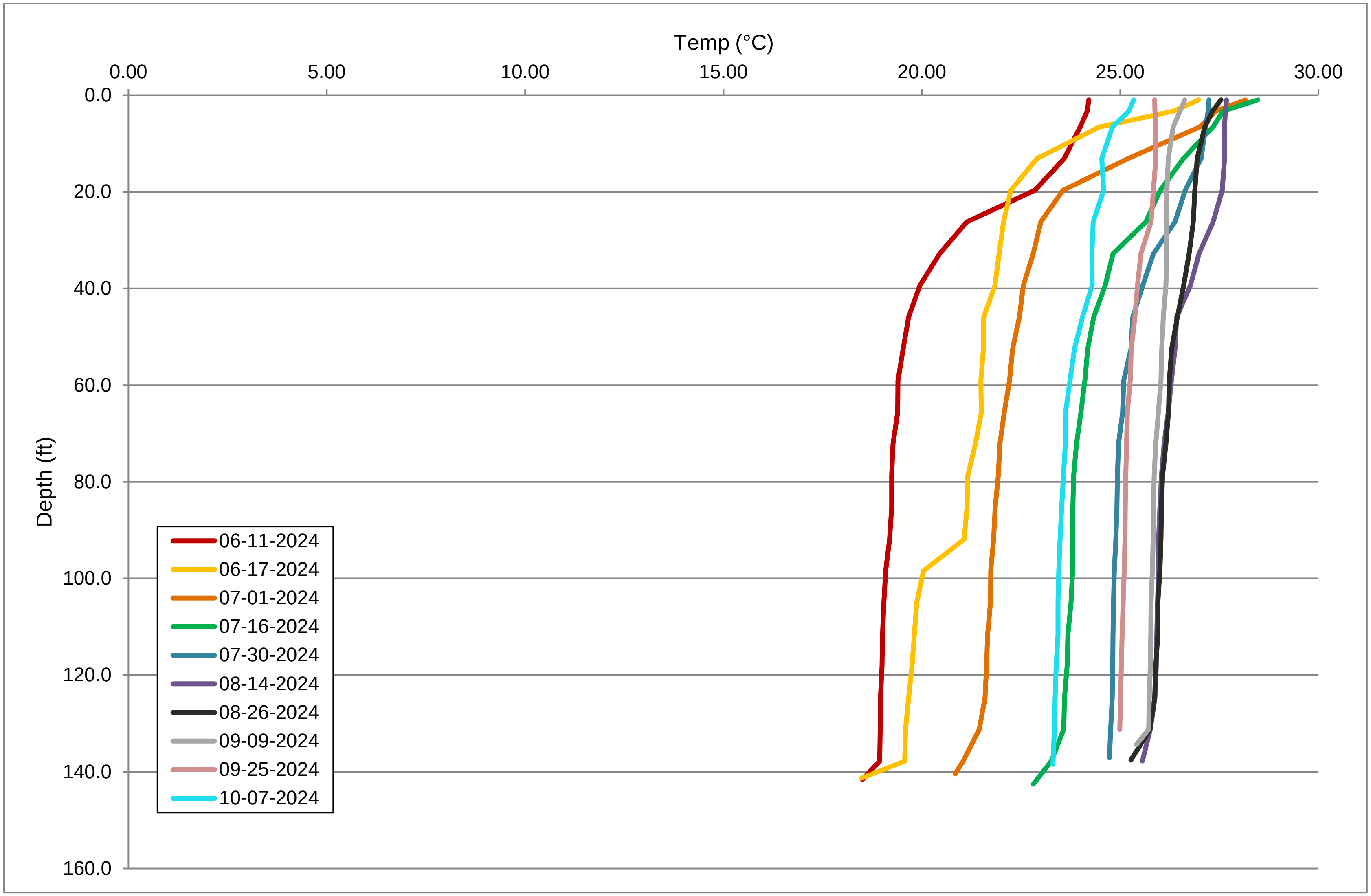


Figure 14. Water Temperature Profiles for Monitoring Station 564.1

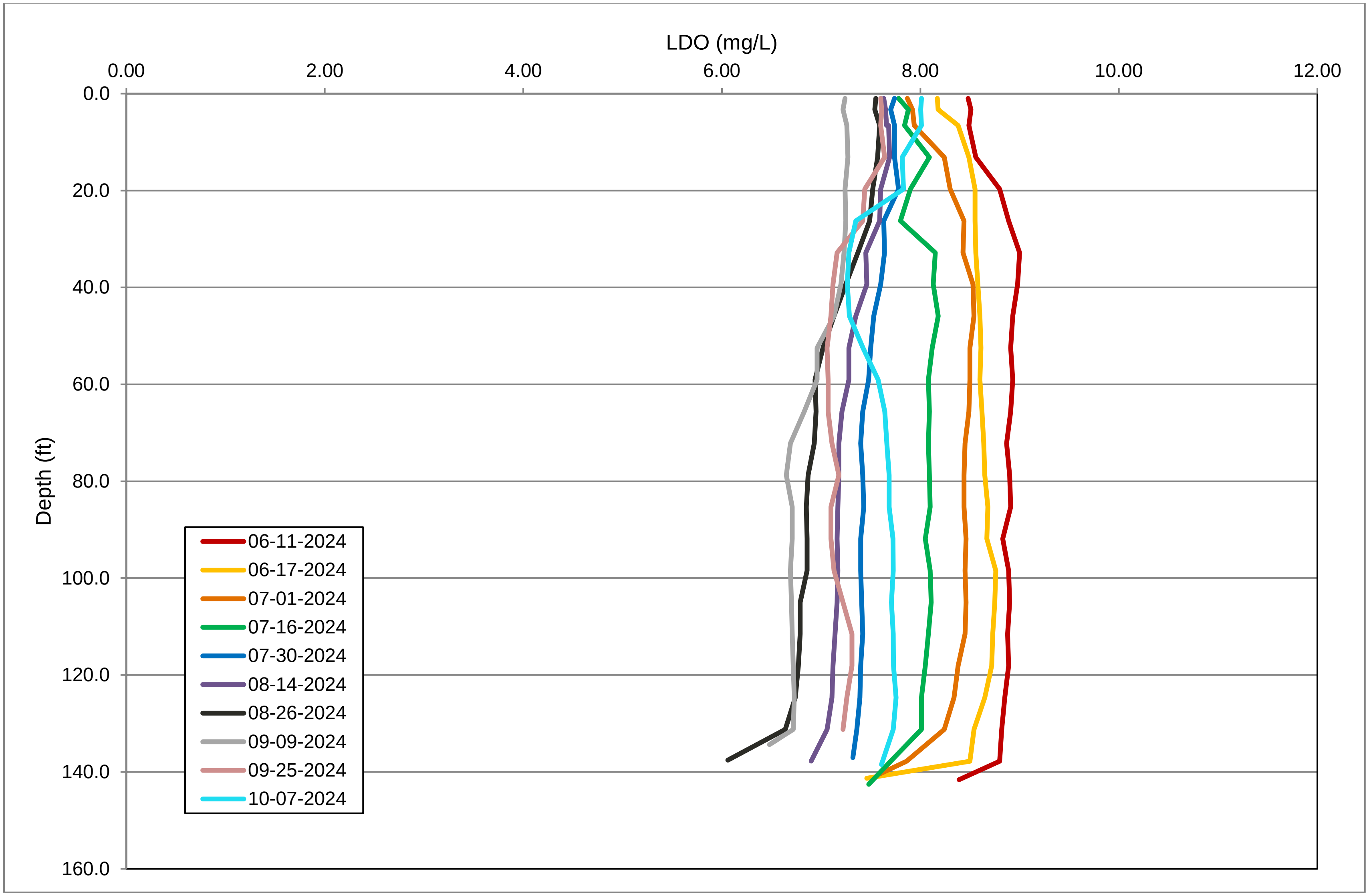


Figure 15. Dissolve Oxygen Concentrations for Monitoring Station 564.1

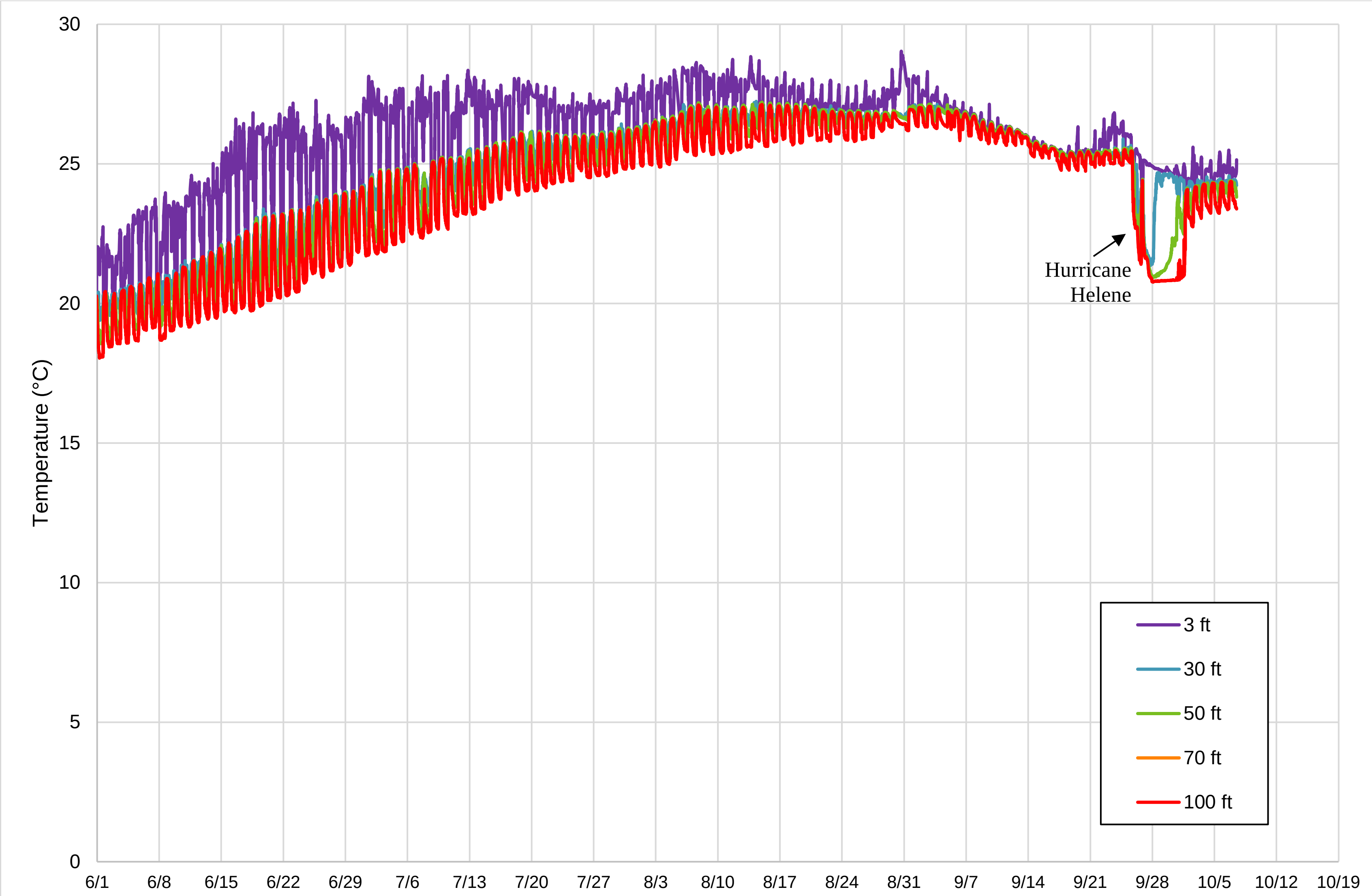


Figure 16. Continuous Water Temperature Profiles for Monitoring Station 564.1

3.2.2 Station 564.0

The recorded surface water temperature at Station 564.0 exhibited a seasonal progression of stratification, characterized by a thermal increase throughout the summer months with a peak temperature of 28.2°C in mid-July followed by a gradual decline throughout the end of the monitoring period (Figure 17). The thermal stratification at this station was more pronounced compared to Station 564.1, with a distinct thermocline observed at approximately 100 feet, separating the epilimnion and hypolimnion. DO concentrations exhibited a decline over the monitoring period, with epilimnetic concentrations ranging from 7.5 to 8.9 mg/L, while concentrations in the hypolimnion ranged from 0.7 to 7.0 mg/L (Figure 18). This stratification, made evident by the thermocline, indicates the presence of hypoxic conditions at depths greater than 150 feet, where vertical mixing does not occur.

The submerged weir is a significant factor in preventing vertical mixing downstream, allowing for natural thermocline development in Lake Jocassee. The stable thermocline at Station 564.0 was also confirmed through CFD modeling and previous water quality monitoring.

Continuous temperature data (Figure 19) also shows distinct thermal characteristics at the various datalogger depths. The surface water temperatures recorded at the 3-ft-deep logger reached a maximum of approximately 28.2°C in early August, while depths ≥ 30 ft displayed a peak in late August, and declined until the end of the monitoring period. As observed in 2023, surface temperatures exhibited diurnal fluctuations, while depths at 30, 50, and 70 ft showed thermally stable profiles (Figure 17).

Continuous temperature data at 100 ft observed higher variability than at other depths, which can be attributed to the complex flow circulation patterns influenced by the submerged weir. CFD modeling supports the conclusion that the presence of the submerged weir minimizes mixing downstream of the weir allowing natural thermal stratification to develop.

The landfall of Hurricane Helene in the Upstate of South Carolina on September 26-27 impacted temperatures in the Whitewater River arm (see Figure 19); this is discussed in Section 3.2.4.

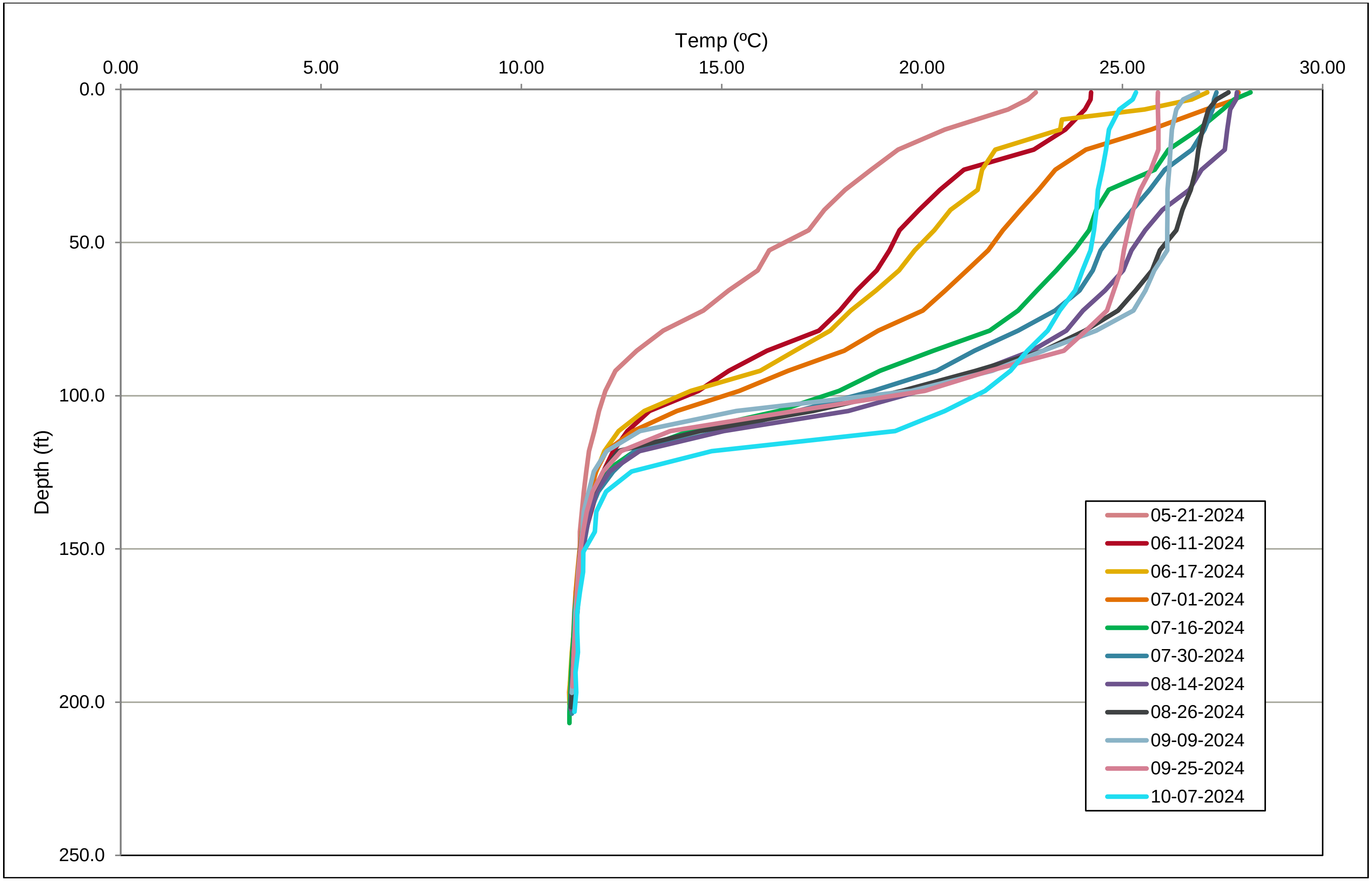


Figure 17. Water Temperature Profiles for Monitoring Station 564.0

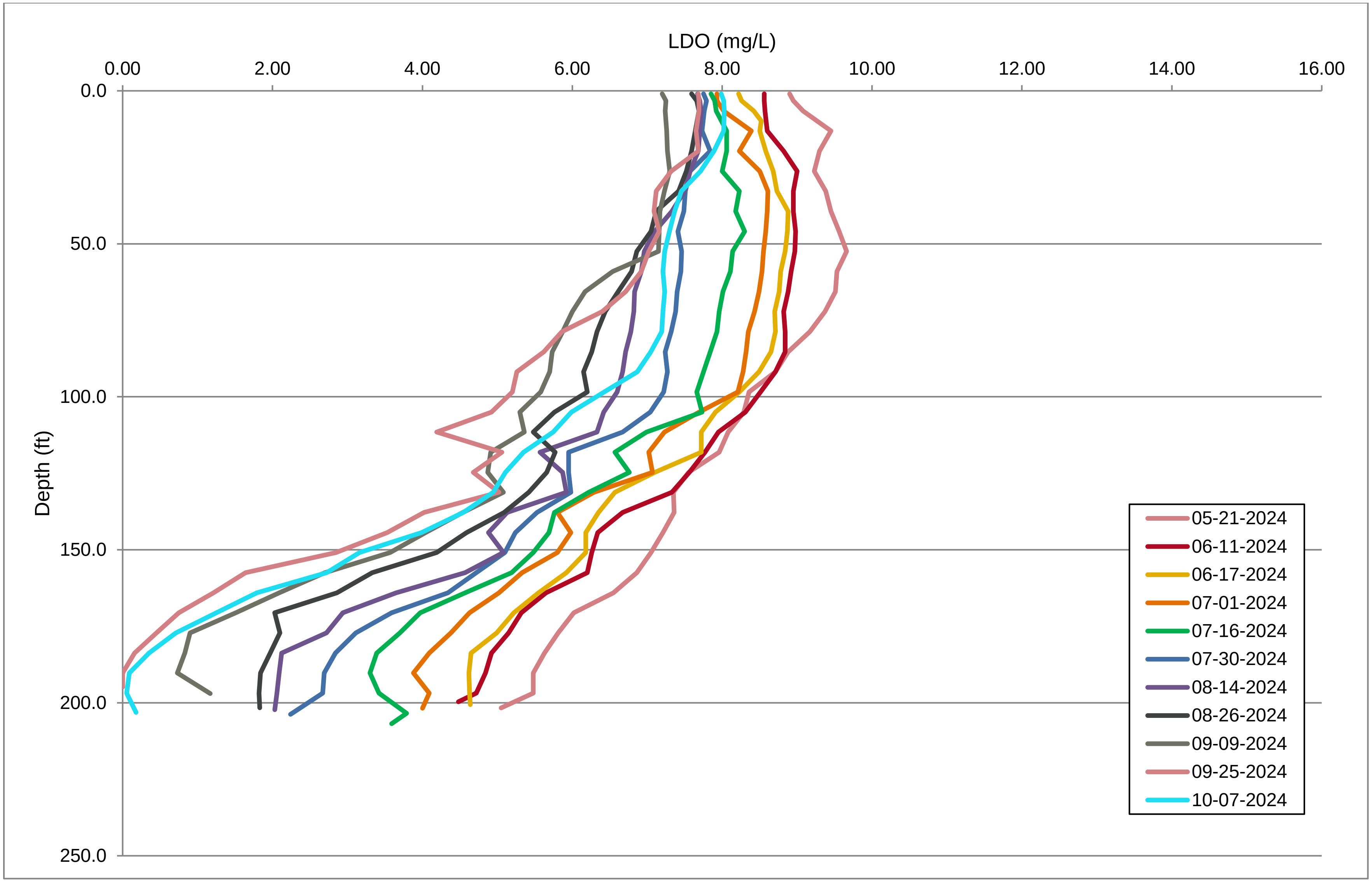


Figure 18. Dissolved Oxygen Concentrations for Monitoring Station 564.0

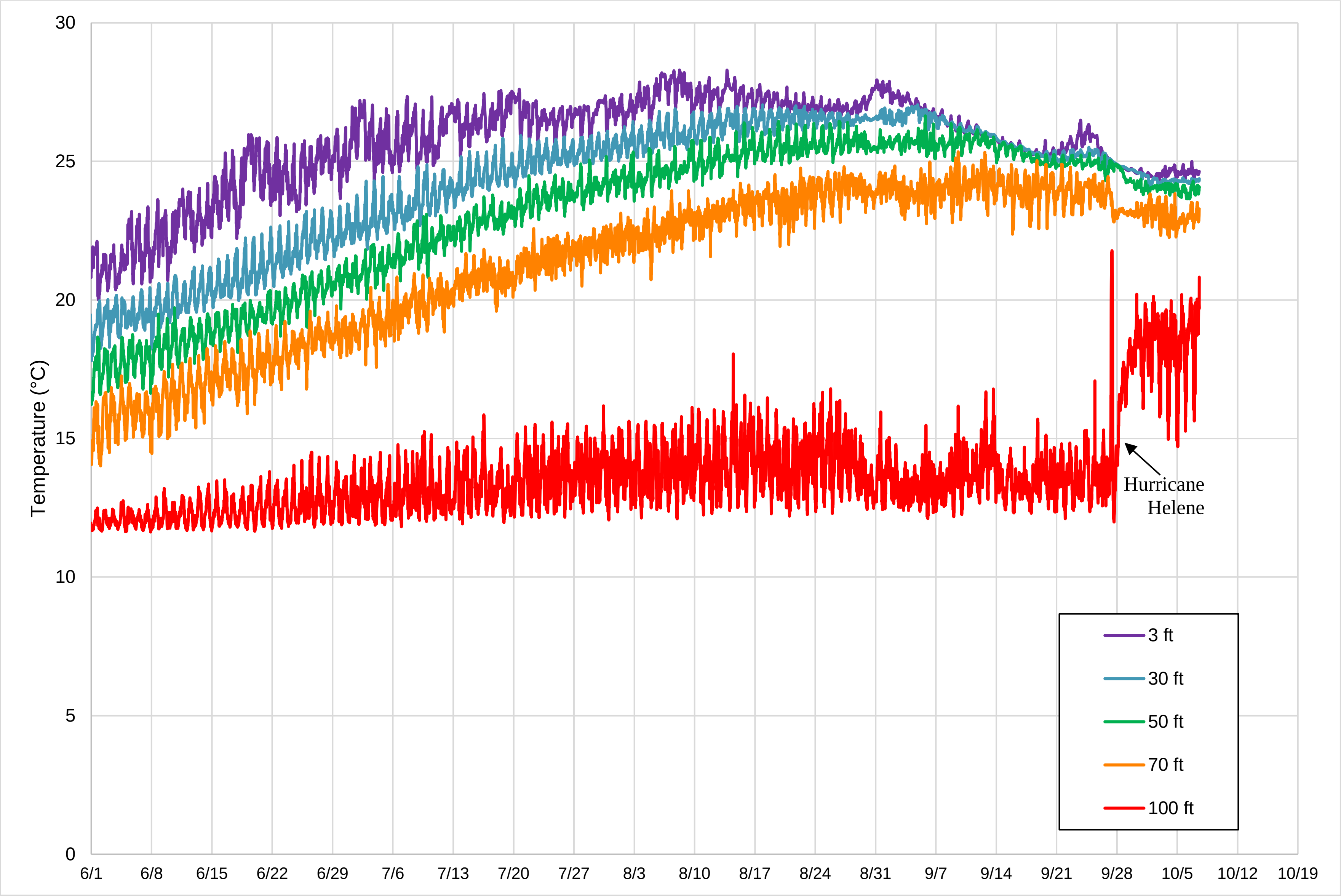


Figure 19. Continuous Water Temperature Profiles for Monitoring Station 564.0

3.2.3 Station 560.0

The temperature and DO profiles at Station 560.0 displayed similar stratification patterns to those observed at Station 564.0. Surface water temperatures peaked near the end of August at 28.3°C while DO concentrations in the epilimnion ranged from 6.3 to 8.9 mg/L to (Figure 20 and Figure 21). Also similar to Station 564.0, a defined thermocline was present at approximately 100 feet.

Temperatures recorded in the hypolimnion ranged from 11.0 to 17.6 °C, while DO concentrations ranged from 3.9 to 6.3 mg/L. The greater depth and wider channel at this station likely contributed to the observed stratification by promoting a stable thermal gradient inhibiting thermal mixing.

Continuous water temperature monitoring further illustrated the seasonal thermal dynamics observed at this station. Surface water temperatures peaked at approximately 28.7°C in early August, while temperatures at greater depths than 30 ft peaked in 25.8°C in early September, followed by a gradual decline toward the end of the monitoring period. Diurnal fluctuations in surface water temperatures were observed, as expected, reflecting diel cycles of solar heating and radiative cooling. Similar to Station 564.0, water temperature fluctuations at the 100-ft depth were also evident, likely influenced by complex circulation patters and thermal density gradients downstream of the weir as discussed above. This effect, supported by CFD modeling, highlights the significant role of the weir, as it dissipates effects of Project operations (Figure 22).

The landfall of Hurricane Helene in the Upstate of South Carolina on September 26-27 impacted temperatures in the Whitewater River arm; this is discussed in Section 3.2.4.

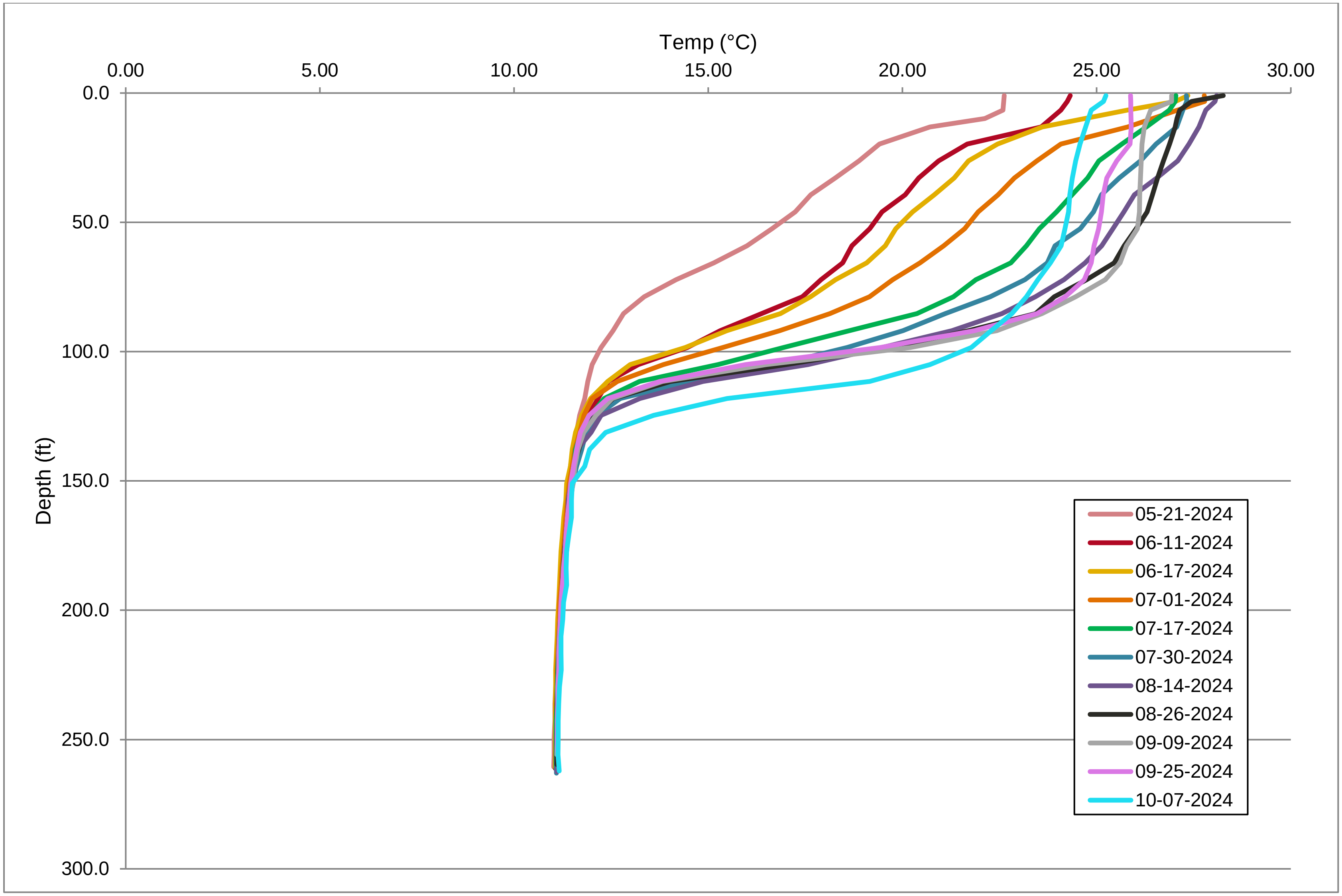


Figure 20. Water Temperature Profiles for Monitoring Station 560.0

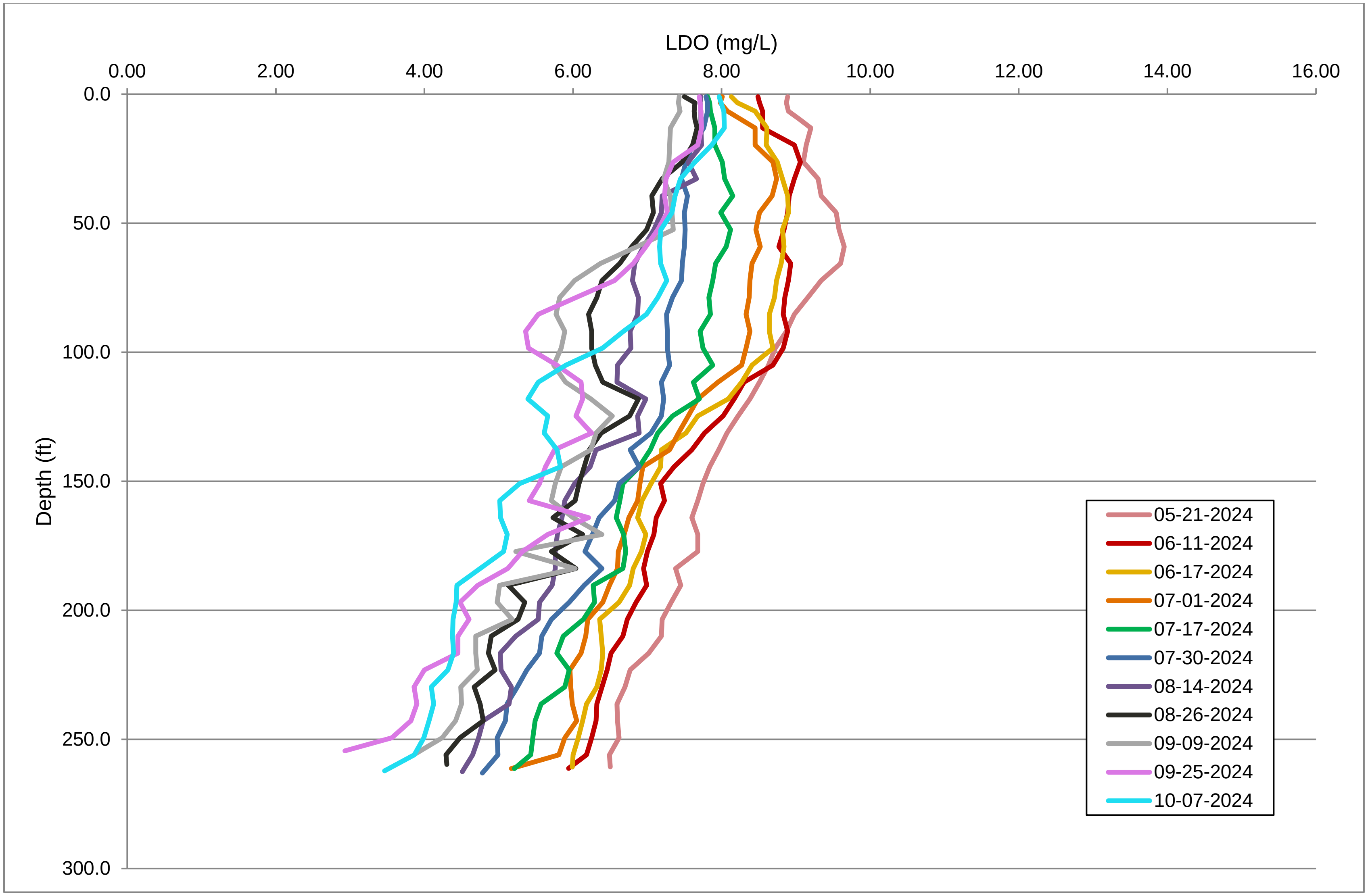


Figure 21. Dissolved Oxygen Concentrations for Monitoring Station 560.0

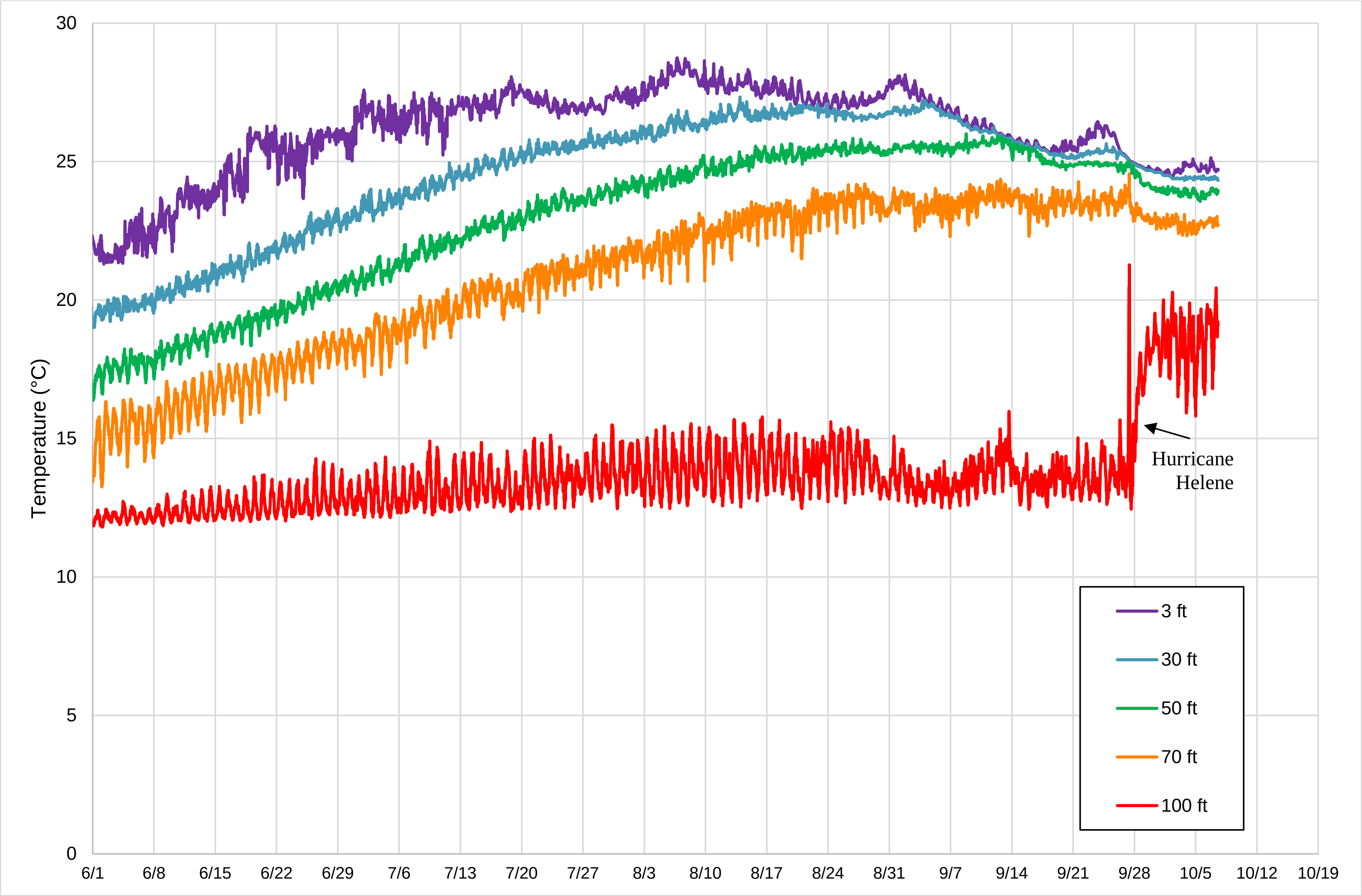


Figure 22. Continuous Water Temperature Profiles for Monitoring Station 560.0

3.2.4 Hurricane Helene

On September 23, 2024, the National Oceanic and Atmospheric Administration classified a developing storm system near the Cayman Islands as a tropical storm, projected to impact northwestern Florida. By September 26, the tropical storm intensified into a Category 4 Hurricane with sustained wind speeds reaching 140 miles per hour (mph) making landfall with a 15-ft storm surge near Tallahassee, Florida. Over the next 24 hours, Hurricane Helene headed northwest affecting Georgia, South Carolina, North Carolina, Tennessee, and Virginia, with a storm radius extending over 300 miles (NOAA 2024).[8]

During this event, the Jocassee Gorges watershed experienced up to 18 inches of precipitation over a three-day period. Rainfall at the Project totaled 15.89 inches (Alan Stuart, personal communication). This extreme precipitation event is considered a 1,000-year flood, a hydrological occurrent with a 0.1 percent annual probability (NOAA 2024). Continuous temperature data in Lake Jocassee for the day before the event and for several days after the event are shown below on Figure 23 (Station 564.1), Figure 24 (Station 564.0), and Figure 25 (Station 560.0).

Continuous temperature monitoring at Station 564.1 (Figure 23) showed a sudden decline in water temperatures (except for surface temperatures) and temperatures reached approximately 21°C at the three deepest dataloggers. This pattern indicates a substantial influx of cooler water from the Whitewater River into Lake Jocassee consistent with the timing of the hurricane event. Temperatures recovered (i.e., became mixed) after the initial decline, with the lower datalogger (100-ft) taking longest to recover to pre-hurricane temperatures. Figure 23 also shows Lake Jocassee elevations; Duke Energy drew the lake down to 1,099 ft msl on September 26 in preparation for the predicted storm.

As shown on Figure 24 and Figure 25, the combined effects of storm-driven wind stress, colder inflows, and decreasing air temperatures promoted vertical mixing, facilitating the descent of cooler, denser epilimnetic water. This, in turn, caused an upwelling of hypolimnetic water, leading to a temporary downward shift in the thermocline, which was observed at the deepest dataloggers for both stations downstream of the weir.

The rainfall from Hurricane Helene and impacts from this event on water temperatures and mixing in Whitewater River arm, while significant, were temporary and not typical.

---

[8] https://www.noaa.gov/

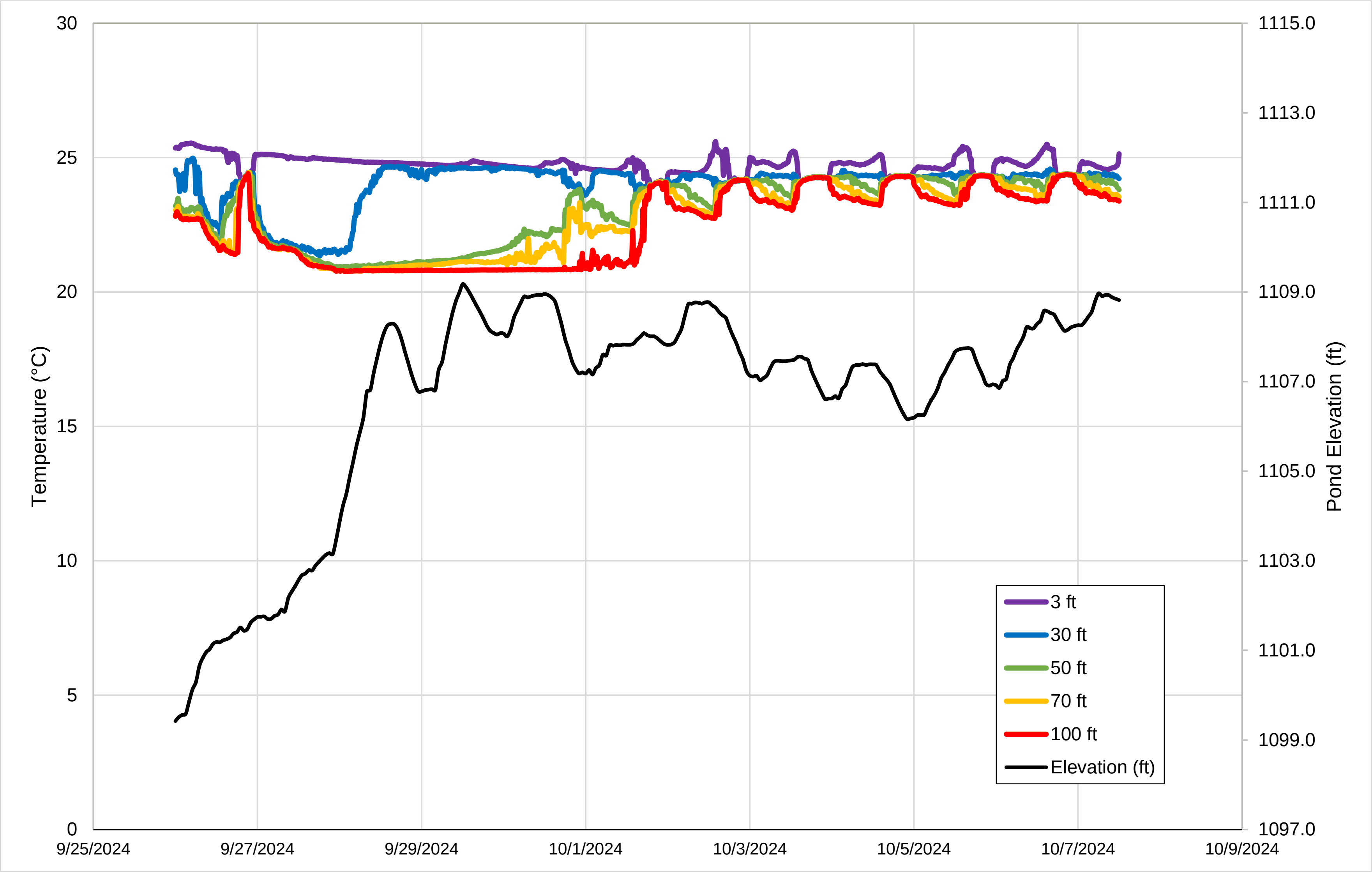


Figure 23. Continuous Water Temperature Profiles for Monitoring Station 564.1 (September 26-October 7, 2024) vs Lake Jocassee Pond Elevation

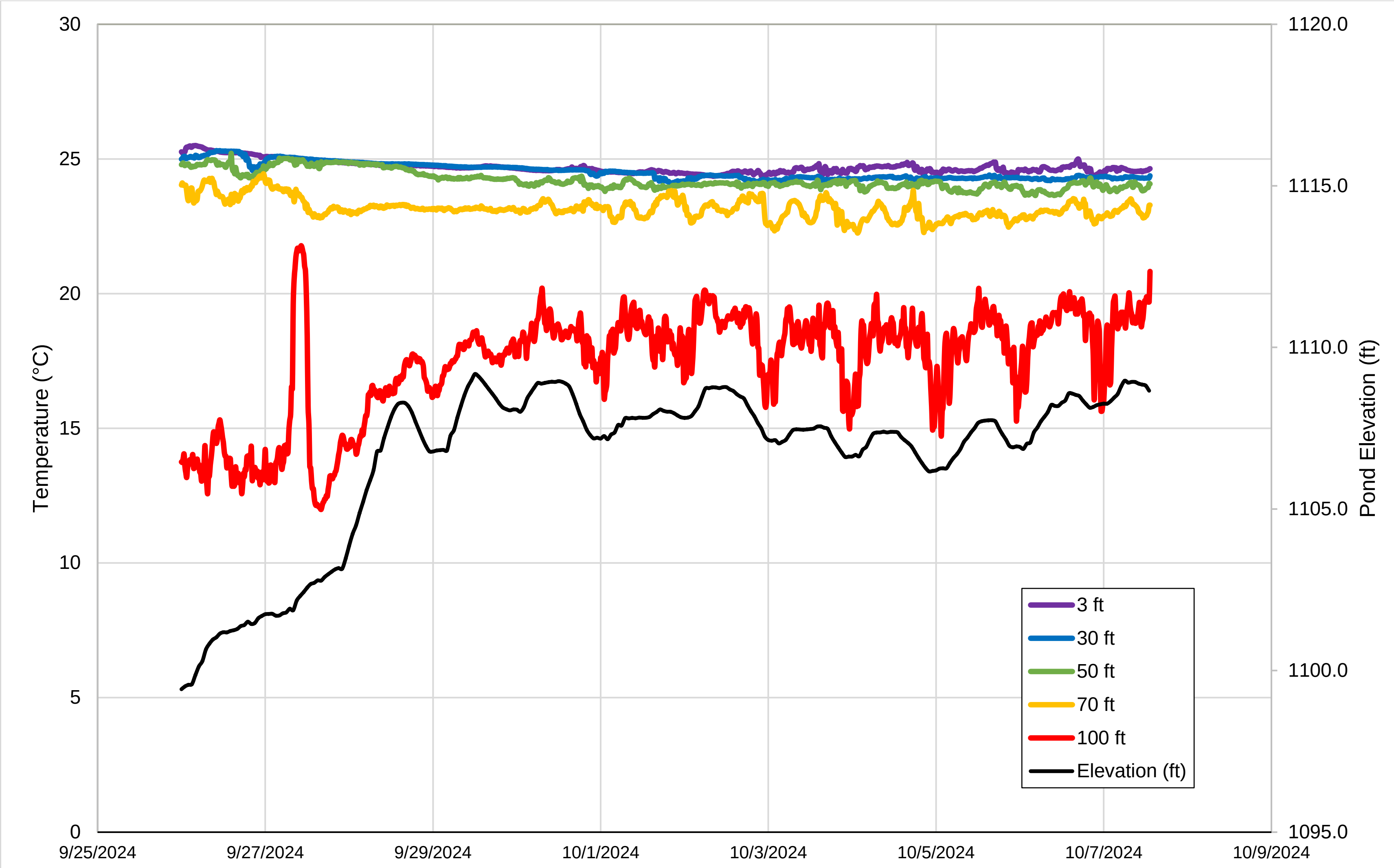


Figure 24. Continuous Water Temperature Profiles for Monitoring Station 564.0 (September 26-October 7, 2024) vs Lake Jocassee Pond Elevation

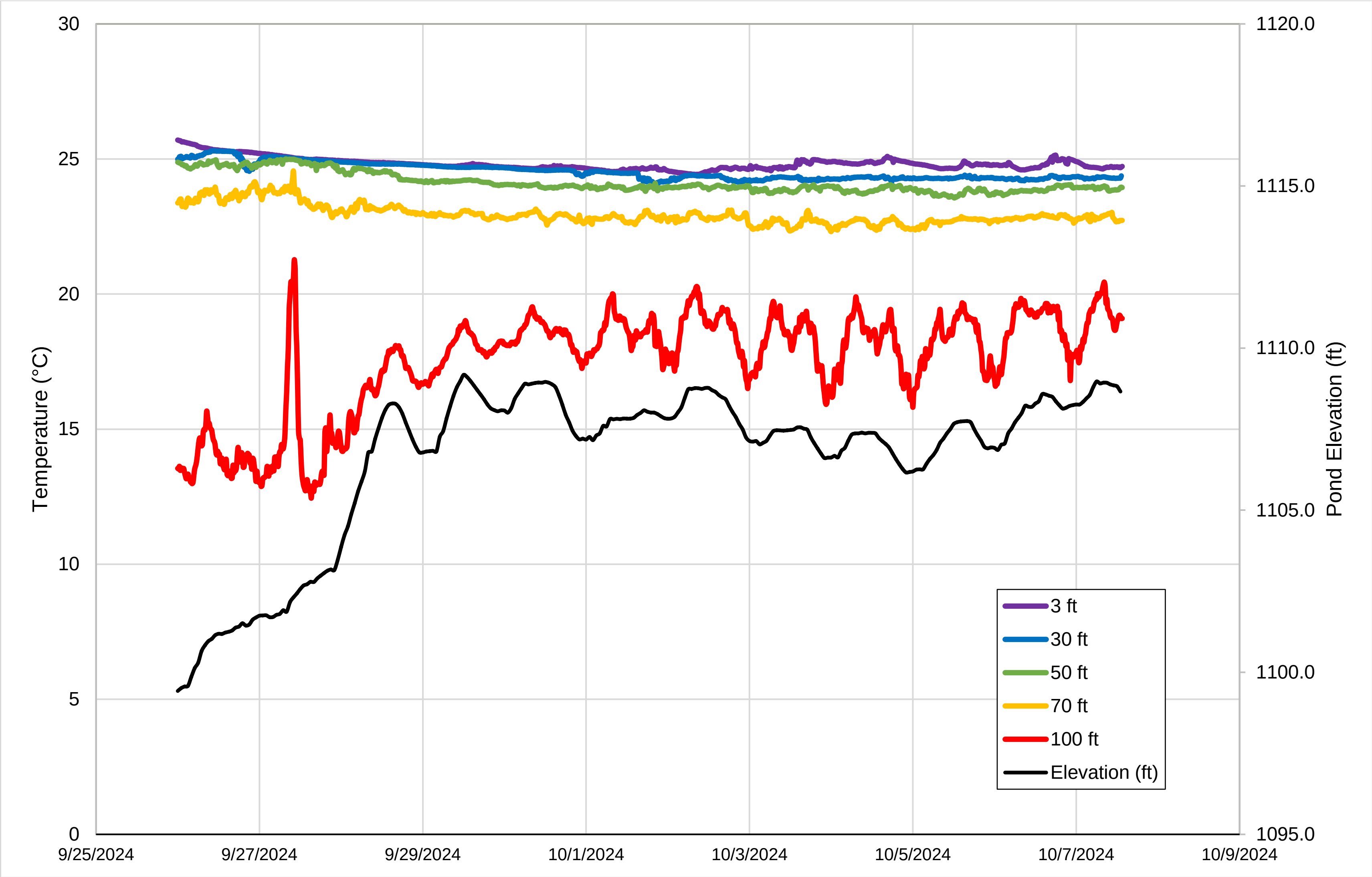


Figure 25. Continuous Water Temperature Profiles for Monitoring Station 560.0 (September 26-October 7, 2024) vs Lake Jocassee Pond Elevation

4 Summary

Duke Energy collected continuous water temperature data and periodic DO concentration data (bi-weekly) from locations near three historic monitoring stations to determine current-day representative (i.e., baseline) water quality information. Data collected in 2023 represented conditions under three-unit operations and data collected in 2024 represented conditions under fully upgraded four-unit operations at the Project. There is no noticeable difference in the water quality datasets due to increased pumping or generation. Results from both years indicate water upstream of the submerged weir is, as expected, well-mixed and does not stratify, or is weakly stratified for a short period of time in early summer in the upper water column. Data from monitoring locations downstream of the weir reveal stratification under all pumping and generation scenarios, indicating the weir is functioning as it was designed and helps to dissipate energy from the I/O structure. This preservation of stratification downstream of the weir is also supported by historical water quality monitoring and by CFD model results under current project conditions as well as Bad Creek II conditions, which will have near double the flows generated from the combined powerhouses.

Due to the relatively small surface area, high degree of mixing, and short residence time of water in the Bad Creek Reservoir, warming impacts due to solar radiation in the upper reservoir are limited, therefore, conditions in the Whitewater River arm are reflective of conditions in the upper reservoir.

Duke Energy plans to develop a Water Quality Monitoring Plan in consultation with agencies and other relicensing stakeholders focused on effects of construction and operation of Bad Creek II on water quality in the Whitewater River arm. The Water Quality Monitoring Plan is currently under development and will be submitted with the Draft License Application (March 2025).

5 Variances from FERC-approved Study Plan

There were no variances from the FERC-approved RSP.

6 Germane Correspondence and Consultation

Consultation documentation for the Water Resources Study is included in Appendix A of the Updated Study Report.

Attachment 3

Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse

This page intentionally left blank.

VELOCITY EFFECTS AND VERTICAL MIXING IN LAKE JOCASSEE DUE TO A SECOND POWERHOUSE

FINAL REPORT

WATER RESOURCES STUDY

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

October 27, 2023

This page intentionally left blank.

VELOCITY EFFECTS AND VERTICAL MIXING IN LAKE JOCASSEE DUE TO A SECOND POWERHOUSE
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740

TABLE OF CONTENTS

Section	**Title**	**Page No.**

Section	Title	Page No.

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS
CONTINUED

Section	Title	Page No.

TABLE OF CONTENTS
CONTINUED

Section	Title	Page No.

Appendices

ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
2-D	2-dimensional
3-D	3-dimensional
ADCP	acoustic Doppler current profiler
Bad Creek (or Project)	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
Bad Creek Reservoir	Upper Reservoir
CFD	computational fluid dynamics
cfs	cubic feet per second
DTM	digital terrain model
Duke Energy or Licensee	Duke Energy Carolinas, LLC
fps	feet per second
ft	feet
ft msl	feet above mean sea level
FERC or Commission	Federal Energy Regulatory Commission
ICM	Innovyze Catchment Model
ISR	Initial Study Report
I/O	Inlet/Outlet
KT Project	Keowee-Toxaway Hydroelectric Project
mi^2	square miles
RSP	Revised Study Plan
SCDNR	South Carolina Department of Natural Resources
STI	Supporting Technical Information
STID	Supporting Technical Information Document

This page intentionally left blank.

1 Project Introduction and Background

Duke Energy Carolinas, LLC (Duke Energy or Licensee) is the owner and operator of the 1,400-megawatt Bad Creek Pumped Storage Project (Project) (FERC 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 (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 expiration date of 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, 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 developed a Revised Study Plan (RSP) for the Project and proposed six studies for Project relicensing. The RSP was filed with the Commission and made available to stakeholders on December 5, 2022. FERC issued the Study Plan Determination on January 4, 2023, which included modifications to one of the six proposed studies (Recreational Resources Study).

This report includes the methods and results of Task 3 (Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse) of the Water Resources Study. The Water Resources Study is ongoing in support of preparing an application for a new license for the Project in accordance with 18 CFR §5.15, as provided in the RSP.

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

2 Study Goals and Objectives

Tasks carried out for the Bad Creek Water Resources Study employ standard methodologies that are consistent with the scope and level of effort described in the RSP. This report is intended to provide sufficient information to support an analysis of the potential Project-related effects on water resources with clear nexus to the Project.

The main objectives of this task include:

- Use a two-dimensional (2-D) hydrologic model to determine the downstream extent of potential effects (i.e., mixing) from an additional powerhouse in the Whitewater River cove; results of the 2-D modeling will be used to develop physical model boundaries of Lake Jocassee for three-dimensional (3-D) computational fluid dynamics (CFD) modeling.
- Use the CFD model to evaluate flows and the extent of vertical mixing in the Whitewater River cove and downstream of the submerged weir due to the addition of a second inlet/outlet structure.

Note that associated potential effects on shoreline erosion in the Whitewater River cove due to a second powerhouse were assessed during the preliminary feasibility study. Results indicated erosion on the bank opposite the inlet/outlet (I/O) structure would not be affected by additional flows; the final report was included in the RSP.

3 Study Area

The study area encompasses the western portion of Lake Jocassee that includes the Whitewater River arm and the Thompson River arm (Figure 3-1); this is the extent of the CFD model domain.

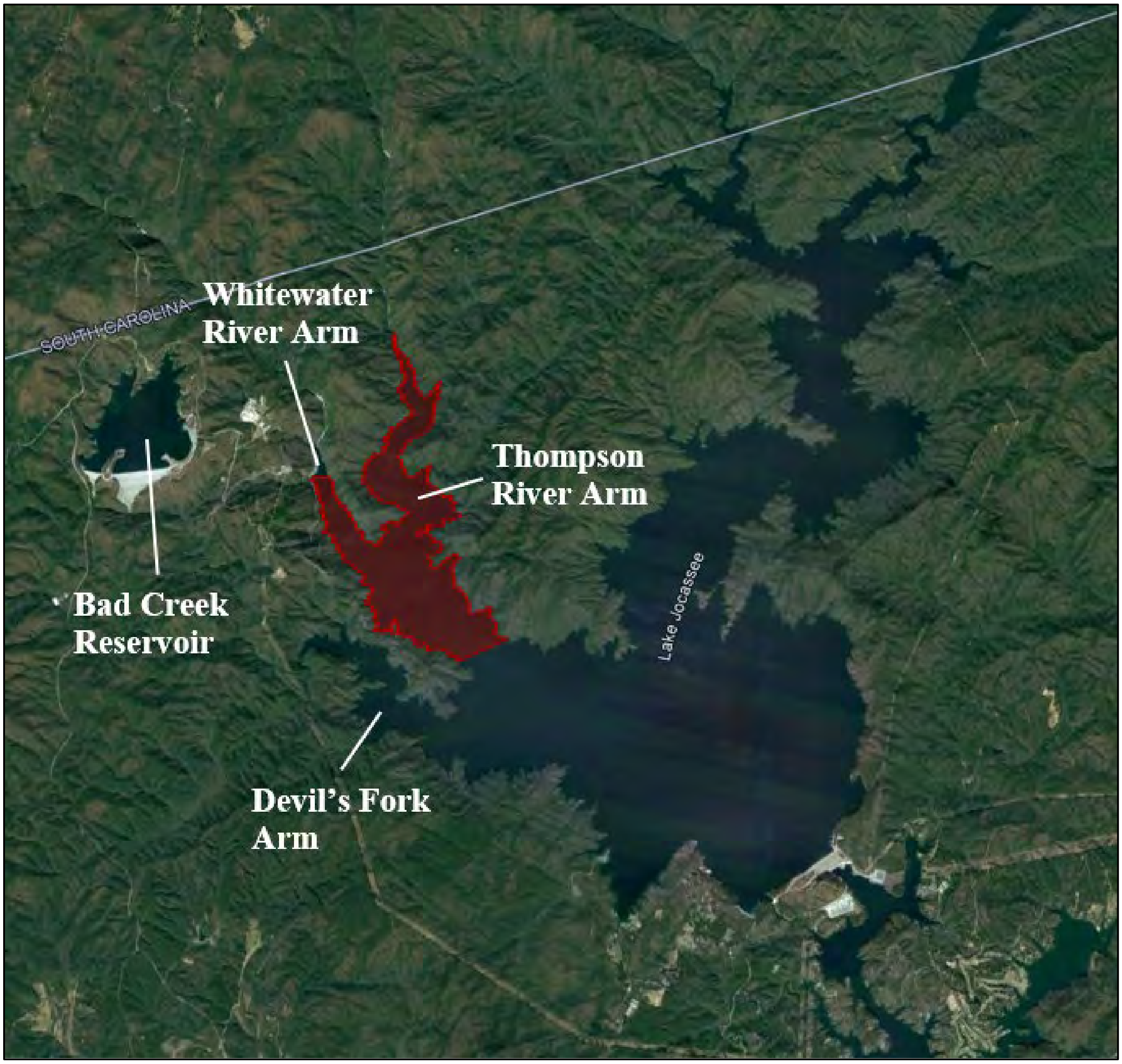


Figure 3-1. CFD Modeling Study Area

As described in the Bad Creek relicensing pre-application document, nearly half a million cubic yards of material from the original Project excavation was placed approximately 550 meters (1,804 feet [ft]) downstream of the Project's I/O structure to form a submerged weir. The function of the weir is to help minimize the effects of Project operations on the natural stratification of Lake Jocassee; the weir prevents the mixing of warmer water from the pumped storage discharge with the cooler water in the lower layer of the lake for the protection of cold-water fish habitat. The weir also serves to dissipate the energy of the discharging water from the I/O structure. Duke Energy is considering expanding the existing submerged weir in the downstream direction with newly excavated rockfill from the proposed Bad Creek II Complex. A schematic drawing showing a profile of the existing weir in Whitewater River cove as well as the proposed expanded weir is depicted on Figure 3-2.

The Study Area includes three historic Duke Energy water quality monitoring stations (Stations 564.1, 564.0, and 560.0) in the Whitewater River arm of Lake Jocassee as shown on Figure 3-3. Water quality data (e.g., temperature, dissolved oxygen) from these monitoring stations are included in the Summary of Existing Water Quality Data and Standards Report, which was developed as a desktop study under Task 1 of the Water Resources Study and will be included in the Initial Study Report (ISR). Results from that study indicate the water column is completely mixed (i.e., no natural stratification) near the I/O structure upstream of the weir; however, just downstream of the weir, stratification is comparable to rest of the waterbody, indicating the weir is functioning as intended and mixing is confined to the Whitewater River cove upstream of the weir.

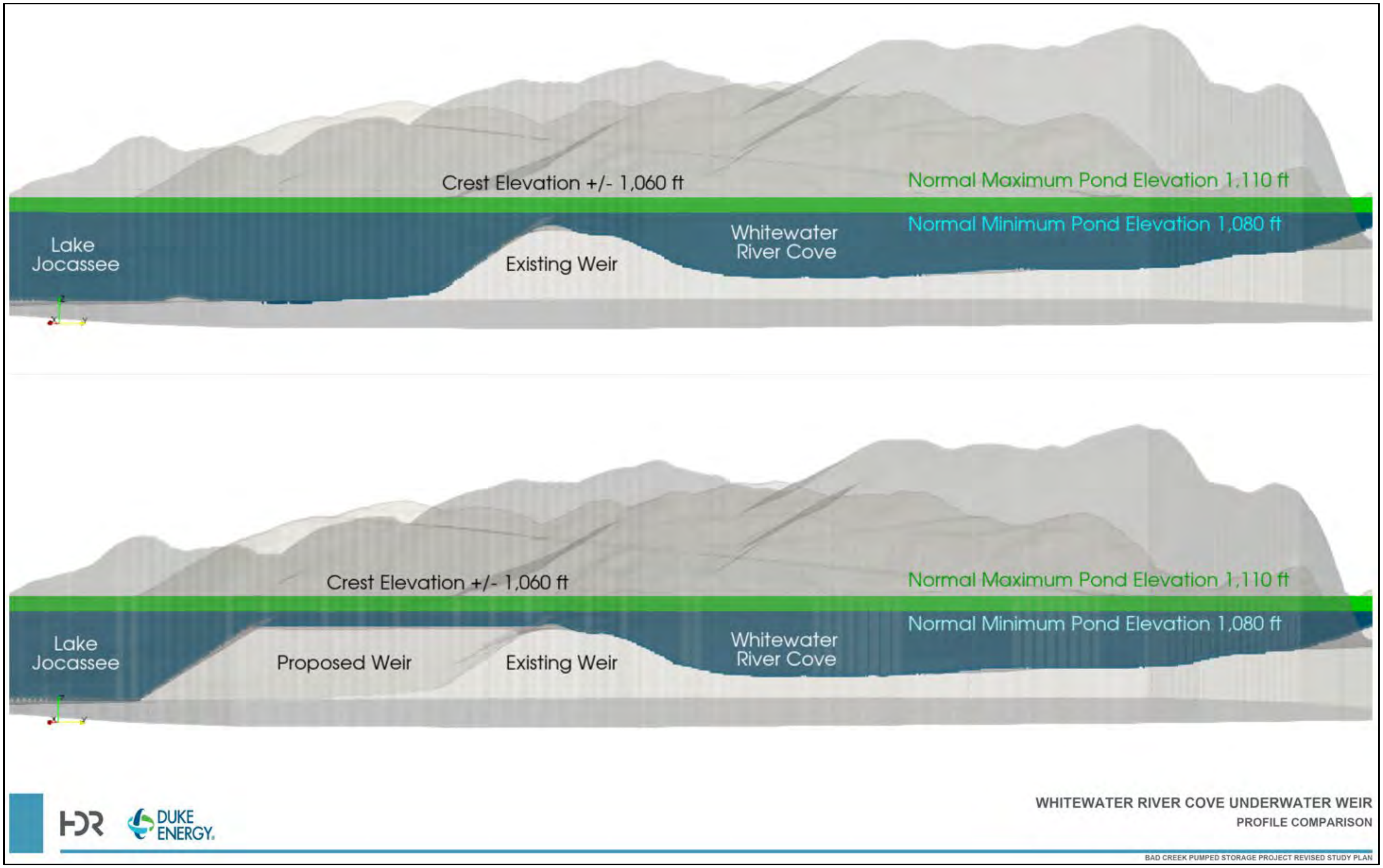


Figure 3-2. Submerged Weir in Whitewater River Cove (Existing and Proposed)

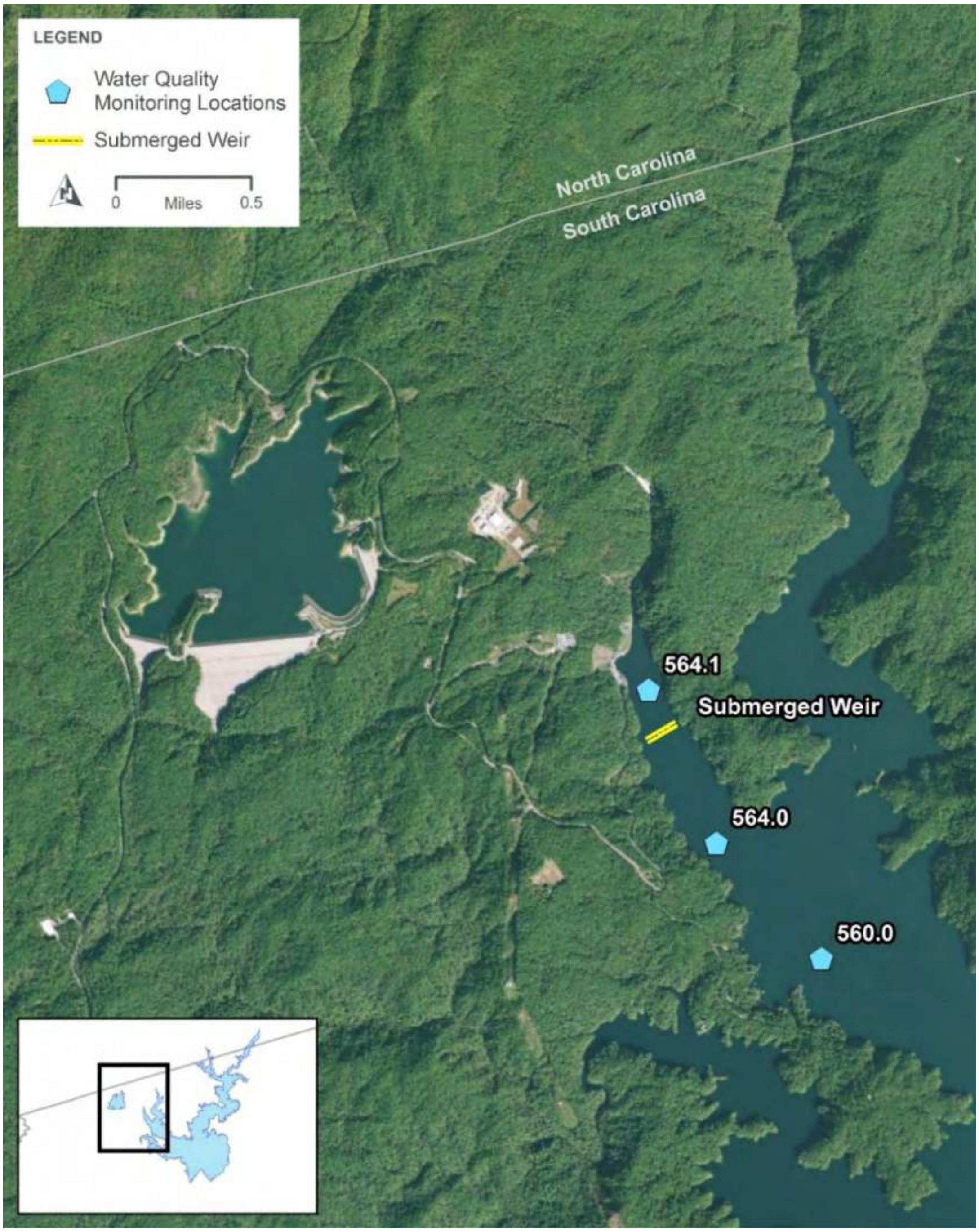


Figure 3-3. Water Quality Monitoring Stations in the Whitewater River Arm of Lake Jocassee

4 Methods and Model Description

4.1 2-D Model Development

A 2-D model was developed using Innovyze Infoworks Integrated Catchment Model (ICM) software (Innovyze Infoworks ICM Version 2023.2.0 [Innovyze 2023]) to evaluate the hydraulics of the Whitewater River cove with the goal of determining the CFD model boundary.

Because CFD modeling is a time-consuming process, the 2-D model was developed prior to the CFD model to more efficiently establish the required modeling extent (i.e., model domain). Results from the 2-D model were used as input into the CFD model to determine the downstream modeling boundary; the significantly reduced computational run time of the 2-D model was able to achieve this step in a single model run as opposed to a lengthy iterative process. The ICM software is considered appropriate to approximate the extent of hydraulic effects in the Whitewater River arm downstream of the submerged weir.

4.1.1 Modeling Approach

The ICM is a fully integrated 2-D hydrodynamic model which facilitates accurate representation of flow paths while enabling complex hydraulics and hydrology to be incorporated into a single model. The model uses the shallow water equations to develop depth-averaged hydraulic results. It does not directly model turbulence, but accounts for energy losses due to bed resistance via the Manning’s n roughness coefficient. The model provides detailed hydraulic information and reasonable variability in average flow, depth, and velocity from one water column element to the next throughout the modeled area. For the Bad Creek study, scenarios assume full generation/pumping capacity for the entirety of the simulation.

Simulation length was determined by the time it takes to drain/fill the Bad Creek Reservoir from full pond to maximum drawdown (160 ft). The Bad Creek Reservoir usable storage ranges from elevation 2,310 ft to 2,150 ft and the usable storage volume is 31,808 acre-ft. Table 4-1 presents the simulation run times for various operating conditions under existing, upgraded, and proposed flowrates in cubic feet per second (cfs) using Bad Creek Reservoir storage of approximately 30,000 acre-ft. Upgraded conditions include an ongoing pump-turbine upgrade at the existing Project that will increase the total capacity by 280 megawatts (MW) (70 MW per unit). Proposed conditions refer to the existing Project plus the addition of Bad Creek II.

Table 4-1. Bad Creek Simulation Times

Powerhouse Configuration	Generation		Pumping	
	Max. Hydraulic Capacity (cfs)	Time (hours)	Max. Hydraulic Capacity (cfs)	Time (hours)
Existing	16,000	22.9	13,780	26.5
Upgraded	19,760	18.8	15,000	24.4
Proposed	39,200	9.3	32,720	11.2

4.1.2 Digital Terrain Model Development

The digital terrain model (DTM) used in the 2-D model was constructed with data from two sources:

- Bathymetry measurements collected in Lake Jocassee by Duke Energy in 2010;
- Light Detection and Ranging (i.e., LiDAR) data from the South Carolina Department of Natural Resources (SCDNR) online portal.

The data sources were converted into triangulated irregular network surface files and merged using Environmental Systems Research Institute (ESRI™) ArcGIS Pro version 2.8.8 Geographic Information System (GIS) software (ESRI 2021). The resulting DTM encompassed Lake Jocassee and was used in the 2-D and CFD models. The DTM is presented in Figure 4-1. For increased detail, Figure 4-1 shows the southern portion of Lake Jocassee, but the DTM used in the 2-D model includes the entirety of Lake Jocassee.

The process of creating the terrain model for both the existing and expanded weir geometry was the same; however, existing bathymetry data in the vicinity of the submerged weir and proposed powerhouse was replaced with the proposed weir geometry for the expanded weir model scenarios. The expanded weir and proposed powerhouse terrain model are shown in detail on Figure 4-2.

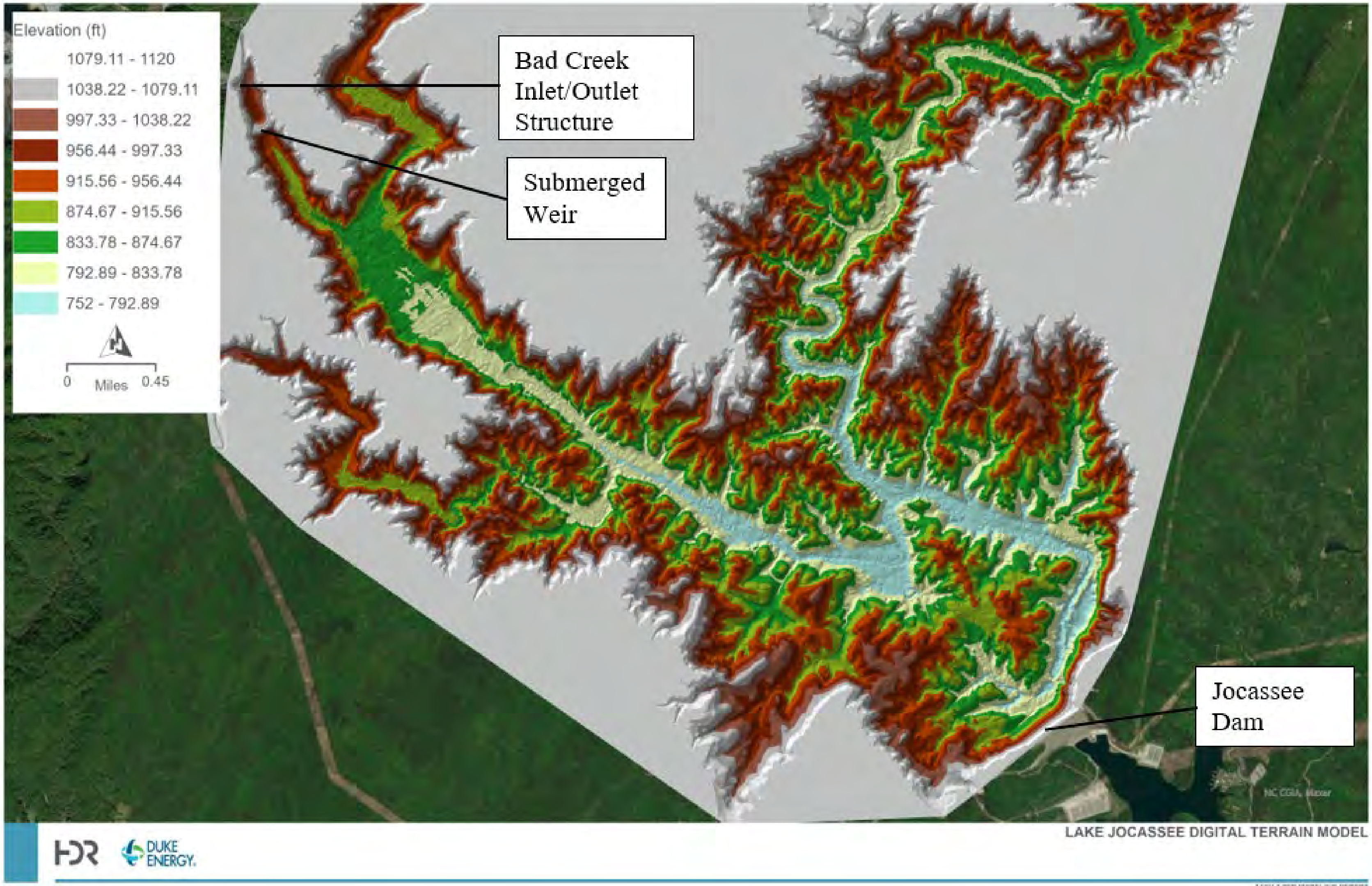


Figure 4-1. Digital Terrain Model of Lake Jocassee

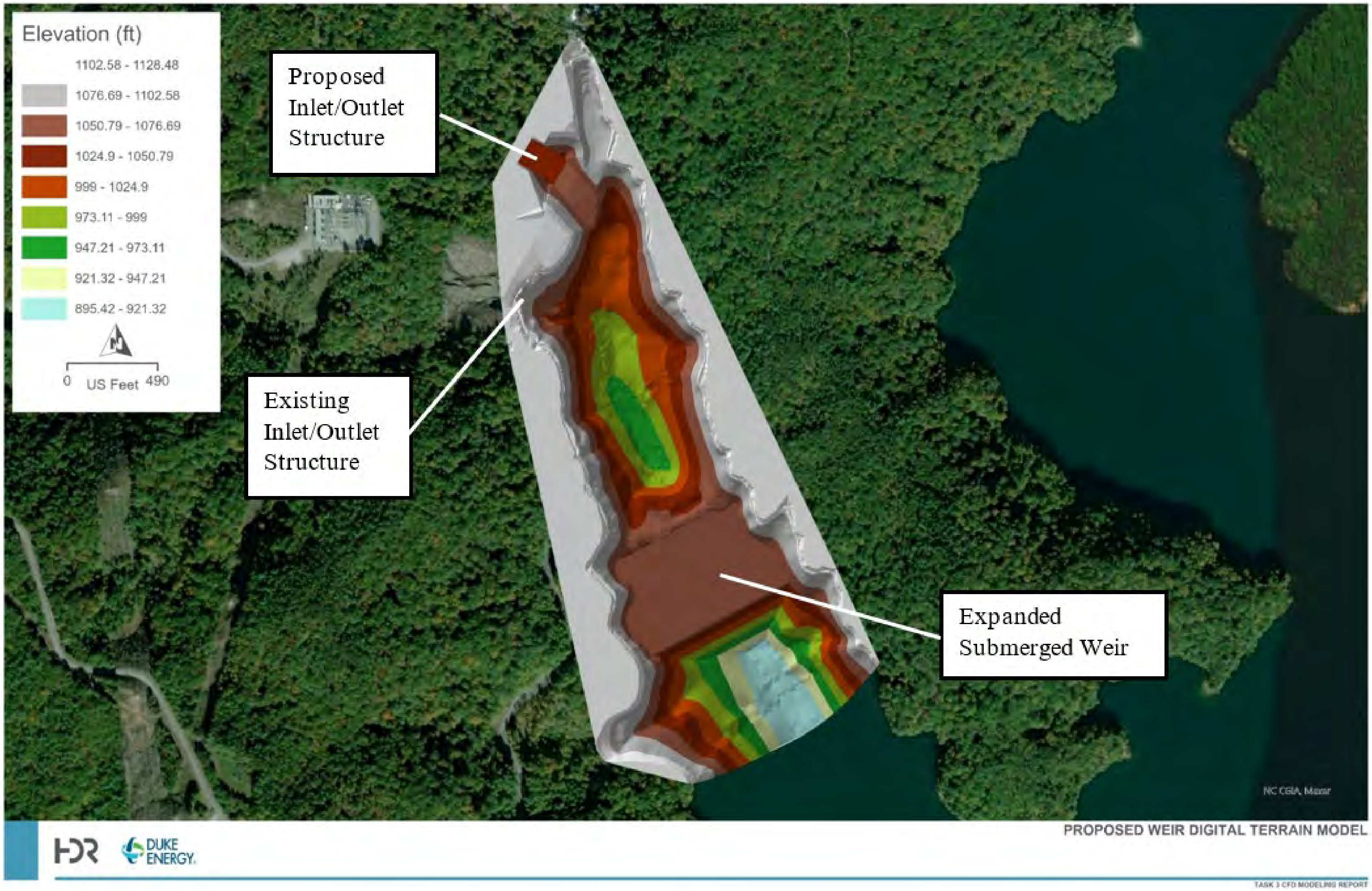


Figure 4-2. Expanded Weir and Proposed Inlet/Outlet Structure Terrain Model

4.1.3 Mesh Development

The 2-D Zone defining the ICM Model includes Lake Jocassee and surrounding contours to elevation 1,120 ft above mean sea level (msl). Figure 4-3 provides a view of a portion of the 2-D Zone extent.

For the 2-D simulation, ICM subroutines were used to perform a meshing of the 2-D Zone. The 2-D mesh is comprised of an irregular array of triangles. Descriptions of the user input 2-D Zone data fields that are pertinent to this analysis are as follows:

- Minimum element area – Minimum mesh element area used for calculating results. Mesh elements with area less than the minimum area specified are aggregated with adjoining elements until the minimum area is met. This is done for the purpose of calculating results to improve simulation stability and run time.
- Boundary points – Boundary condition for 2-D Zone.
- Terrain-sensitive meshing – Meshing is used to increase the resolution of the mesh in areas that have a large variation in height without increasing the number of elements in relatively flat areas.
- Maximum height variation – The maximum height variation that is permitted within a single triangle. Triangles with a height variation greater than the assigned value are split provided this would not result in a triangle smaller than the minimum element area.
- Minimum triangle angle – Minimum allowable angle between triangle vertices when creating a 2-D mesh.
- Roughness – Manning's n roughness values, used when creating a 2-D mesh. The roughness value assigned to mesh elements in areas in the 2-D Zone that are not in a roughness zone. Roughness values were selected from published tables (Innovyze 2023).

Table 4-2 provides a summary of the selected user input values for the ICM meshing routine as well as the total 2-D Zone area.

Table 4-2. ICM Meshing User Inputs and Area Summary

2D zone Object Properties		
Polygon definition		
ID	Lake_Joc_2D	
Area (acre)	8063.583	#D
Maximum triangle area (ft2)	100.000	
Minimum element area (ft2)	50.000	
Mesh generation	Classic	
Boundary points	Vertical Wall	#D
Terrain-sensitive meshing	☒	
Maximum height variation (ft)	5.000	
Minimum angle (degree)	25.00	#D
Roughness (Manning's n)	0.0400	
Roughness definition		#D
Apply rainfall etc directly to mes	☐	
Apply rainfall etc	everywhere	#D
Rainfall profile	1	#D
Infiltration surface		#D
Turbulence model		#D
Rainfall percentage	100.000	#D
Mesh summary	---->	
Mesh data	---->	
General properties		
Notes		
Hyperlinks		
User defined properties		

A section of the resulting mesh is shown on Figure 4-4. The model mesh contains 1,147,067 elements. The approximate minimum, average, and maximum, element areas are 9.3 ft^2, 18.2 ft^2, and 46.5 ft^2, respectively.

A uniform Manning's *n*-value of 0.04 was used for the entire model which is appropriate for modeling open water such as a large reservoir (Chow 1959).

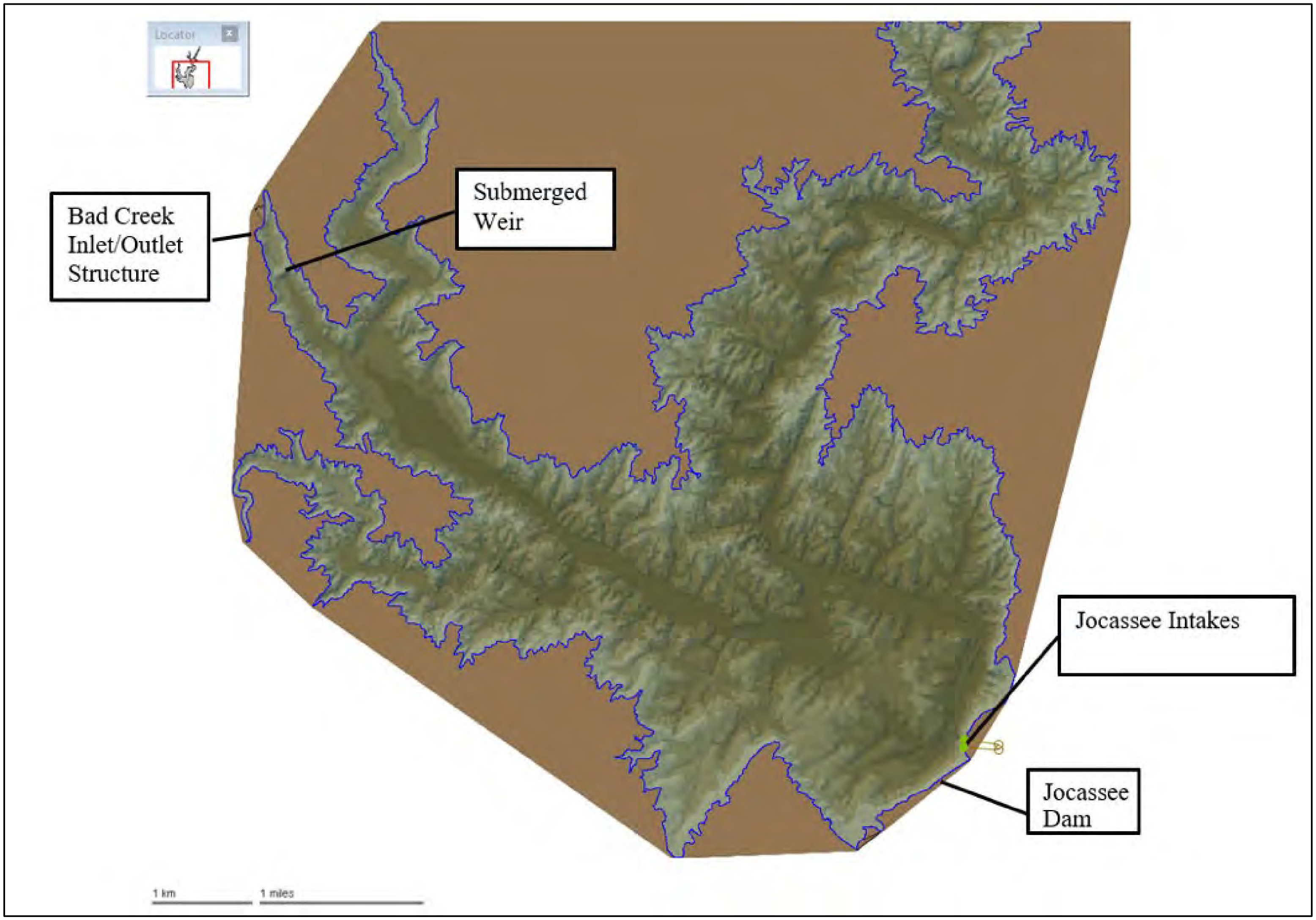


Figure 4-3. Extent of 2-D Zone and ICM Mesh

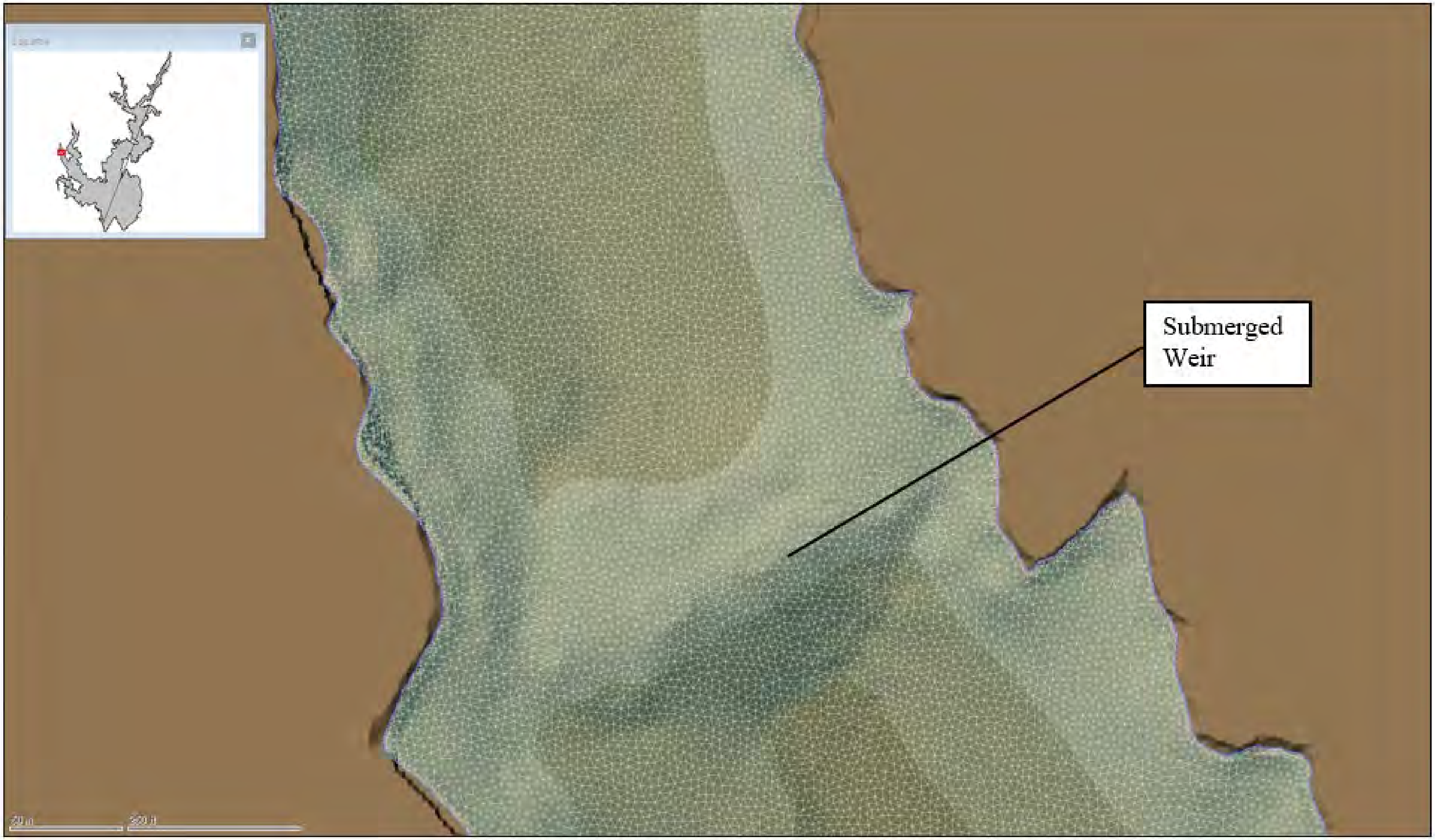


Figure 4-4. Example of 2-D Model Mesh Section

4.1.4 2-D Model Scenarios

It was assumed the scenarios with the greatest effect on the Whitewater River cove would be those where Lake Jocassee was operating at minimum pond (elevation 1,080 ft msl). The extent of those hydraulic effects was then evaluated under the existing and proposed weir configuration (i.e., weir geometry). Table 4-3 presents the two scenarios analyzed with the 2-D model.

The conservative assumption that Jocassee Hydroelectric Station would operate to maintain the lake level at the target elevation (full pond/maximum drawdown) for the entirety of the simulation was used.

Table 4-3. 2-D Model Scenarios

Scenario	Flowrate	Operating Mode	Submerged Weir Geometry
Existing	16,000 cfs	Generation	Existing
Proposed	39,200 cfs	Generation	Expanded

4.2 CFD Model Development

FLOW-3D was developed and is supported by Flow Science, Inc. (Flow Science 2023) and is a commercially available computational model capable of solving three-dimensional (3-D) unsteady Reynolds Averaged-Navier Stokes equations. The software utilizes a Volume of Fluid method to calculate the free surface within the model domain (Hirt and Nichols 1981). The software package contains the meshing module (pre-processor), solver, and post-processor.

4.2.1 Modeling Approach

The FLOW-3D software solves unsteady Reynolds Averaged-Navier Stokes equations on structured grids and the governing equations used in the model are provided in the FLOW-3D user's guide (Flow Science 2023). A model-fitted mesh was developed for the model domain. Depending on the scenario, a specified water surface elevation (full pond or maximum drawdown) was applied to the upstream reservoir mesh boundary.

4.2.1.1 Pressure Solver Options

Two numerical schemes are available for the pressure solver module with multiple options (i.e., implicit and explicit). Within the implicit solver, limited compressibility models can be toggled to relax the constraints of the pressure solver for cases where solution stability is an issue. The explicit solver allows for improved accuracy of the solution, though it results in longer computational time (Hirt 2000). The explicit pressure solver was applied in the Bad Creek II CFD modeling effort.

4.2.1.2 Turbulence Models

Various one-equation (Prandtl Mixing Length and Turbulent Energy Model) and two-equation (k-e, k-w, and Renormalized Group) turbulence modules are available in FLOW-3D (Yakhot and Orszag 1986). The Renormalized Group model was selected for the model based on anticipated flow patterns in the Whitewater River cove. Additionally, the Renormalized Group model is robust enough to handle the anticipated increased turbulence in the Whitewater River cove as a result of a second I/O structure.

4.2.1.3 Model Domain

The model domain was approximated using the 2-D model. Extents of hydraulic effects due to the operation of the second powerhouse were analyzed in the 2-D model, and the CFD model was appropriately sized based on that analysis. Detailed discussion of this analysis is presented in Section 5.2.

4.2.1.4 Model Limitations

The CFD model is a numerical approximation of hydraulic conditions and, as with all numerical models, results are a product of model input and assumptions. For instance, some hydrodynamic features cannot be precisely modeled, and turbulence closure models and recirculation patterns and vortices are approximate in size and strength; however, the selected features used to produce the results for this study are considered appropriate for the intended use of the model results.

4.2.2 Model Geometry

The DTM developed for the 2-D model was utilized in the CFD model. Detailed information on DTM development is presented in Section 4.1.2.

CFD models can be sensitive to shallow depths. Model iteration convergence is challenging when the depth of water in a given mesh cell is low compared to the mesh size. More discussion of the model mesh is presented in the following section, but to achieve reasonable run times for this model, a larger mesh was used.

Because shorelines can be difficult to resolve, geometry modifications were made along the shoreline of the CFD model. Vertical walls were assumed along the shoreline starting 10 ft below the target elevation (i.e., 1,070 ft msl) for the minimum pond level, and 1,100 ft msl for the full pond level. This modification ensured that a minimum depth of 10 ft was present throughout the model, and significantly improved model stability and simulation run times. An example of vertical walls at full pond is shown on Figure 4-5.

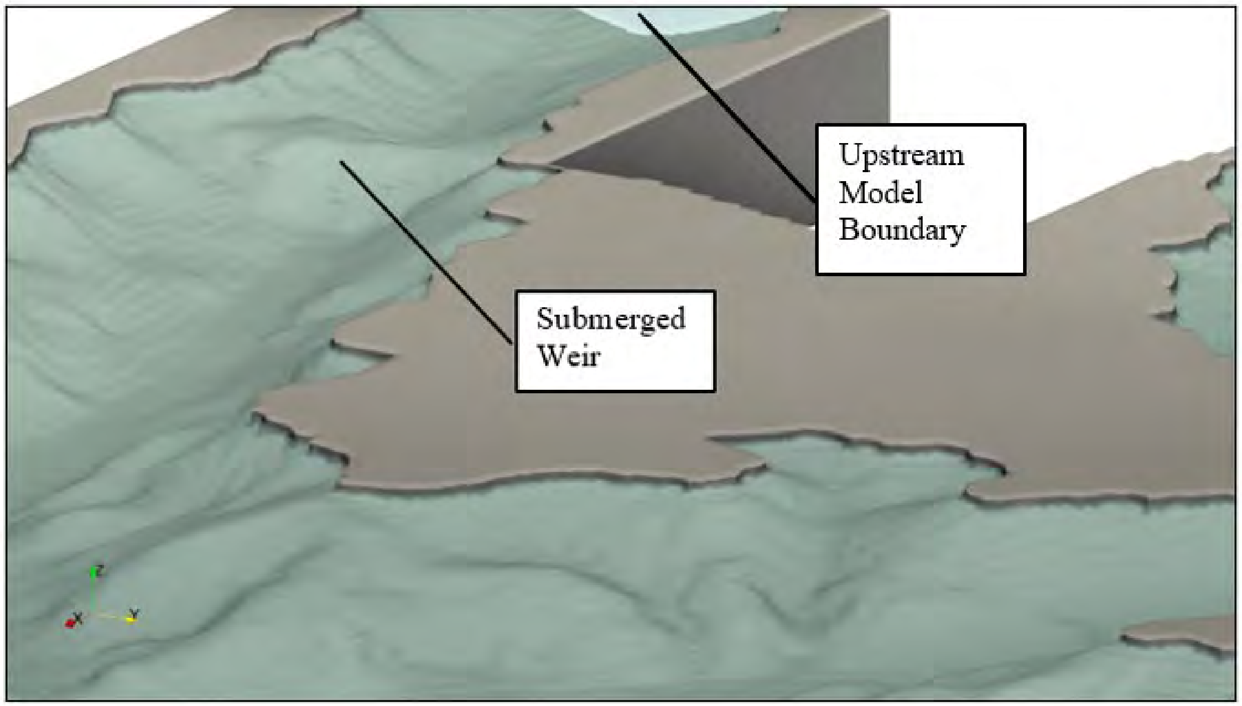


Figure 4-5. CFD Model Geometry with Vertical Walls

4.2.3 Mesh Development

The CFD model determines flow field throughout the volume of water in discrete sections. A computational mesh is used to discretize the solution within the domain. FLOW-3D requires the computational mesh to be comprised of orthogonal elements (faces align with the x, y, or z direction). The model topography and features were translated to represent significant features with fewer elements.

The CFD model domain covers approximately 922 acres. To manage simulation run times for a model of this size, a coarse mesh was required. As a general rule with CFD modeling, there is a trade-off between computational run time and mesh density. A denser, more refined mesh will more accurately resolve complicated hydraulic phenomena such as vortices and turbulence. A coarser mesh will have less resolution of these features but allows the model domain to be much larger without creating unreasonable model simulation times.

Flow in Lake Jocassee is deep, and very slow, meaning a coarse mesh is appropriate for the CFD model. The computational mesh block used was 20-ft by 20-ft by 10-ft (length by width by height). Figure 4-6 presents a plan and profile view of the model mesh in the vicinity of the existing submerged weir.

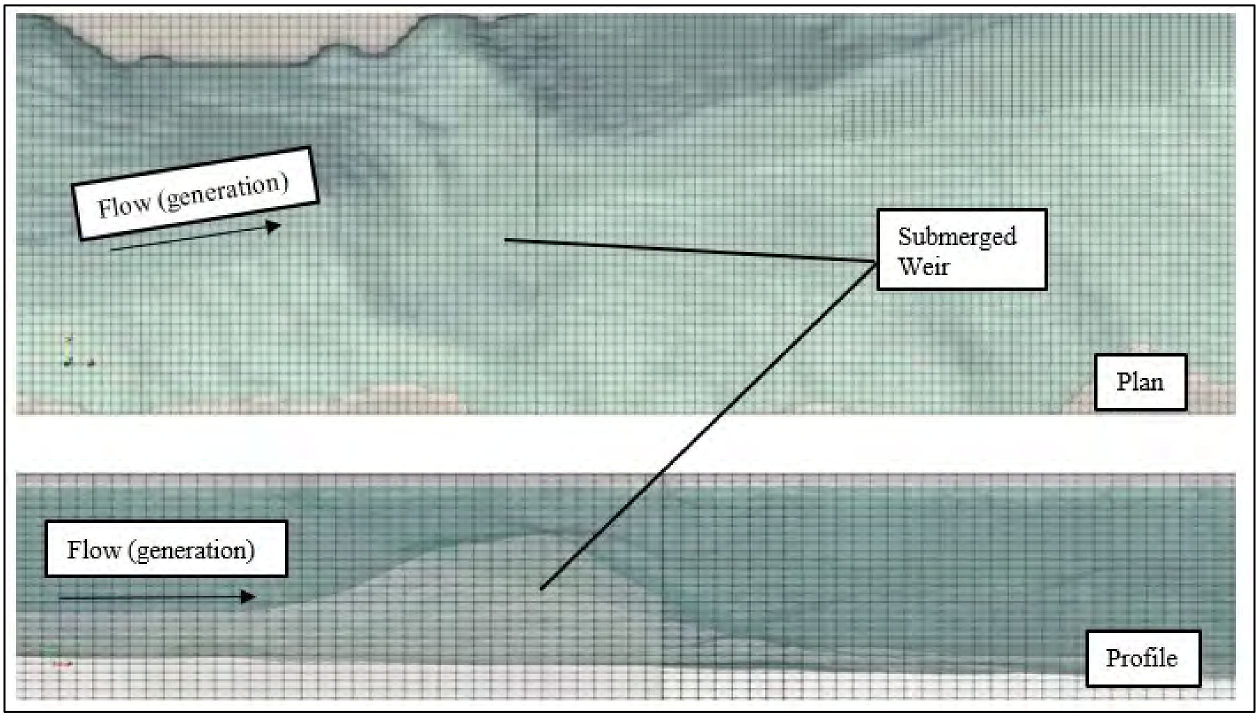


Figure 4-6. CFD Model Mesh

4.2.4 Model Scenarios

Sixteen scenarios listed in Table 4-4 were evaluated to help determine effects of Project operations on vertical mixing in the Whitewater River arm. Scenarios modeled the existing and expanded submerged weir configuration in both generating and pumping mode; and at full pond (elevation 1,110 ft msl) and maximum drawdown (elevation 1,080 ft msl). Results under full pond and maximum drawdown provide potential upper and lower limits of hydraulic effects of Bad Creek II operations. Figure 4-7 provides an exceedance plot of the Lake Jocassee pond level from 1975 to 2020. This plot shows the percentage of time the reservoir is at or above a given elevation. Lake Jocassee operates within 5 ft of the full pond elevation of 1,110 ft roughly 50 percent of the time, and in the 45-year period of record Lake Jocassee has never reached the minimum drawdown elevation.

Table 4-4. CFD Model Scenarios

Station	Operating Mode	Submerged Weir Geometry	Scenario	Flow (cfs)	Jocassee Reservoir Elevation (ft msl)
Bad Creek Only	**Generating**	Existing	1	16,000	1,110
			2	16,000	1,080
	Pumping		7	13,780	1,110
			8	13,780	1,080
	Upgraded Generation	Existing	13	19,440	1,110
			14	19,440	1,080
	Upgraded Pumping		15	15,000	1,110
			16	15,000	1,080
Bad Creek & Bad Creek II	**Generating**	Existing	3	39,200	1,110
			4	39,200	1,080
	Pumping		9	32,720	1,110
			10	32,720	1,080
	Generating	Expanded	5	39,200	1,110
			6	39,200	1,080
	Pumping		11	32,720	1,110
			12	32,720	1,080

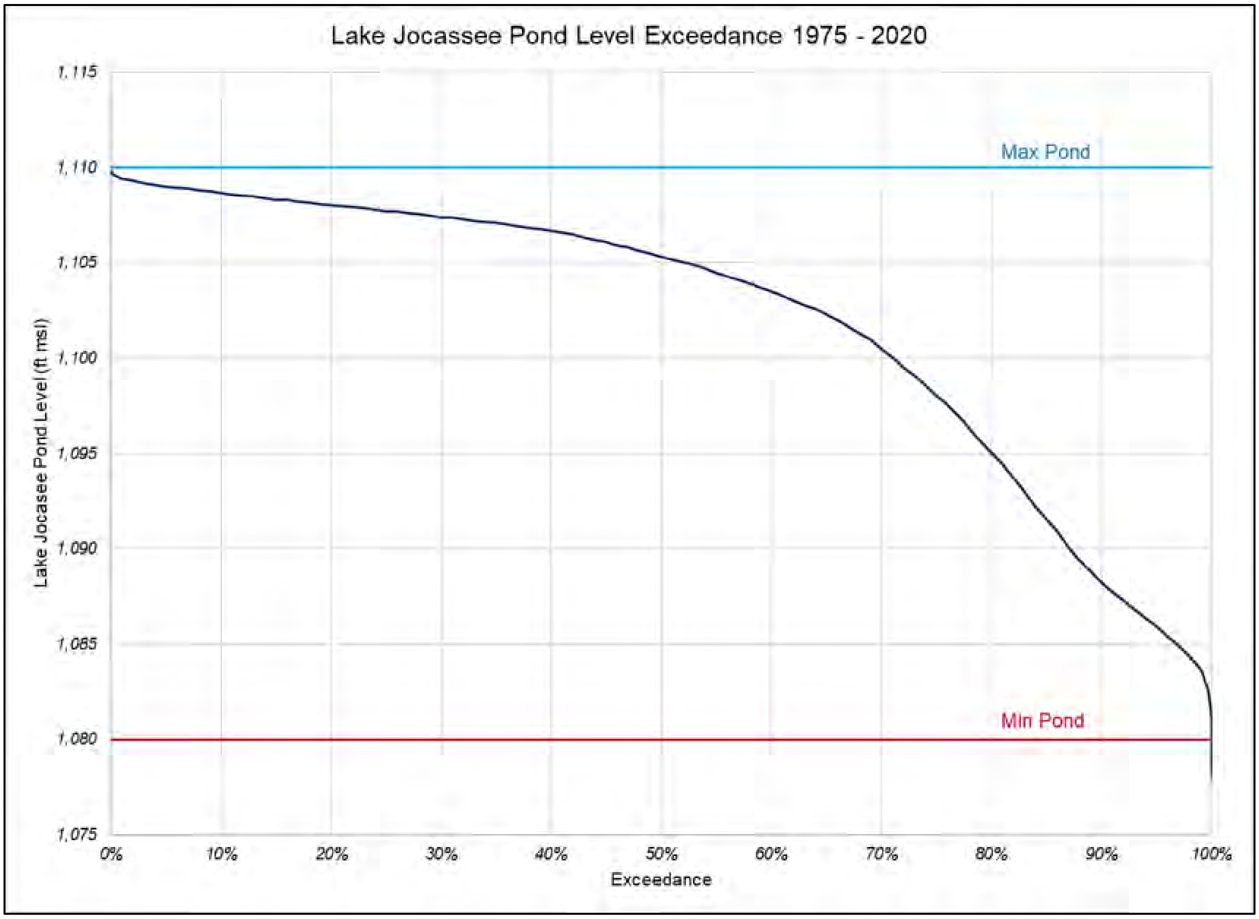


Figure 4-7. Lake Jocassee Pond Level Exceedance 1975-2020

4.2.5 Boundary Conditions

Boundary conditions for the CFD model were applied through multiple boundary types; boundary types are briefly described in the following sections. Boundary condition definitions were consistent between existing and proposed model configurations.

4.2.5.1 Volume Flowrate

A volume flowrate boundary condition was used to define the upstream boundary of the model where generation flows enter the Whitewater River cove, and where pumping flows exit the model extent. Because the focus of this model is to determine hydraulic effects downstream of the submerged weir, detailed resolution of the hydraulics in the vicinity of the I/O structures was not necessary. The inflow to the CFD model was held constant throughout the scenarios and assumed to be a uniform flow pattern approaching the weir at a scenario's specific flowrate.

Additionally, the long-term average flowrate from the Thompson River arm was included in the model to incorporate flows downstream of the weir. Because there is no gaging station on the Thompson River near Lake Jocassee, a drainage area proration[2] was performed between the now-retired U.S. Geological Survey (USGS) Howard Creek gage (USGS 02184475) (2.16 square miles [mi^2]) and the Thompson River (11.6 mi^2 at confluence with Lake Jocassee). Data from the Howard Creek gage extend from 1988 to 1996. Monthly average flows in the Thompson River range from 10 cfs to 130 cfs with an annual average of 40 cfs. This 40 cfs was introduced to the model at the upstream end of the Thompson River arm. Table 4-5 presents the prorated monthly average Thompson River flows entering Lake Jocassee.

Table 4-5. Thompson River Prorated Average Monthly Flows (cfs)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	**Annual**
1988	-	-	-	-	13.4	13.3	22.2	18.8	18.6	23.1	24.4	18.6	19.1
1989	25.8	36.4	60.1	45.8	45.6	111.2	97.8	76.3	79.9	103.0	66.8	61.4	67.5
1990	81.5	129.9	103.9	60.2	63.7	24.2	31.0	31.5	33.8	45.3	28.0	32.8	55.5
1991	31.9	33.6	43.3	46.8	33.6	33.8	35.5	56.9	40.6	26.4	33.1	35.0	37.5
1992	29.4	41.2	58.7	40.0	28.7	35.1	21.2	47.5	43.4	31.8	67.3	68.8	42.8
1993	53.8	48.1	50.0	57.0	43.0	21.5	13.7	13.5	13.2	10.0	14.4	18.1	29.7
1994	28.2	35.2	47.0	38.2	23.2	25.9	27.7	81.7	43.7	42.3	31.2	34.2	38.2
1995	48.0	55.8	47.0	24.8	18.0	22.6	20.0	27.1	20.1	44.6	39.6	29.7	33.1
1996	56.6	58.1	43.1	32.1	23.2	23.4	19.5	46.9	61.3	-	-	-	40.5
Average	44.4	54.8	56.6	43.1	32.5	34.6	32.1	44.5	39.4	40.8	38.1	37.3	40.4

4.2.5.2 Outflow Boundary

The outflow boundary was applied to the downstream limit of the model. This boundary allows pressure to be balanced through the model. A hydrostatic pressure condition was applied at the outflow and set to the target reservoir water surface elevation of 1,110 or 1,080 ft msl for the full and maximum drawdown Lake Jocassee levels, respectively.

It was assumed that Jocassee operations would maintain the target pond elevation (full pond/maximum drawdown) for the entirety of the simulation.

[2] The drainage-area ratio method commonly is used to estimate streamflow for sites where no streamflow data are available using data from one or more nearby streamflow-gaging stations.

4.2.5.3 Boundary Type Wall

The boundary type wall applied the no-slip condition at the outer boundary of the mesh blocks as well as a zero-velocity condition normal to the boundary.

4.2.6 CFD Simulation Evaluation

Model runs focused on the flow patterns and velocities downstream of the submerged weir. Multiple methods were used to monitor the progress of the model during the simulation. This section highlights the methods used to evaluate the model during the simulation and in post-processing. Flux surfaces and monitoring points provided data during the simulations.

4.2.6.1 Flux Surfaces

Flux surfaces were used to monitor the volumetric flow through over the weir and near the model outlet. The flux surfaces are vertical planes placed at specific locations in the CFD model. The surfaces were monitored for mass/volume balance of flow through the model.

4.2.6.2 Monitoring Points

Monitoring points were placed within the model to gather point data in Lake Jocassee during model simulations. Modeled velocities and water surface elevations were actively monitored during the simulation to track model stability.

4.2.7 Model and Scenario Evaluation

4.2.7.1 Model Verification

An acoustic Doppler current profiler (ADCP) was used to measure velocities throughout the water column along transects in the Whitewater River arm in July and August of 2023 under pumping and generation. Operations data (i.e., individual unit generation in megawatts, forebay elevation, and tailwater elevation) during field data collection were obtained from Duke Energy for Bad Creek and Jocassee Hydro Station. The field conditions were compared to modeled scenarios and, where appropriate, transects of modeled velocity were compared qualitatively against the field data. Preliminary evaluations of the data show the CFD model is a reasonable numerical estimation of flow patterns and velocities in the Whitewater River arm.

Model verification scenarios will be built using operations and reservoir elevation data from the time of the field data collection to present a range of error or confidence in the modeled results. These runs will provide a direct comparison between the modeled and field data under the same hydraulic conditions. This analysis will be performed in fall of 2023; an addendum to the study report will be provided with the final report.

4.2.7.2 Reservoir Elevation Criteria

The purpose of analyzing two reservoir elevations (i.e., pond levels) was to determine if the hydraulic effects vary between minimum and maximum water surface elevations (i.e., 1,080 ft msl and 1,110 ft msl, respectively). Flow velocity or other hydraulic thresholds or criteria were not established, and for a given operating configuration hydraulic results were directly compared between reservoir elevations.

4.2.7.3 Operation Mode Criteria

Pump and generation operating modes were analyzed with the CFD model. Scenarios were compared against each other to assess how pumping and generating affect the hydraulics downstream of the submerged weir. No specific hydraulic thresholds or criteria were established for the comparison.

4.2.7.4 Submerged Weir Geometry

The effect of varying the submerged weir geometry was studied using the CFD model. Scenarios were compared against each other to assess how the geometry of the submerged weir affects the flow patterns and vertical mixing downstream of the weir. No specific hydraulic thresholds or criteria were established for the comparison.

4.3 Previous CFD Modeling – Upper Whitewater River Cove

As part of the Bad Creek II Feasibility Study authorized by Duke Energy, a three-dimensional CFD model for the lower reservoir (i.e., Lake Jocassee) was developed to support the evaluation of a second additional I/O structure and the potential associated effects on the Whitewater River cove of Lake Jocassee. [3] The model boundary for this effort included the area of Whitewater River cove immediately downstream of the I/O structure for the purpose of establishing velocity and flow patterns in the channel and near the east bank of the cove opposite of the discharge structure.

The CFD modeling framework included a calibration phase (phase I) focused on replicating the existing dominant flow and velocity patterns predicted by the Alden Research Laboratory physical model (Larsen and White 1986), followed by phase II, which focused on evaluating the velocity and flow pattern effects of the proposed second I/O structure at two reservoir elevations (1,110 ft and 1,080 ft msl). The second phase utilized discharge flows based on the upgraded Bad Creek units, plus the assumed discharge from the conceptualized Bad Creek II project.

Unit operations in both the turbine and pump mode were simulated with the existing and proposed structures at reservoir levels 1,110 ft msl, 1,096 ft msl, and 1,080 ft msl. Model results indicated that velocities produced by full generation from the existing project at the upper and lower reservoir levels are similar to the velocities physically modeled in 1986. Additional discharge from proposed Bad Creek II operations created a concentrated area of higher velocity flows extending downstream to the existing Bad Creek I/O structure. As expected, this effect was more pronounced at lower reservoir levels. The concentrated area of high velocity and change in location of velocities would not affect existing bank conditions/erosion assuming the geology of the east bank is consistent along the shoreline (i.e., predominantly exposed bedrock). Additional scenarios to simulate pumping operations were performed and showed distinct flow patterns specific to each I/O structure. Velocities and flow patterns in the water column near the expanded submerged weir structure were qualitatively evaluated; velocities increased as the flow depth decreased. Velocities along the eastern bank near the expanded weir were higher when compared to the simulations using the existing weir due to the increased generation flows.

[3] The Lower Reservoir CFD Flow Modeling Report (HDR 2022) was filed with the RSP as Appendix I.

5 2-D Model Results

5.1 Hydraulic Effects

The results of the 2-D modeling scenarios are presented on Figure 5-1. Flow vectors colored and sized by velocity are shown for both the existing (left) and proposed (right) scenarios. While velocities of approximately 1.0 ft per second (fps) are shown in the vicinity of the I/O structure and extending across the top of the submerged weir, velocities decrease to approximately 0.2 fps by the time existing generation flows reach the confluence of the Whitewater River arm and the Thompson River arm of Lake Jocassee. For the proposed generation scenario, velocities of approximately 0.2 fps extend about 5,000 ft further downstream, above the confluence with the Devil's Fork arm. As water always follows the path of least resistance, the area of increased velocity follows the original thalweg of the river.

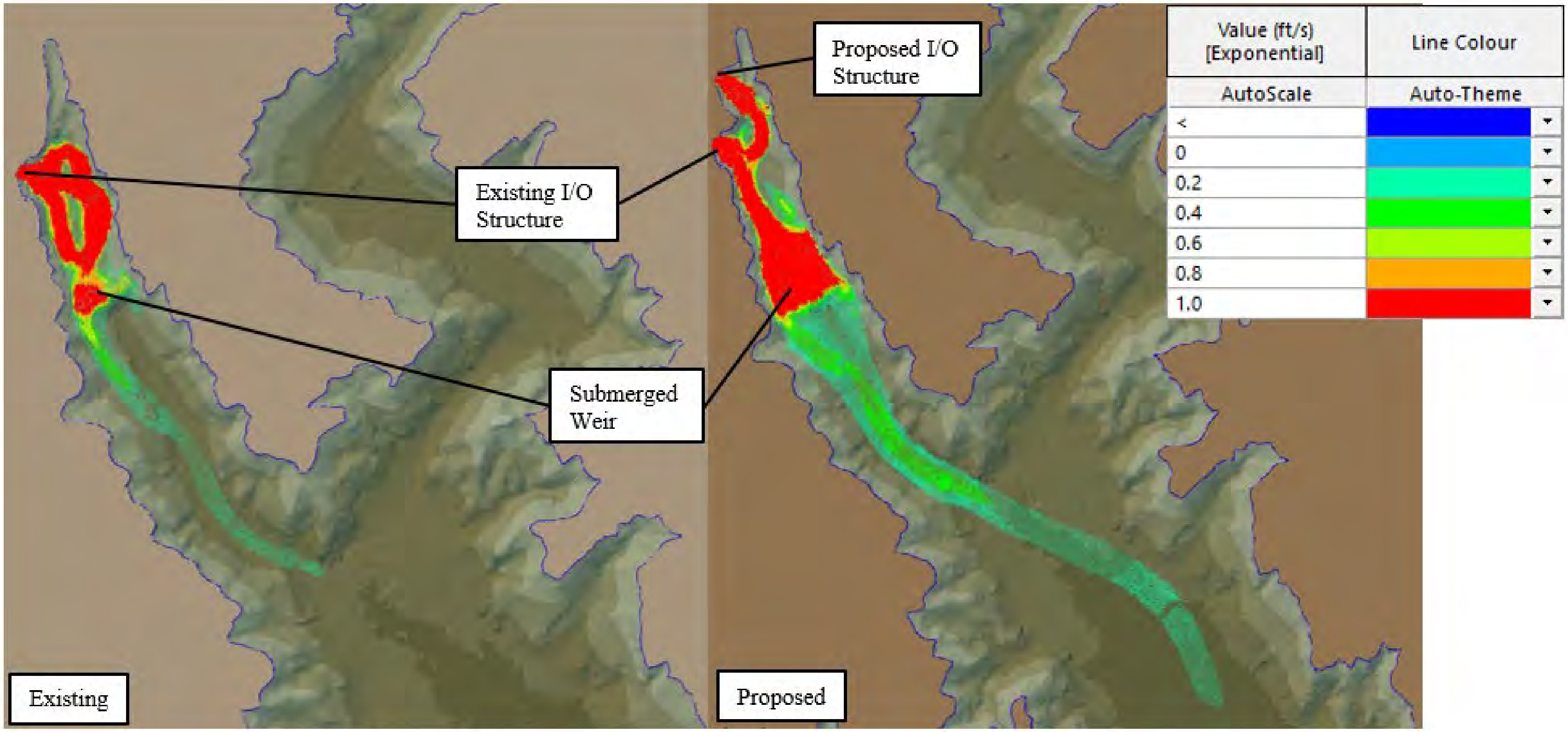


Figure 5-1. 2-D Model Results for Existing (Bad Creek) and Proposed (Bad Creek II) Conditions

5.2 CFD Model Domain

A key purpose of the submerged weir is to dissipate energy and force flows from the Bad Creek I/O structure to the surface of Lake Jocassee (to minimize vertical mixing in the water column downstream of the weir). Because the 2-D model is depth-averaged, the effect of forcing water to the surface over the weir is not fully predicted. To account for the 2-D model's potential under-estimation of the extent of hydraulic effects, the CFD model domain was extended approximately 0.5 mile further downstream. Figure 5-2 outlines the approximate CFD model domain.

The CFD model domain volume is approximately 133,000 acre-ft, while the full-pond volume of Lake Jocassee is about 1.2 million acre-ft. The model represents approximately 11 percent of the total volume of the lake. The relative size of the portion of the lake affected by the Project is important to consider when analyzing the effects of proposed powerhouse operations.

There are approximately five river miles between the Whitewater River and the Lake Jocassee dam. The model domain includes a third of this distance. Figure 5-3 shows a profile of the five miles from the Whitewater River to the dam, highlighting the modeled section.

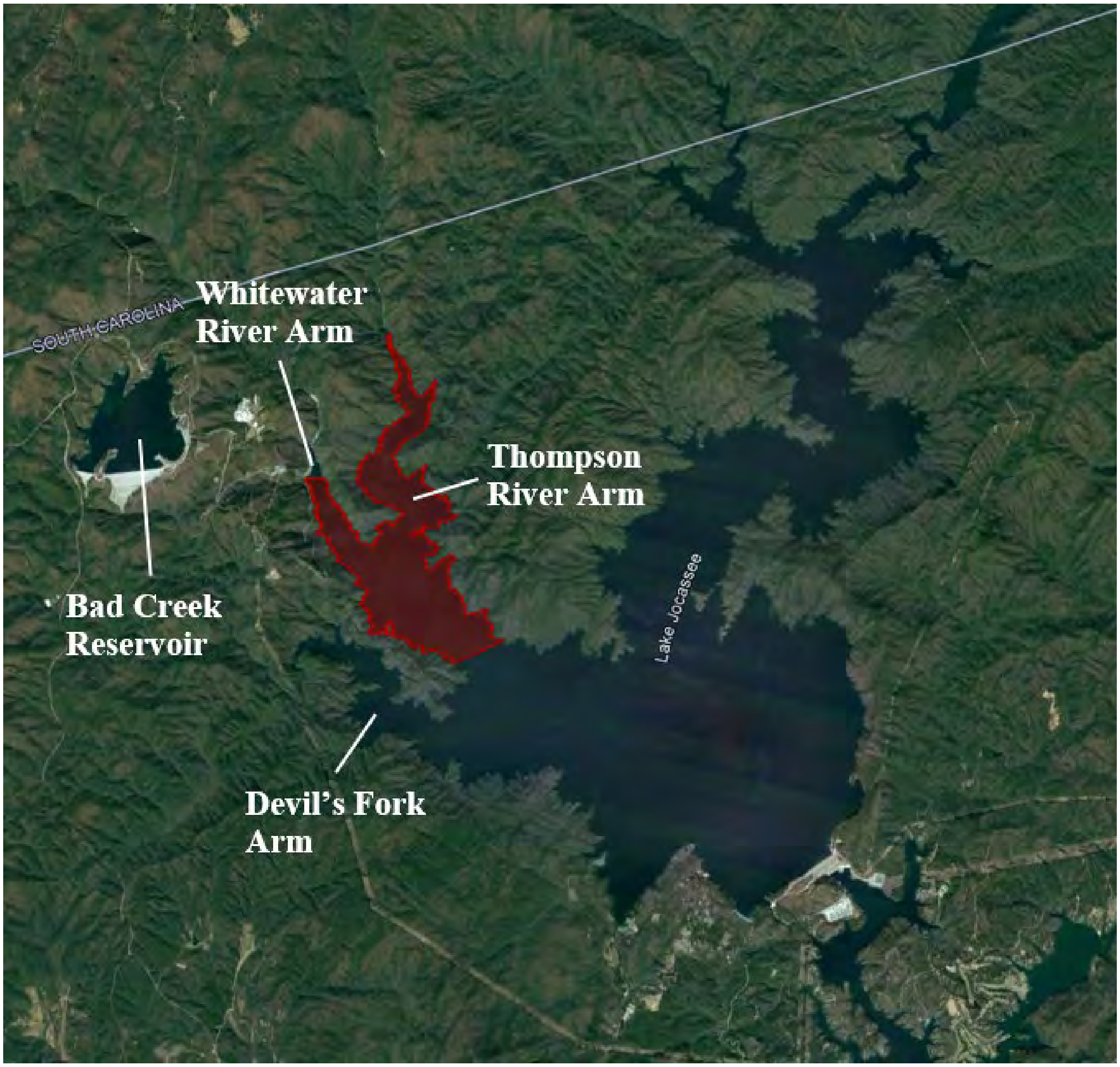


Figure 5-2. Approximate CFD Model Domain

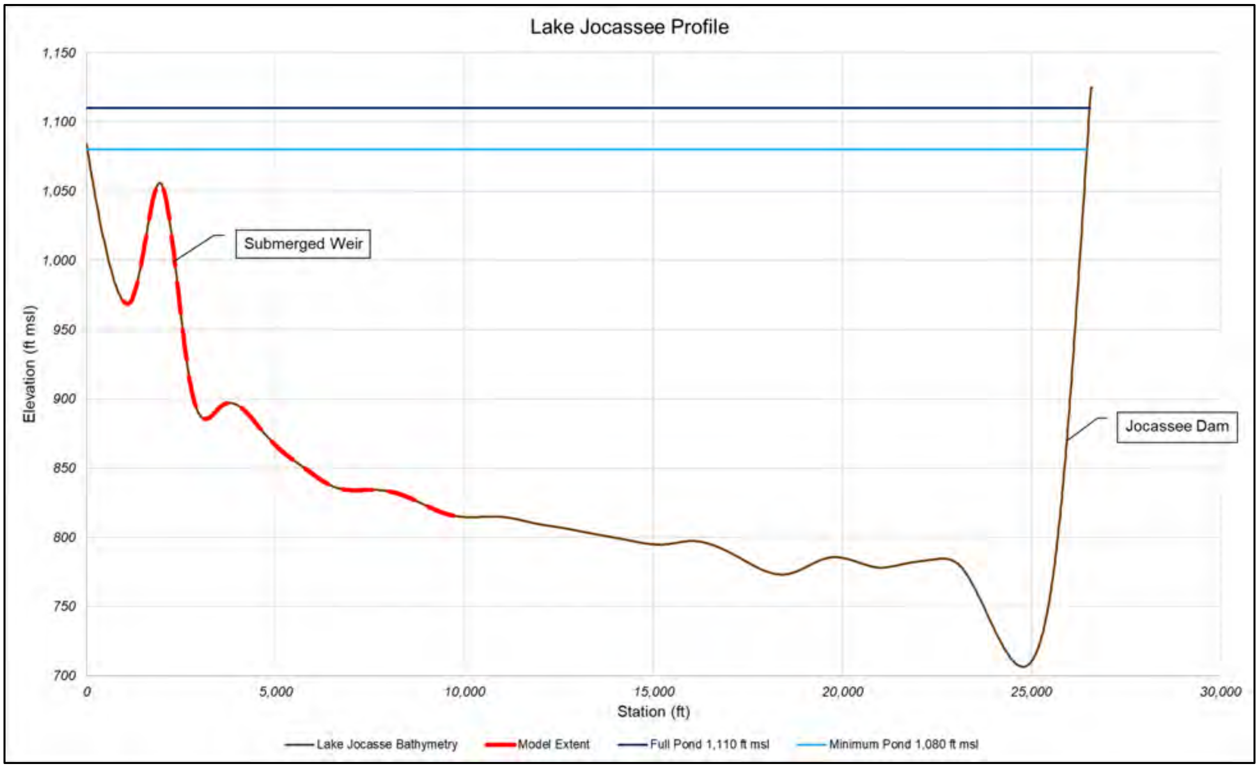


Figure 5-3. Lake Jocassee Profile from the Whitewater River to Jocassee Dam

6 CFD Model Results

6.1 Domain Verification

To confirm the CFD model domain was appropriately sized, the hydraulic profile at the model exit was compared across three scenarios:

- Existing generation with existing submerged weir;
- Proposed generation with existing submerged weir;
- Proposed generation with expanded submerged weir.

Figure 6-1 shows the CFD model domain plan view as well as a vertical slice near the downstream boundary of the model (green). The exit hydraulic profile for the three scenarios was taken at this slice location. When comparing proposed versus existing generation scenarios, the average exit velocity at the downstream extent of the CFD model domain is < 0.1 fps higher on average for the proposed generation scenario (range -0.06 fps to +0.15 fps). This represents a reasonable trade-off in modeling results versus modeling effort as extending the model domain further would not result in additional useful information but would greatly increase the overall modeling effort (including model run time). The small incremental increase in average velocity at the CFD model domain exit due to the proposed generation is much less than incremental velocity effects due to meteorological conditions (i.e., wind-induced effects in the upper water surface layer). Figure 6-2 compares three profiles (i.e., slices) representing three scenarios (existing, proposed with existing weir, and proposed with expanded weir) at the downstream model domain boundary.

Velocity profiles across the three scenarios are nearly identical and show very low (< 0.2 fps) velocities. Two conclusions are made from these results:

1. Because velocities are so low, the model domain has been extended far enough downstream to fully capture hydraulic effects of existing and proposed powerhouse operations.
2. Potential hydraulic effects discussed in this report are limited to the model domain (i.e., there are no appreciable hydraulic effects to Lake Jocassee downstream of the model domain).

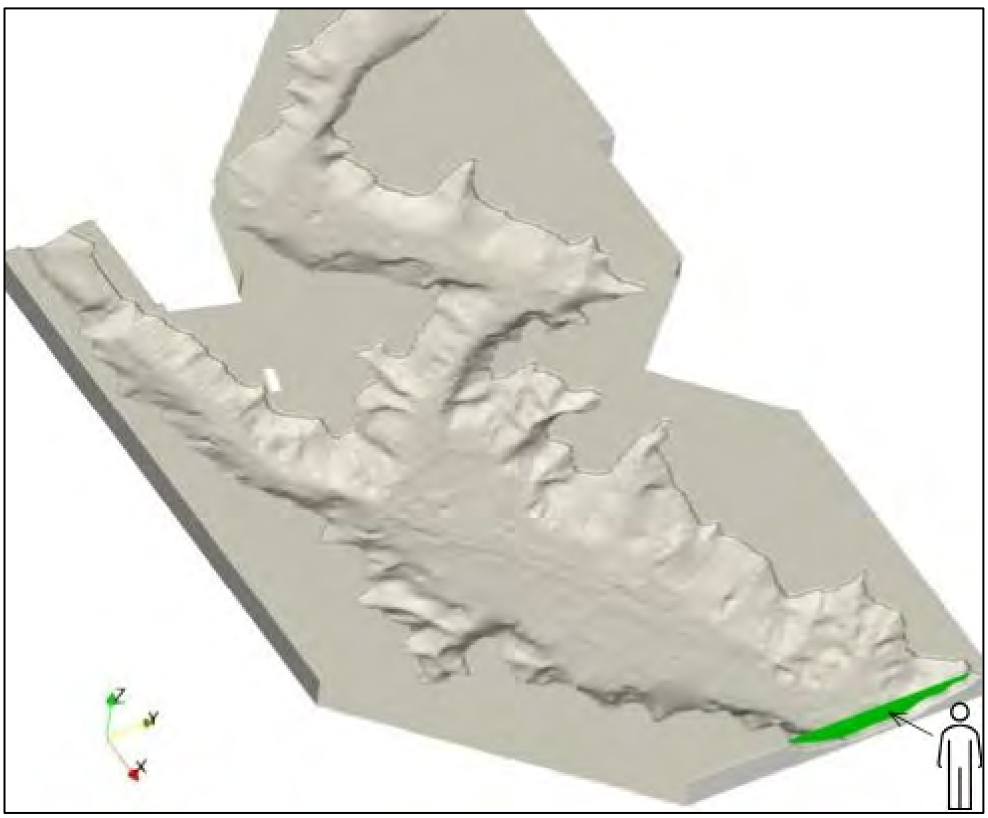


Figure 6-1. Comparison Slice Location (green)

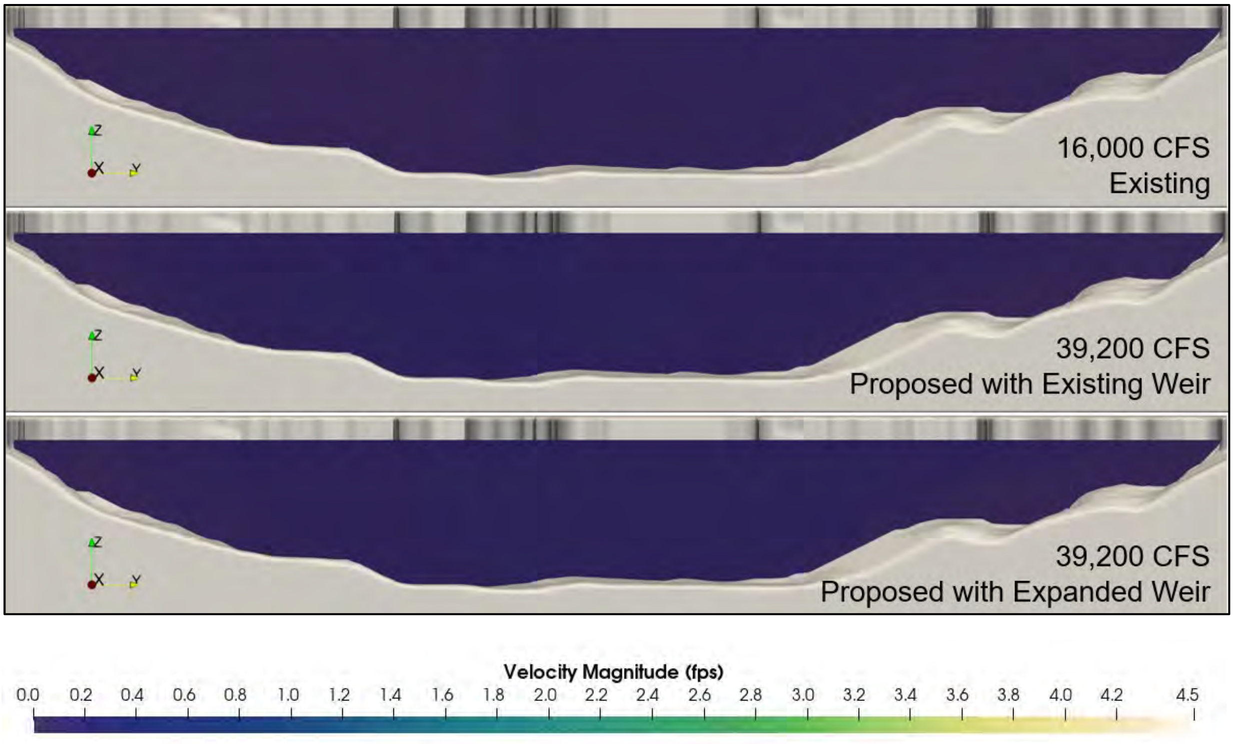


Figure 6-2. Model Exit Hydraulic Profile Comparison

6.2 Existing Project Configuration

To establish a baseline for comparison, the existing Bad Creek configuration and operations were modeled under full pond and maximum drawdown. Scenarios included the maximum generating flow of 16,000 cfs, the maximum pumping flow of 13,780 cfs, and the existing submerged weir geometry. Simulation times for the existing generation and pumping scenarios are 22.9 and 26.5 hours, respectively (see Table 4-1).

The four upgraded powerhouse scenarios (Scenarios 13-16 in Table 4-4) figures are presented in Appendix A. Results from these scenarios are consistent with the other 12 scenarios.

6.2.1 Generation

Full Pond

Existing hydraulic conditions at the full pond elevation are characterized by low flow velocities throughout the model domain. Flow velocities peak across the top of the submerged weir at approximately 0.6 fps. Figure 6-3 shows contours of velocity in an aerial view. Figure 6-4 shows the surface velocity contours in the vicinity of the submerged weir, as well as two vertical slices showing vertical velocity profiles in the Whitewater River arm[4].

Slice A-A’ is located approximately across the crest of the submerged weir, and slice B-B’ is approximately 800 ft downstream of slice A-A’.

Figure 6-5 presents hydraulic flow paths with velocity magnitudes identified by color (in fps) in the Whitewater River cove. For reference, water quality monitoring stations 564.1 and 564.0 are shown on the figure. Dense areas of streamlines downstream of the submerged weir indicate an area of potential mixing that extends approximately 850 ft downstream of the submerged weir.

More information on water quality and mixing at existing monitoring stations in the Whitewater River cove is provided in the Summary of Existing Water Quality and Standards Report (provided in Appendix A of the ISR). Results from the desktop water quality study indicate that flow is well mixed (i.e., lacks stratification) upstream of the weir at water quality monitoring location 564.1 but stratification is present throughout the year at monitoring location 564.0 just downstream of the weir. Results of the CFD modeling align with these field data observations. While flow appears to be mixing downstream of the submerged weir, velocities are very low (less than 0.25 fps) in the reservoir between the weir and monitoring location 564.0. Because the weir dissipates energy from Bad Creek I/O structure, the slow-moving uniform flow regime downstream of the weir creates conditions suitable for vertical stratification, similar to what occurs at other monitoring stations in the main body of Lake Jocassee. This effect (i.e., mixing on the upstream of the weir and vertical stratification on the downstream side) is present across the range of simulations evaluated.

[4] For all vertical slices, viewer perspective includes the viewer standing downstream of the slice looking upstream.

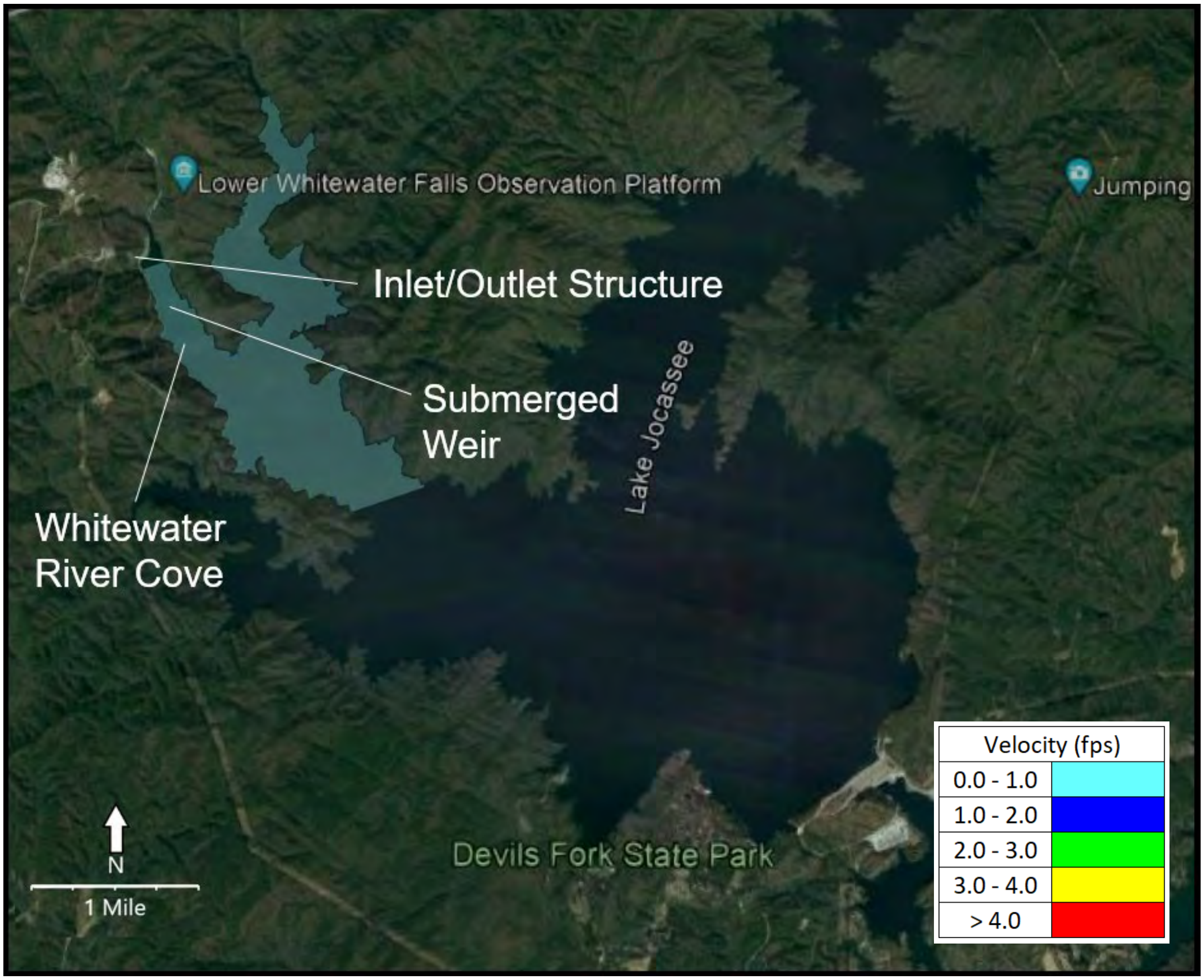


Figure 6-3. Existing Generation at Full Pond – Velocity Contours

Figure 6-4. Existing Generation at Full Pond – Velocity Contours in Submerged Weir Vicinity (Flow is Left to Right)

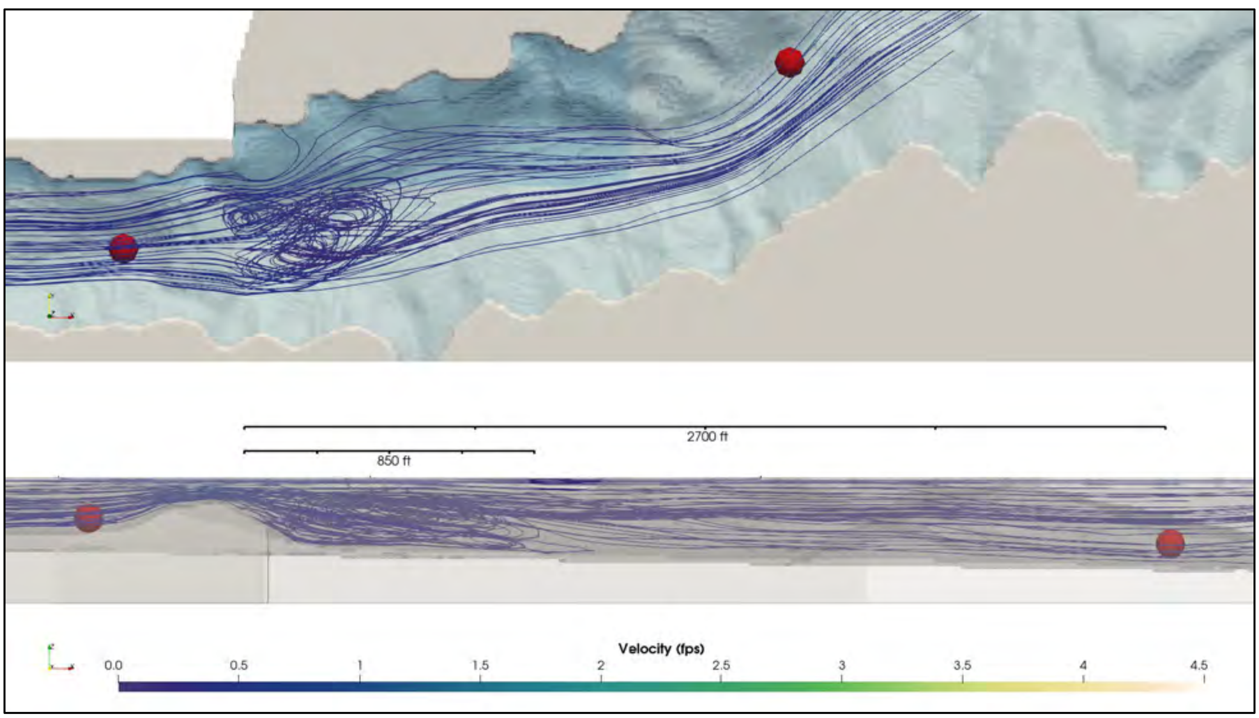


Figure 6-5. Existing Generation at Full Pond – Whitewater River Cove Streamlines (Flow is Left to Right)

Maximum Drawdown

At maximum drawdown, the effect of the submerged weir is more pronounced. Surface velocity contours show an area of slightly elevated velocity in the immediate vicinity of the submerged weir. This area of slightly elevated velocity extends approximately 200 ft from the weir crest and peaks at 1.1 fps. This area of elevated velocity is shown on Figure 6-6 and Figure 6-7. Vertical slices A-A’ and B-B’ in Figure 6-7 indicate the area of higher velocity is present through the majority of the water column across the top of the weir, but as flow expands into the downstream section of the Whitewater River Cove, this effect has dissipated. Figure 6-8 shows hydraulic flow paths with velocity magnitudes identified by color which have a similar flow pattern to those shown in Figure 6-5 (full pond streamlines), however the effect of the weir is more pronounced. At lower reservoir elevations (i.e., pond levels), water velocities are accelerated across the top of the weir as flows are forced to the surface. This results in an area of slightly higher surface velocities, and a slightly shorter potential mixing length downstream of the weir.

As with the full pond scenario, the weir limits downstream mixing and because of the very low velocities downstream of the weir, stratification trends at monitoring station 564.0 mimic the rest of Lake Jocassee.

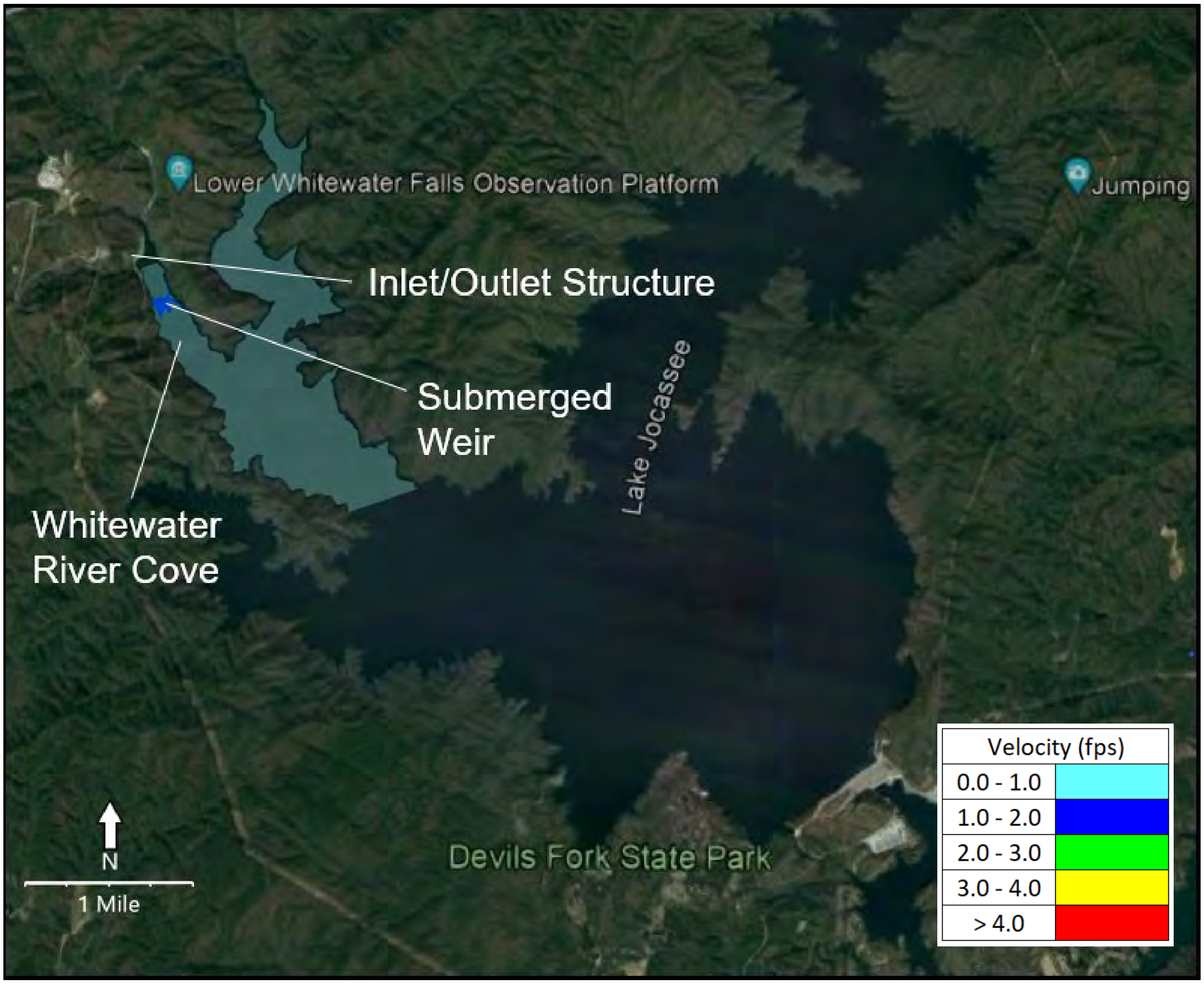


Figure 6-6. Existing Generation at Maximum Drawdown – Velocity Contours

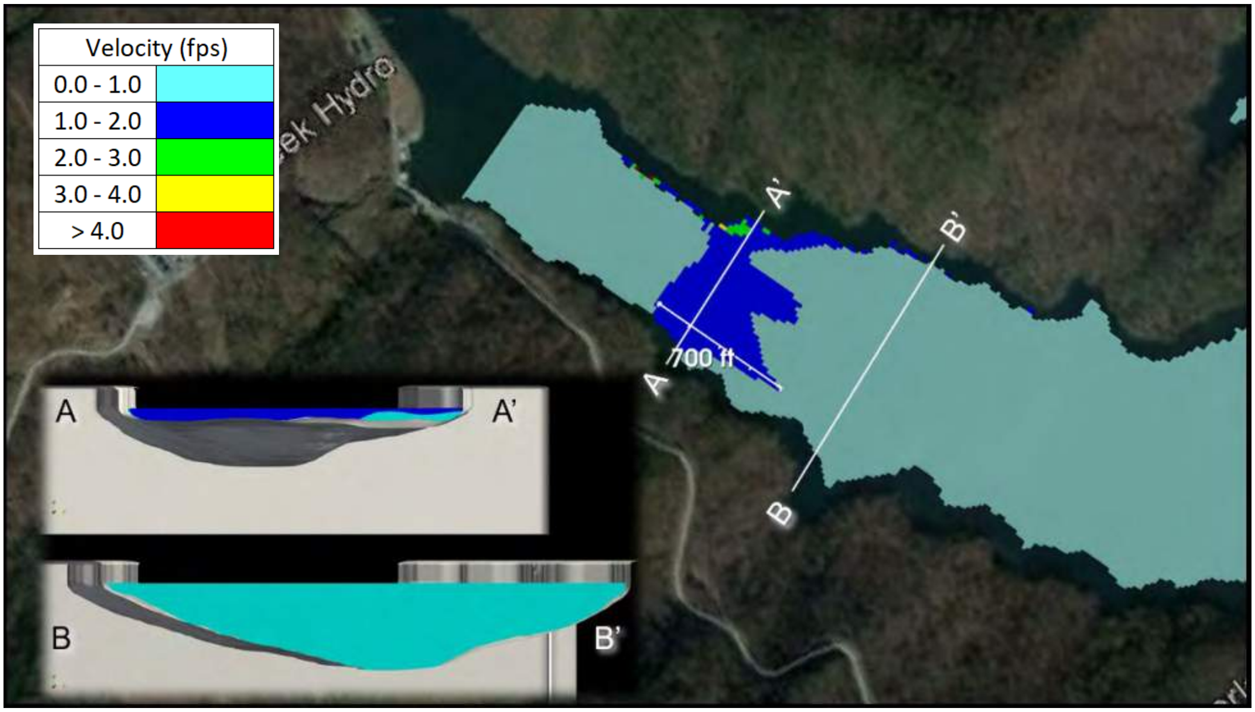


Figure 6-7. Existing Generation at Maximum Drawdown – Velocity Contours in Submerged Weir Vicinity (Flow is Left to Right)

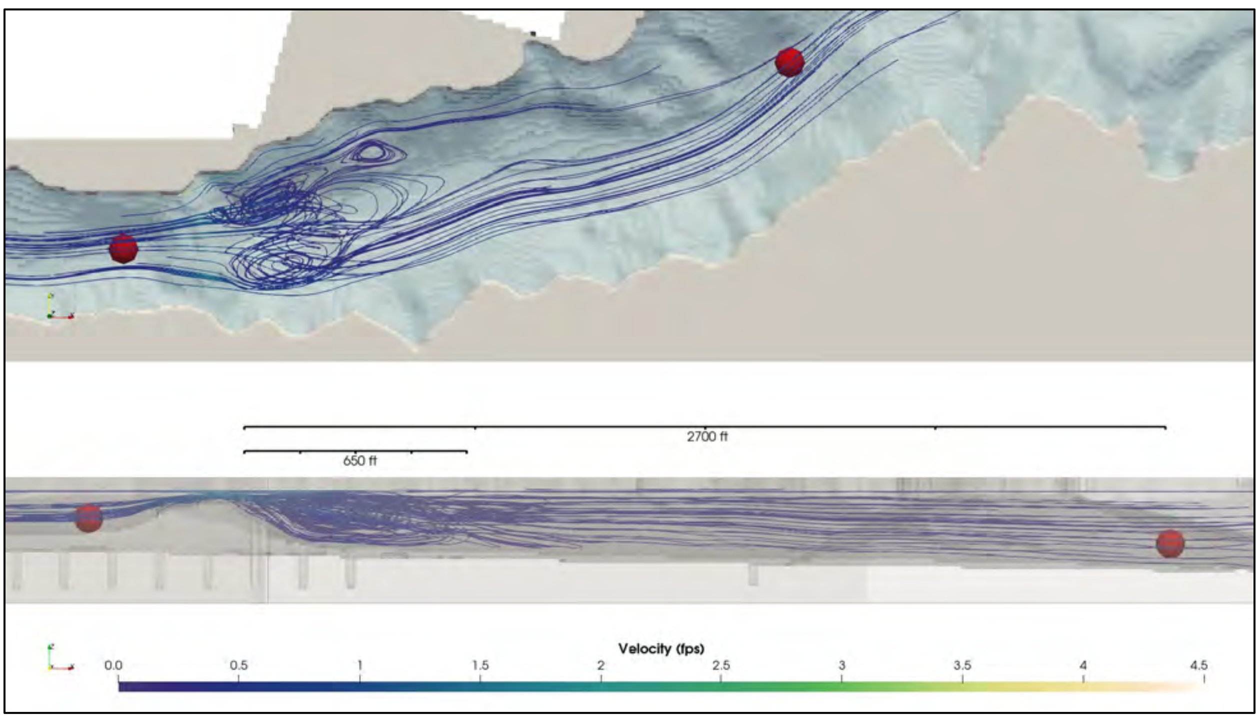


Figure 6-8. Existing Generation at Maximum Drawdown – Whitewater River Cove Streamlines (Flow is Left to Right)

6.2.2 Pumping

Full Pond

Existing pumping conditions at full pond are similar to existing generation conditions at full pond. Low velocities are seen throughout the model domain, and peak across the top of the submerged weir at approximately 0.5 fps. Surface velocities are shown in Figure 6-9 and Figure 6-10, and the same vertical slices A-A' and B-B' presented in previous figures are shown on Figure 6-10. Hydraulic flow paths with velocity magnitudes identified by color in the Whitewater River cove are presented in Figure 6-11. There is little to no vertical mixing downstream of the submerged weir under pumping operations. As flow is pumped to Bad Creek Reservoir, it is gradually pulled from the upper surface layer of Lake Jocassee over the submerged weir resulting in a very uniform, laminar flow regime downstream of the weir. Flow patterns at monitoring location 564.0 extending upstream to the weir are uniform and have velocities less than 0.2 fps indicating seasonal stratification would be maintained throughout the reservoir downstream of the weir.

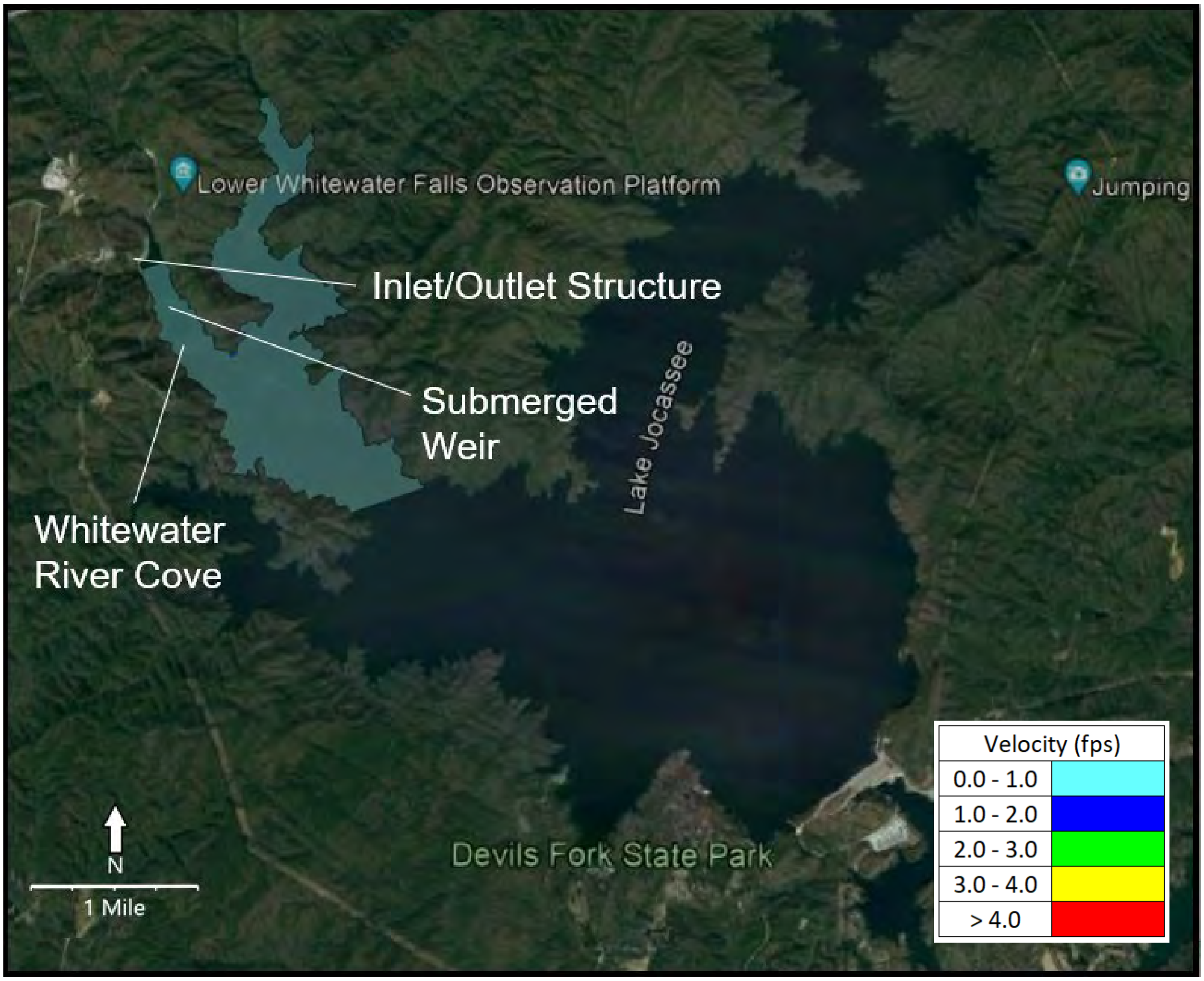


Figure 6-9. Existing Pumping at Full Pond – Velocity Contours

Figure 6-10. Existing Pumping at Full Pond – Velocity Contours in Submerged Weir Vicinity (Flow Right to Left)

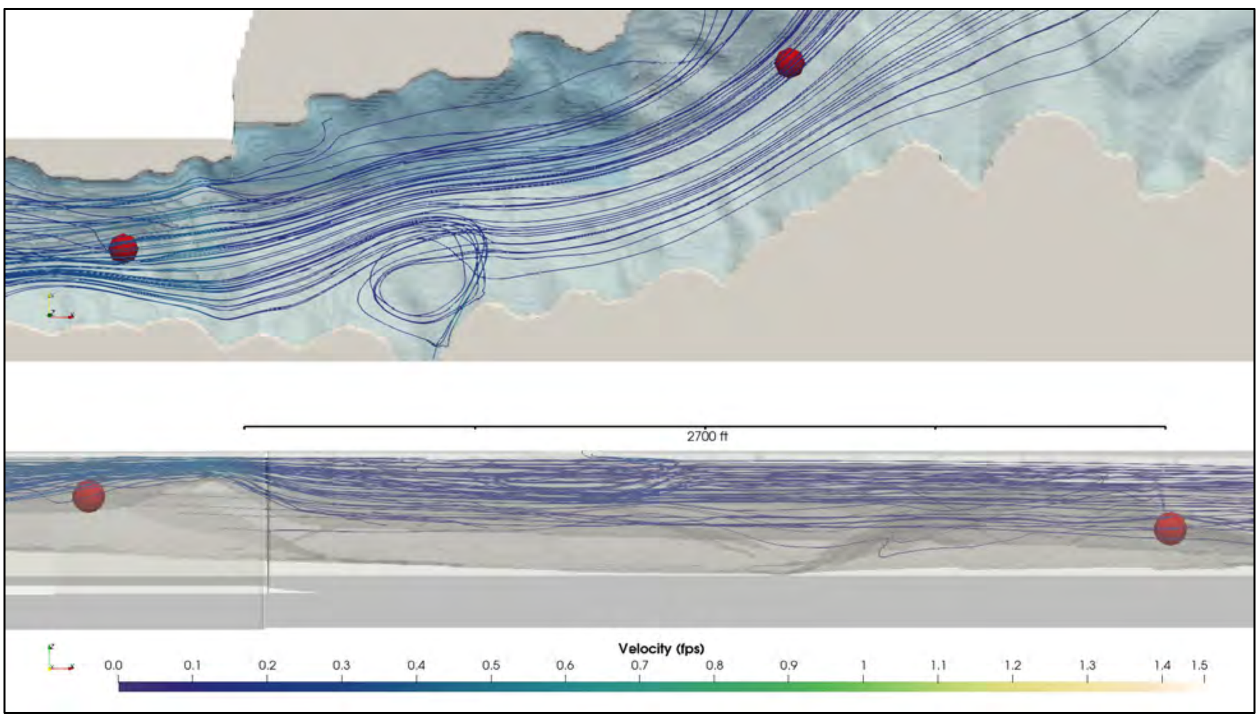


Figure 6-11 Existing Pumping at Full Pond – Whitewater River Cove Streamlines (Flow Right to Left)

Maximum Drawdown

Similar to generating at maximum drawdown, pumping at maximum drawdown increases the effect of the submerged weir. An area of higher velocity extends approximately 1,200 ft upstream of the submerged weir peaking at 1.9 fps. Surface velocities for pumping at maximum drawdown are shown in Figure 6-12 and Figure 6-13. Vertical slices in Figure 6-13 indicate minimal vertical mixing effects are observed downstream of the submerged weir. Velocity streamlines in the Whitewater River cove shown on Figure 6-14 are uniform and slow moving, indicating stratification would be present downstream of the weir. As flow is pulled across the top of the weir it is accelerated near the surface into the upstream section of the Whitewater River cove.

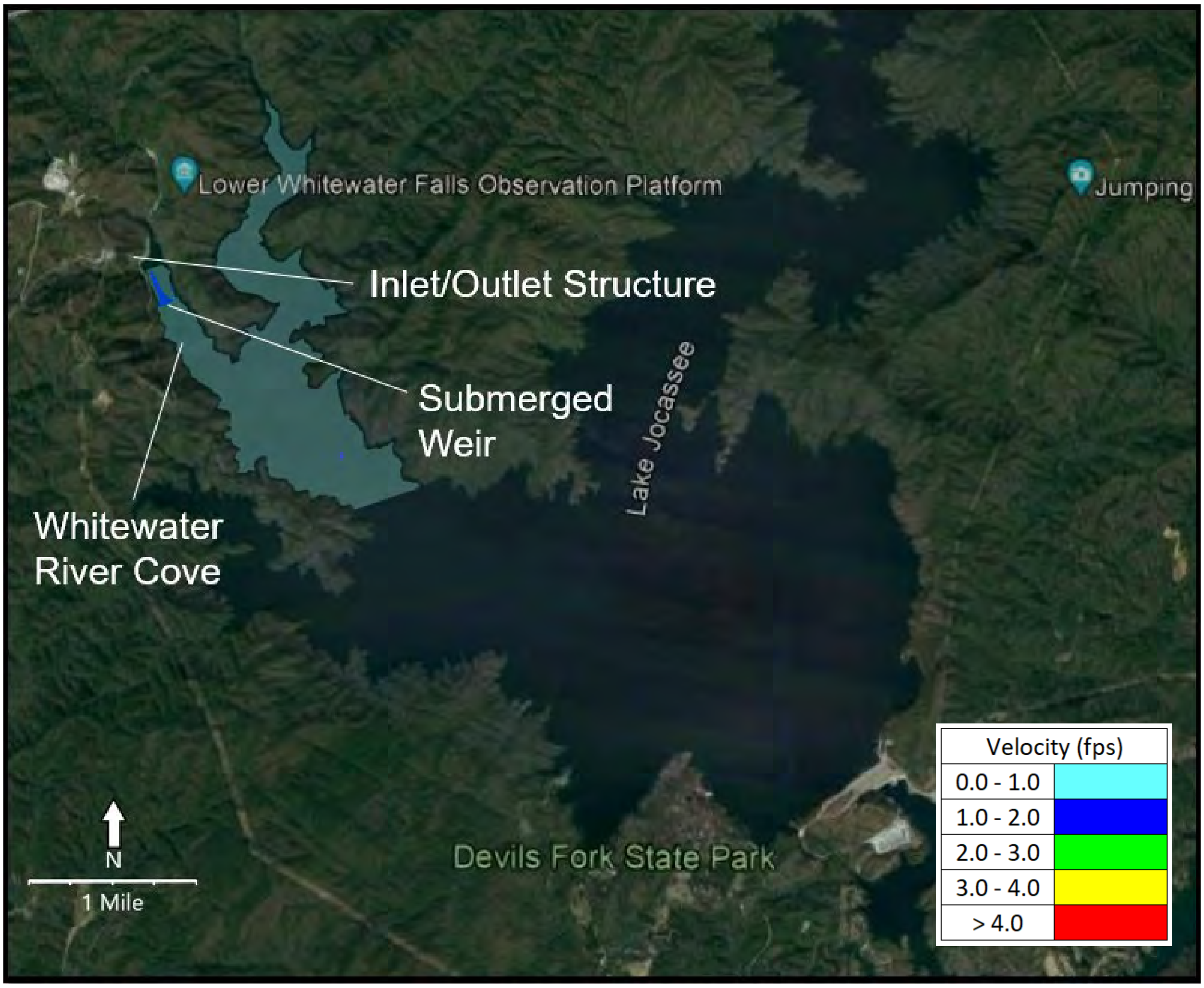


Figure 6-12. Existing Pumping at Maximum Drawdown – Velocity Contours

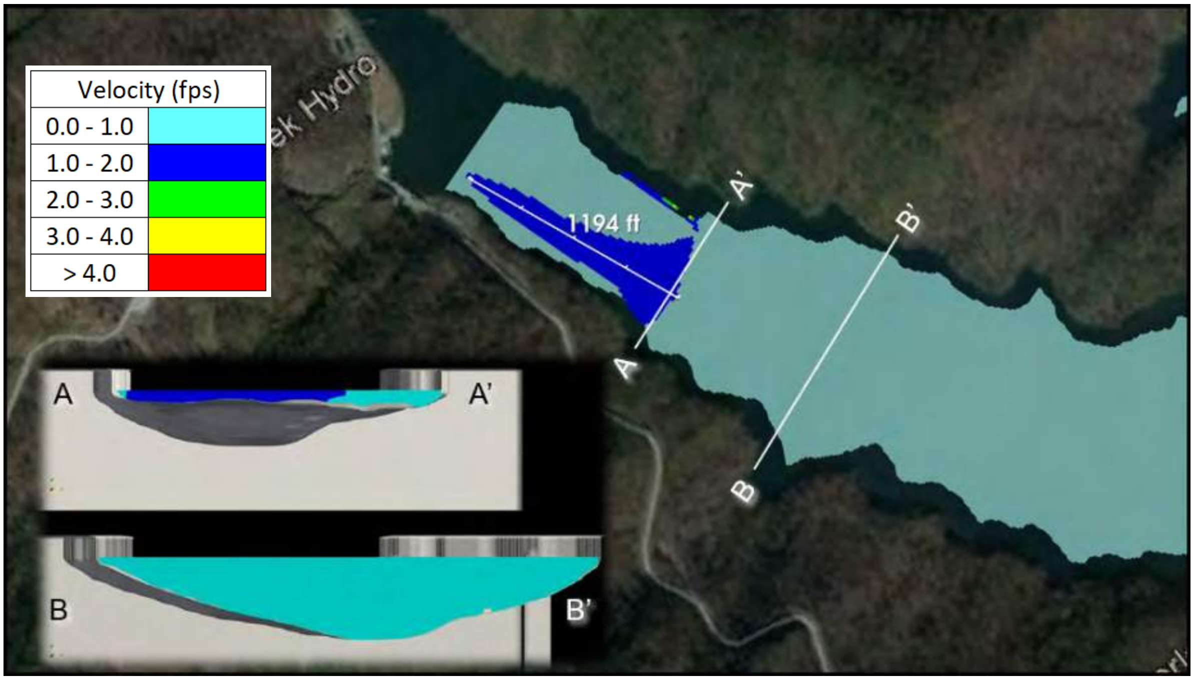


Figure 6-13. Existing Pumping at Maximum Drawdown – Velocity Contours in Submerged Weir Vicinity (Flow Right to Left)

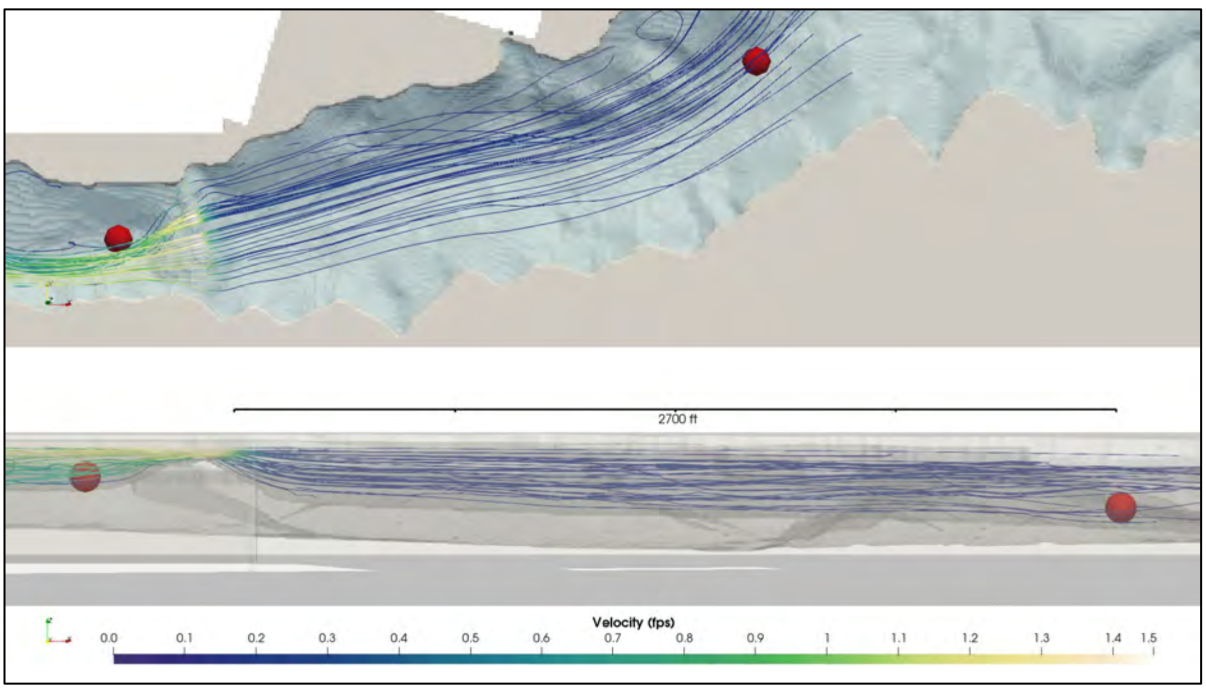


Figure 6-14. Existing Pumping at Maximum Drawdown – Whitewater River Cove Streamlines (Flow Right to Left)

6.3 Proposed Project, Existing Weir

6.3.1 Generation

Full Pond

The proposed generation flow is more than double the existing flow (39,200 cfs vs 16,000 cfs). This significant increase in flow results in a localized increase in velocity at the surface and through the water column. Conditions at the full pond elevation are characterized by low flow velocities throughout the model domain. Flow velocities peak across the top of the submerged weir at approximately 1.4 fps. Figure 6-15 shows contours of velocity in an aerial view. Figure 6-16 shows the surface velocity contours in the vicinity of the submerged weir, as well as the two vertical slices showing vertical velocity profiles in the Whitewater River arm. The area of elevated velocity (1-2 fps) extends approximately 1,000 ft downstream of the weir crest.

Figure 6-17 presents hydraulic flow paths with velocity magnitudes identified by color in the Whitewater River cove. Note water quality monitoring points 564.1 and 564.0 are shown on the figure. The dense areas of streamlines downstream of the submerged weir indicates that an area of potential mixing extends approximately 850 ft downstream of the submerged weir, which is a similar mixing length as existing generation at full pond. While flow appears to be mixing downstream of the submerged weir, velocities are very low, less than 0.25 fps, between the weir and monitoring location 564.0. These slow, uniform flow patterns are very similar to existing conditions and facilitate conditions for stratification within the water column at water quality monitoring station 564.0 just downstream of the weir.

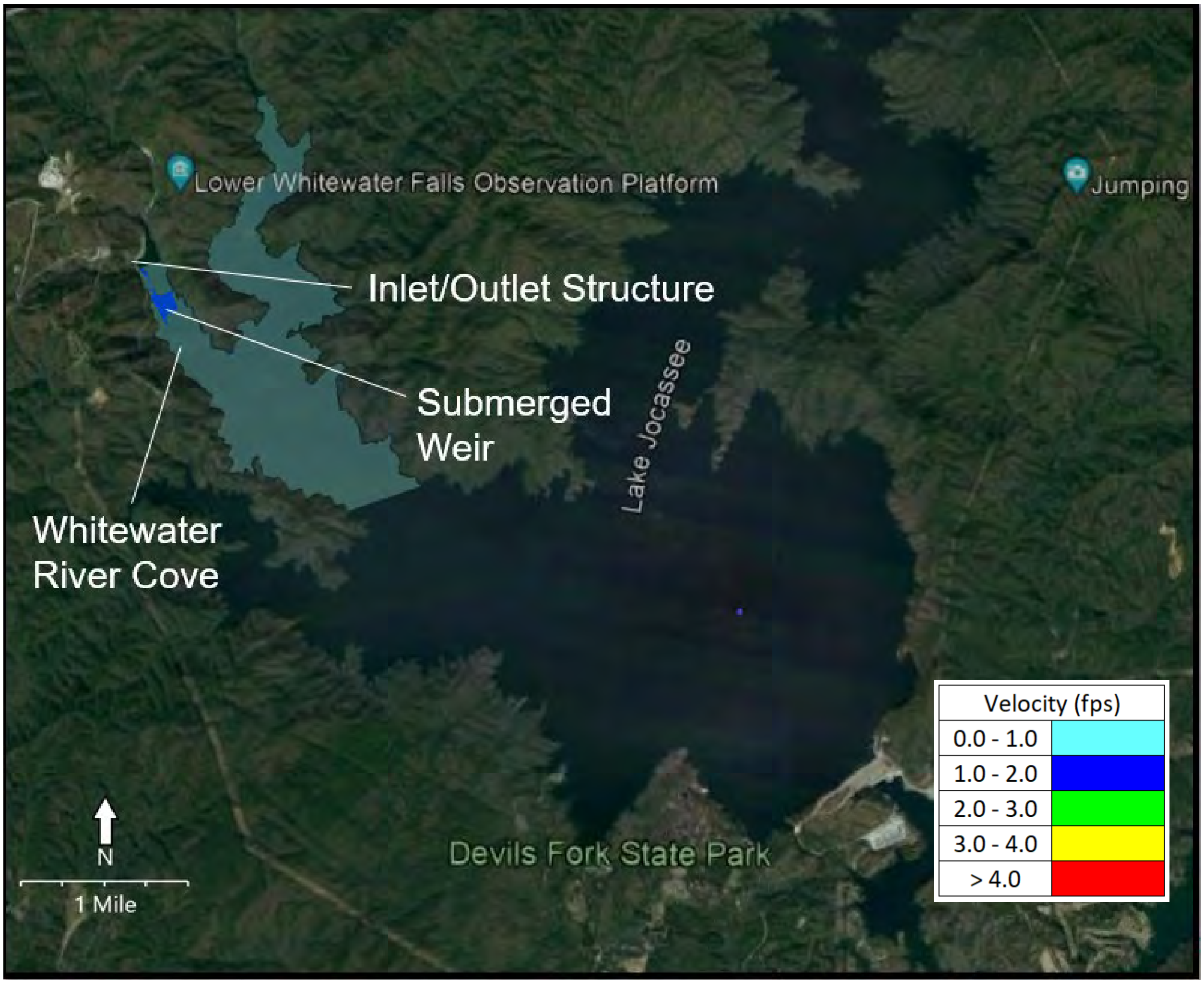


Figure 6-15. Proposed Generation (Existing Weir) at Full Pond – Velocity Contours

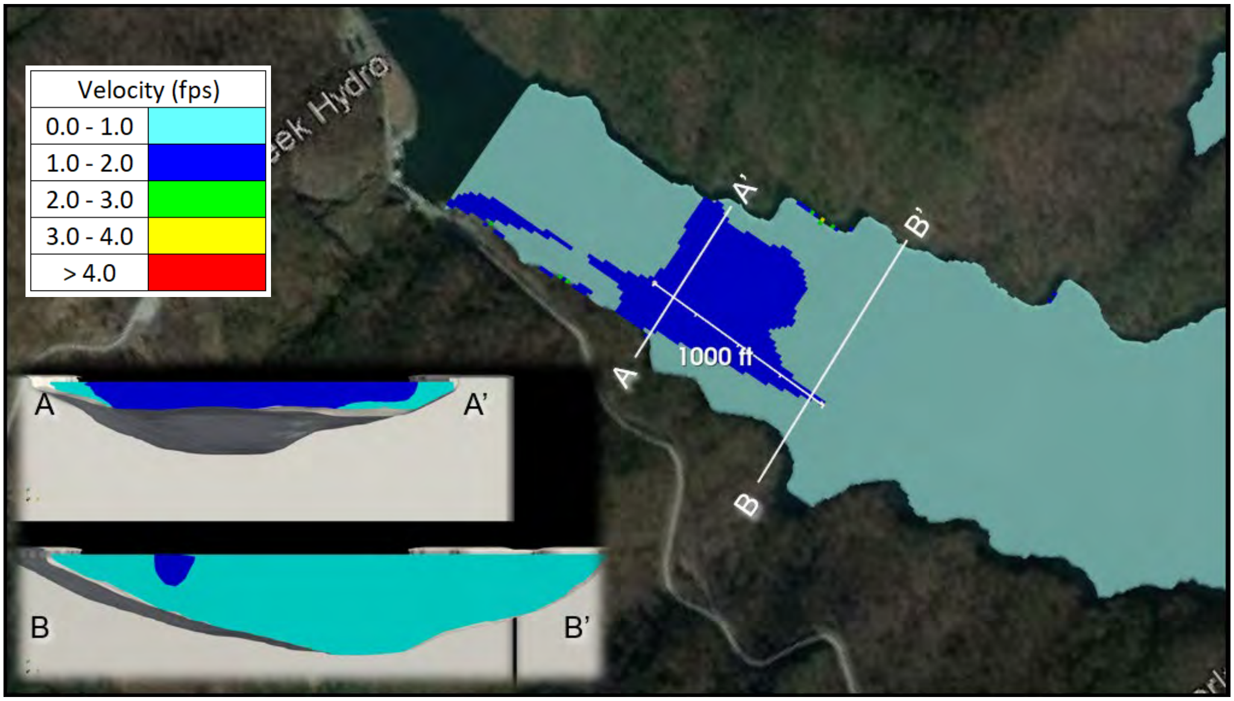


Figure 6-16. Proposed Generation (Existing Weir) at Full Pond – Velocity Contours in Submerged Weir Vicinity (Flow is Left to Right)

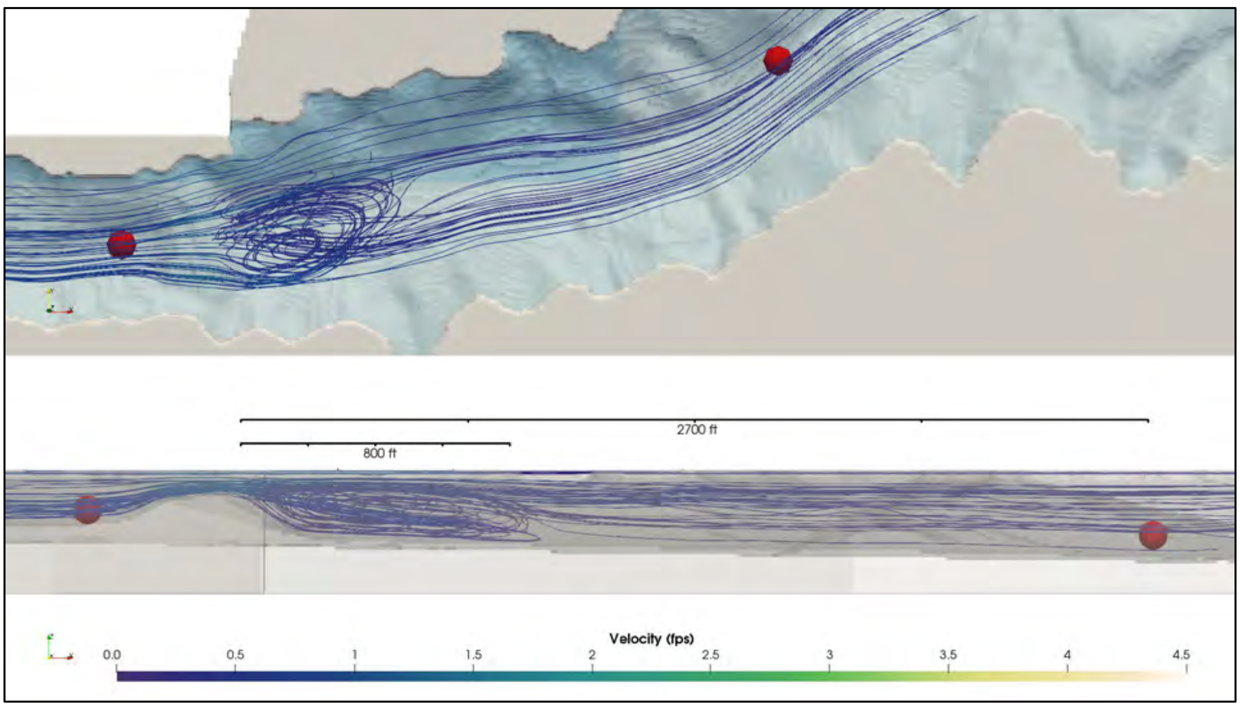


Figure 6-17. Proposed Generation (Existing Weir) at Full Pond – Whitewater River Cove Streamlines (Flow is Left to Right)

Maximum Drawdown

At maximum drawdown, the effect of the submerged weir is more pronounced. Contours of surface velocity show an area of slightly elevated velocity in the immediate vicinity of the weir. This area of slightly elevated velocity extends downstream approximately 2,100 ft from the weir crest and peaks at 3.7 fps. This area of elevated velocity is shown on Figure 6-18 and Figure 6-19. Vertical slices A-A' and B-B' shown on Figure 6-19 indicate the area of higher velocity is present through the majority of the water column across the top of the weir, but as flow expands into the downstream section of the Whitewater River cove, flow is concentrated on the right descending bank, and only in this section are velocities elevated throughout the water column. Figure 6-20 shows hydraulic flow paths with velocity magnitudes identified by color which have a similar flow pattern as shown in Figure 6-17 (full-pond streamlines), however the effect of the weir is more pronounced. At lower pond levels, water velocities are accelerated across the top of the weir and flows are forced to the surface. This results in an area of slightly higher surface velocities, and a slightly shorter potential mixing length downstream of the weir.

As with the full pond scenario, because of the very low velocities downstream of the weir at water quality monitoring location 564.0, it can be reasonably expected that flow conditions would promote stratification.

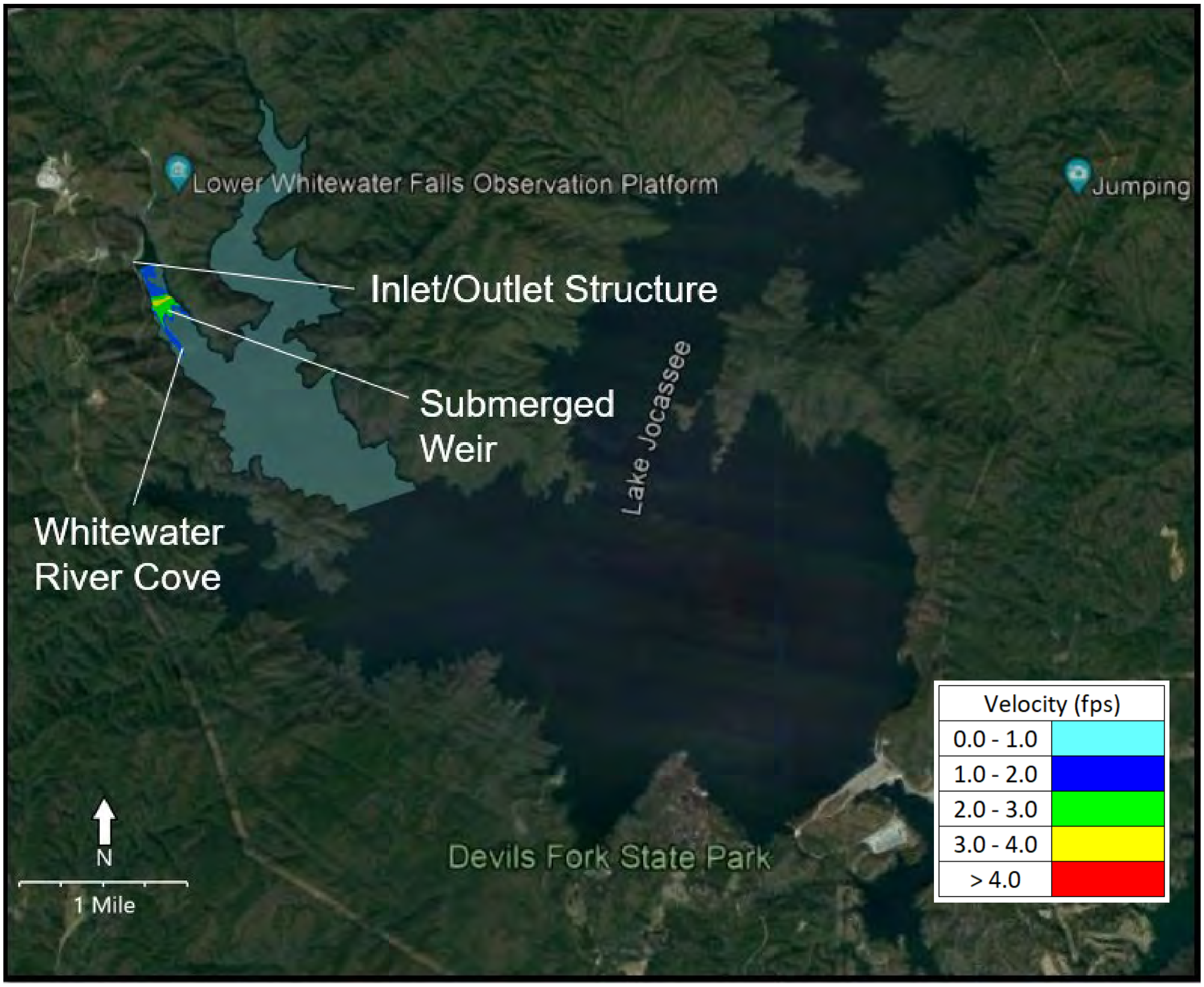


Figure 6-18. Proposed Generation (Existing Weir) Maximum Drawdown – Velocity Contours

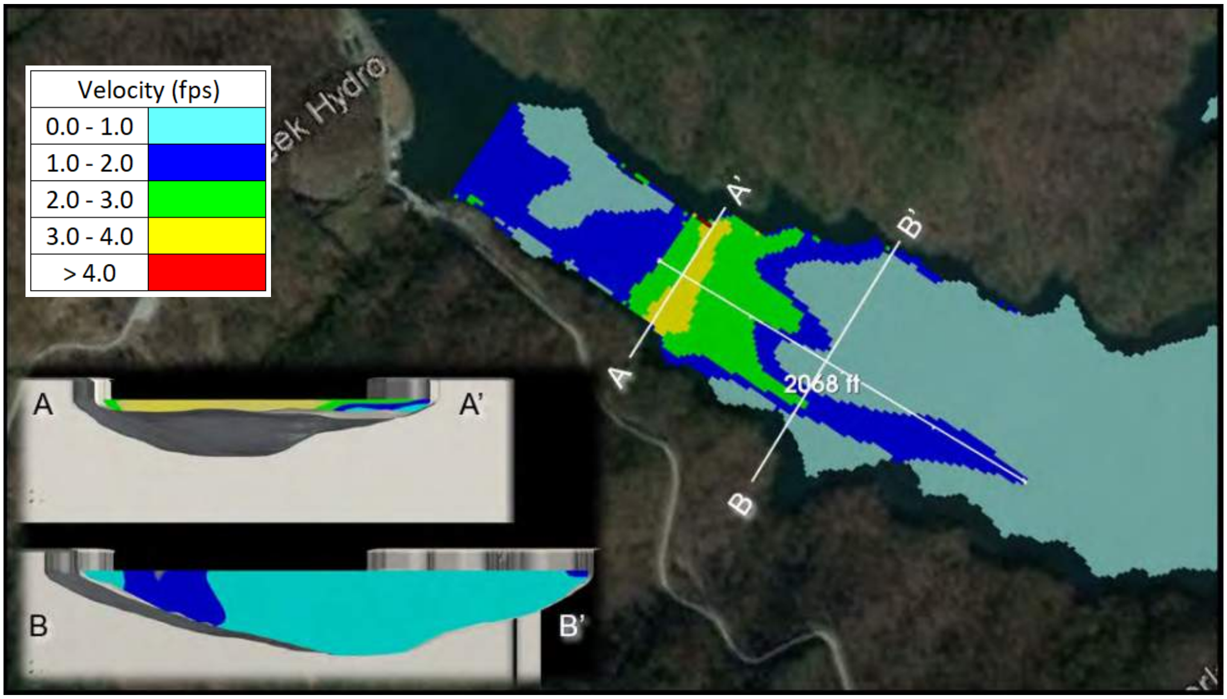


Figure 6-19. Proposed Generation (Existing Weir) at Maximum Drawdown – Velocity Contours in Submerged Weir Vicinity (Flow is Left to Right)

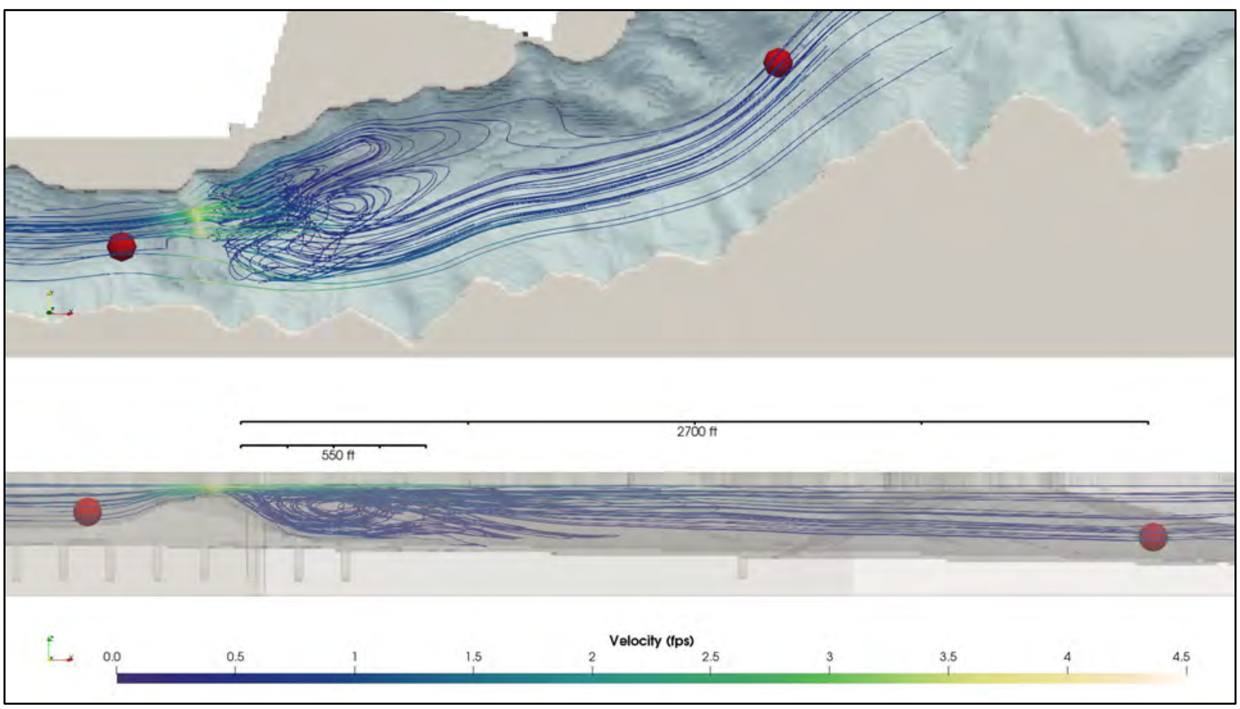


Figure 6-20. Proposed Generation (Existing Weir) at Maximum Drawdown – Whitewater River Cove Streamlines (Flow is Left to Right)

6.3.2 Pumping

Full Pond

The proposed pumping flow is more than double the existing flow (32,720 cfs vs 13,780 cfs). This significant increase in flow results in a localized increase in velocity at the surface and through the water column. Conditions at the full pond elevation are characterized by low flow velocities throughout the model domain. Flow velocities peak across the top of the submerged weir at approximately 1.1 fps. Figure 6-21 shows contours of velocity in an aerial view. Figure 6-22 shows the surface velocity contours in the vicinity of the submerged weir, as well as the two vertical slices showing vertical velocity profiles in the Whitewater River arm. The area of elevated velocity (1-2 fps) extends approximately 160 ft upstream of the weir crest.

Figure 6-23 presents hydraulic flow paths with velocity magnitudes identified by color in the Whitewater River cove. There is little to no vertical mixing downstream of the submerged weir under pumping operations. As flow is pumped to Bad Creek Reservoir, it is gradually pulled from Lake Jocassee across the top of the submerged weir resulting in a very uniform, laminar flow regime downstream of the weir. Flow patterns at monitoring location 564.0 extending upstream to the weir are uniform and have velocities less than 0.2 fps indicating stratification would be present throughout the reservoir downstream of the weir.

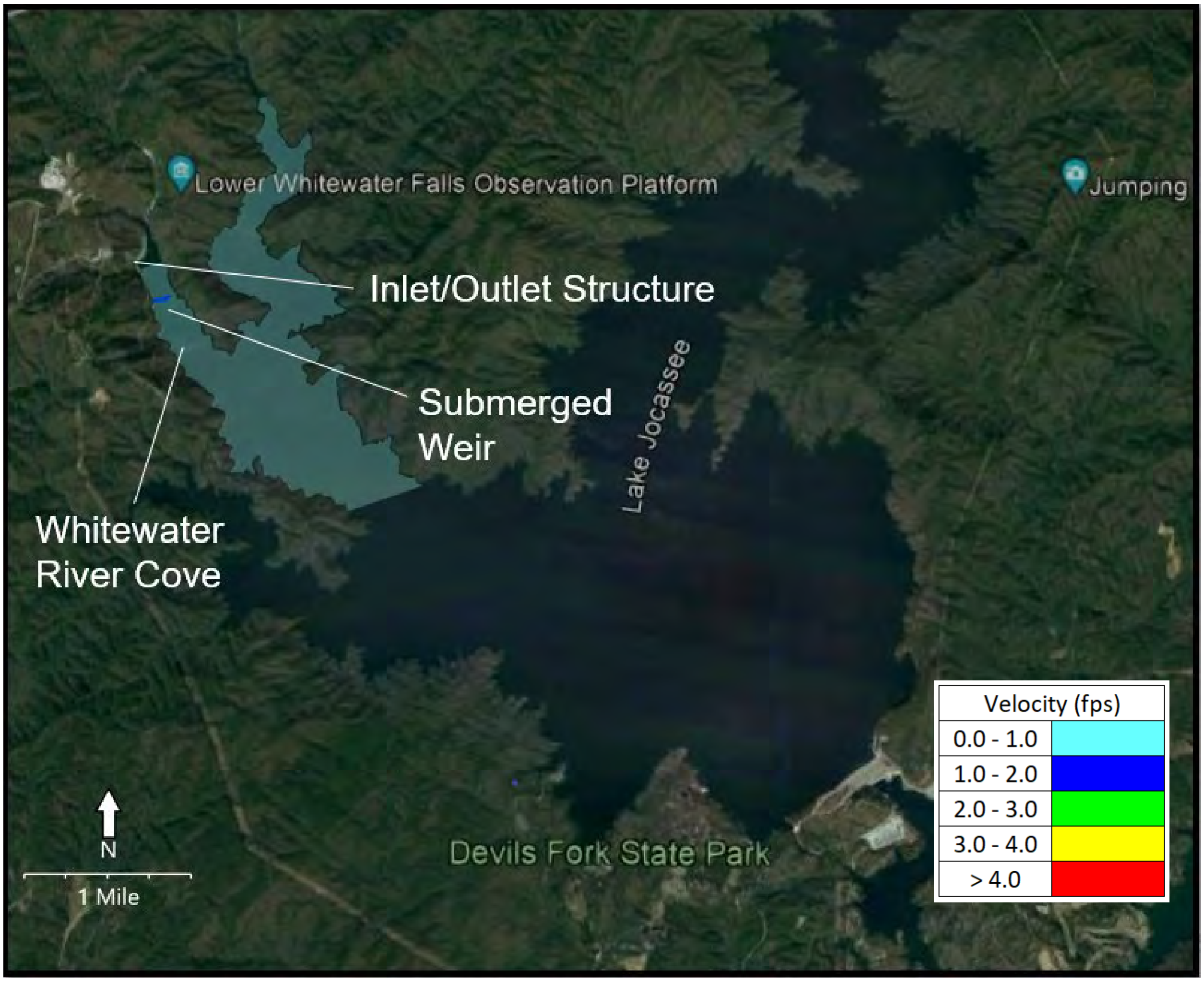


Figure 6-21. Proposed Pumping (Existing Weir) at Full Pond – Velocity Contours

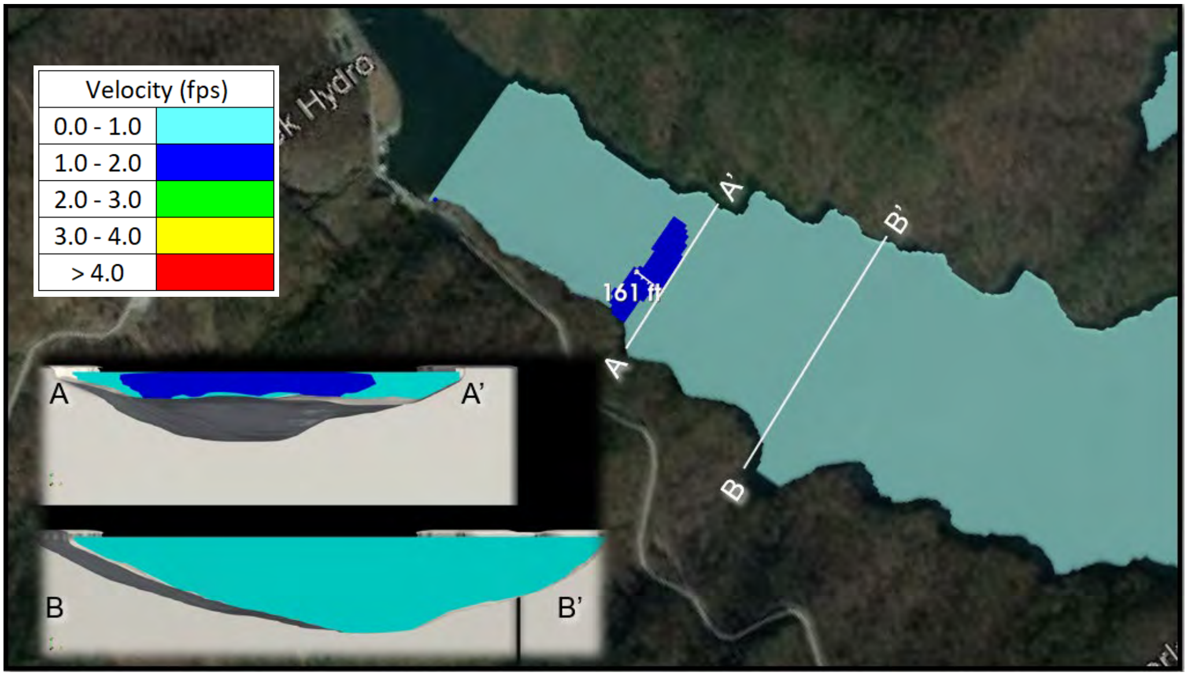


Figure 6-22. Proposed Pumping (Existing Weir) at Full Pond – Velocity Contours in Submerged Weir Vicinity (Flow is Right to Left)

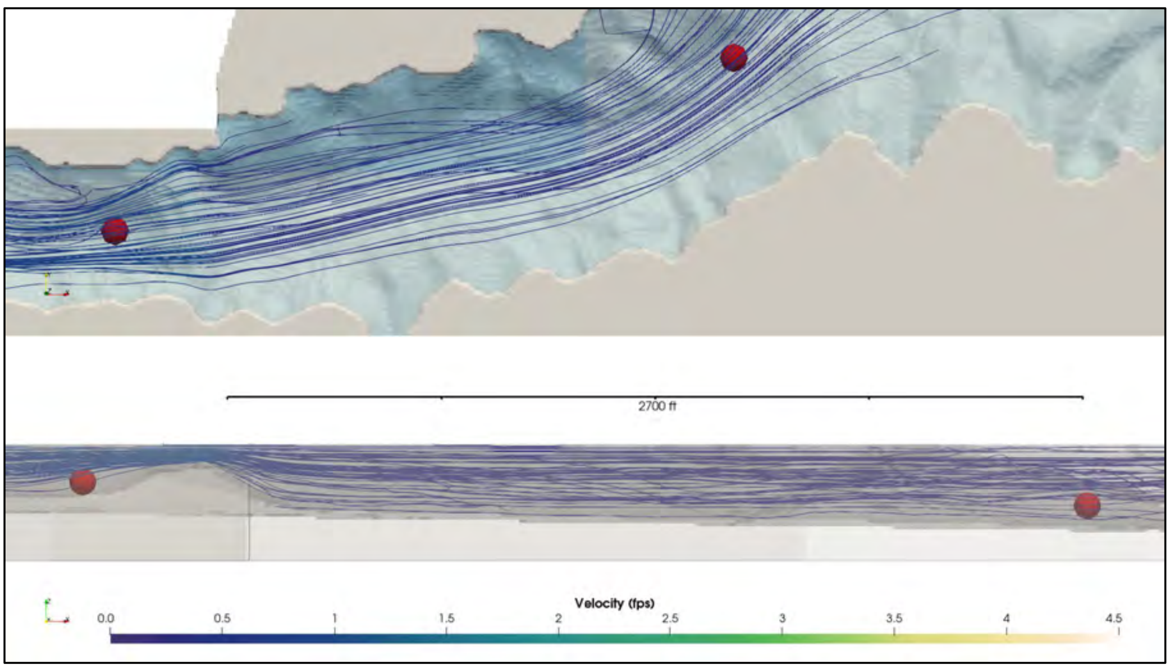


Figure 6-23. Proposed Pumping (Existing Weir) at Full Pond – Whitewater River Cove Streamlines (Flow is Right to Left)

Maximum Drawdown

Similar to generating at maximum drawdown, pumping at maximum drawdown increases the effect of the submerged weir. An area of higher velocity extends approximately 1,200 ft upstream of the submerged weir peaking at 1.9 fps. Surface velocities for pumping at maximum drawdown are shown in Figure 6-24 and Figure 6-25. Vertical slices in Figure 6-25 indicate minimal vertical mixing effects are observed downstream of the submerged weir. Velocity streamlines in the Whitewater River cove shown on Figure 6-26 are uniform and slow moving, indicating stratification would be present downstream of the weir. As flow is pulled across the top of the weir it is accelerated into the upstream section of the Whitewater River cove.

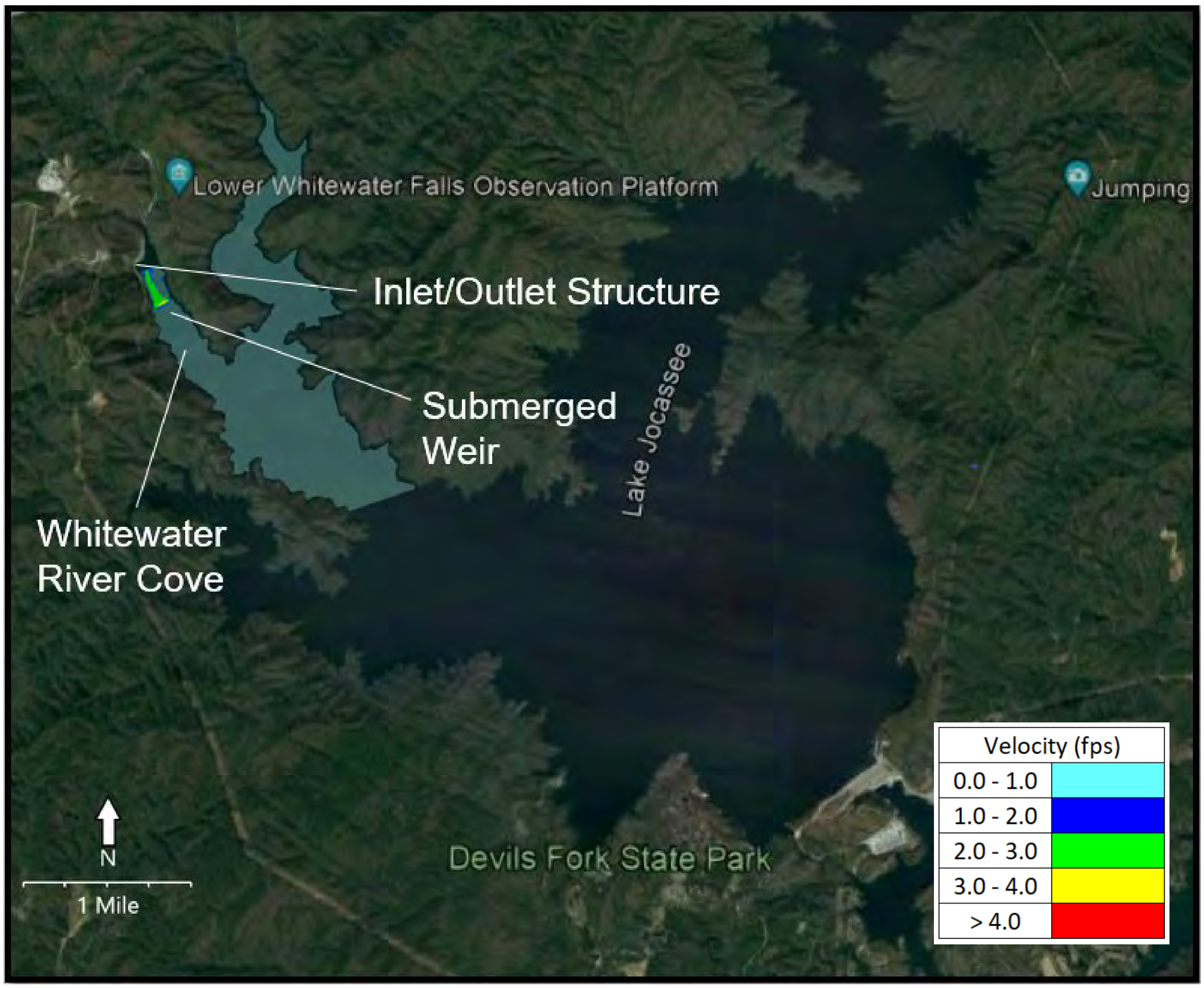


Figure 6-24. Proposed Pumping (Existing Weir) at Maximum Drawdown – Velocity Contours

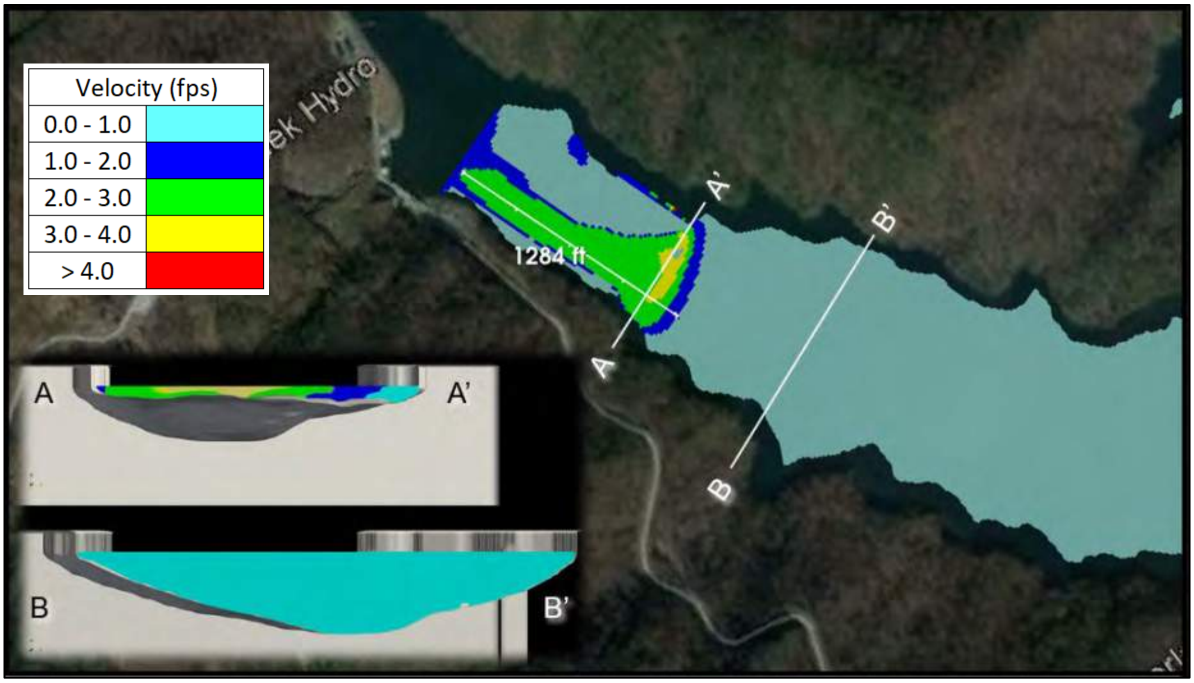


Figure 6-25. Proposed Pumping (Existing Weir) at Maximum Drawdown – Velocity Contours in Submerged Weir Vicinity (Flow is Right to Left)

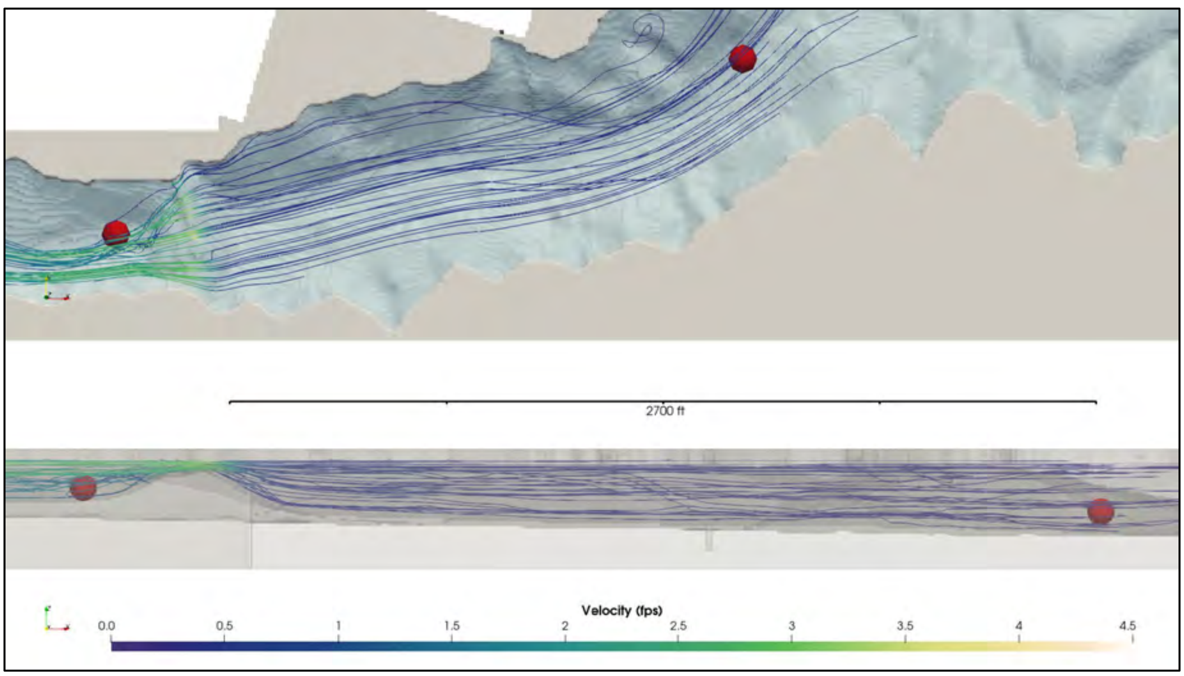


Figure 6-26. Proposed Pumping (Existing Weir) at Maximum Drawdown – Whitewater River Cove Streamlines (Flow is Right to Left)

6.4 Proposed Project, Expanded Weir

6.4.1 Generation

Full Pond

The proposed expanded submerged weir has a slightly stronger effect of accelerating flow across the top of the weir and downstream into the lower Whitewater River cove. Similar to the existing weir configuration, full-pond hydraulic conditions in the Whitewater River cove under proposed flow with the expanded weir geometry are characterized by relatively low velocities. Flow velocities peak across the top of the submerged weir at approximately 1.3 fps. Figure 6-27 shows contours of velocity in an aerial view. Figure 6-28 shows the surface velocity contours in the vicinity of the submerged weir, as well as two vertical velocity profiles in the Whitewater River arm. Slice B-B’ indicates an area of elevated velocity is present in the water column 800 ft downstream of the submerged weir, however it is confined to the top portion of the water column, indicating the proposed weir is functioning as intended. The area of slightly elevated velocity (1.0-2.0 fps) extends about 1,800 ft downstream of the submerged weir.

Figure 6-29 presents hydraulic flow paths with velocity magnitudes identified by color in the Whitewater River cove. Dense areas of streamlines downstream of the submerged weir indicate an area of potential mixing that extends approximately 1050 ft downstream of the submerged weir. While flow appears to be mixing downstream of the submerged weir, velocities are very low, less than 0.25 fps, in the reservoir between the weir and monitoring location 564.0. These slow, uniform flow patterns allow for stratification to be established within the water column at water quality monitoring location 564.0. When compared to Figure 6-20, expanding the weir geometry results in flow patterns and magnitudes that are similar to the flow patterns and magnitudes of the existing submerged weir geometry, which limits downstream vertical mixing.

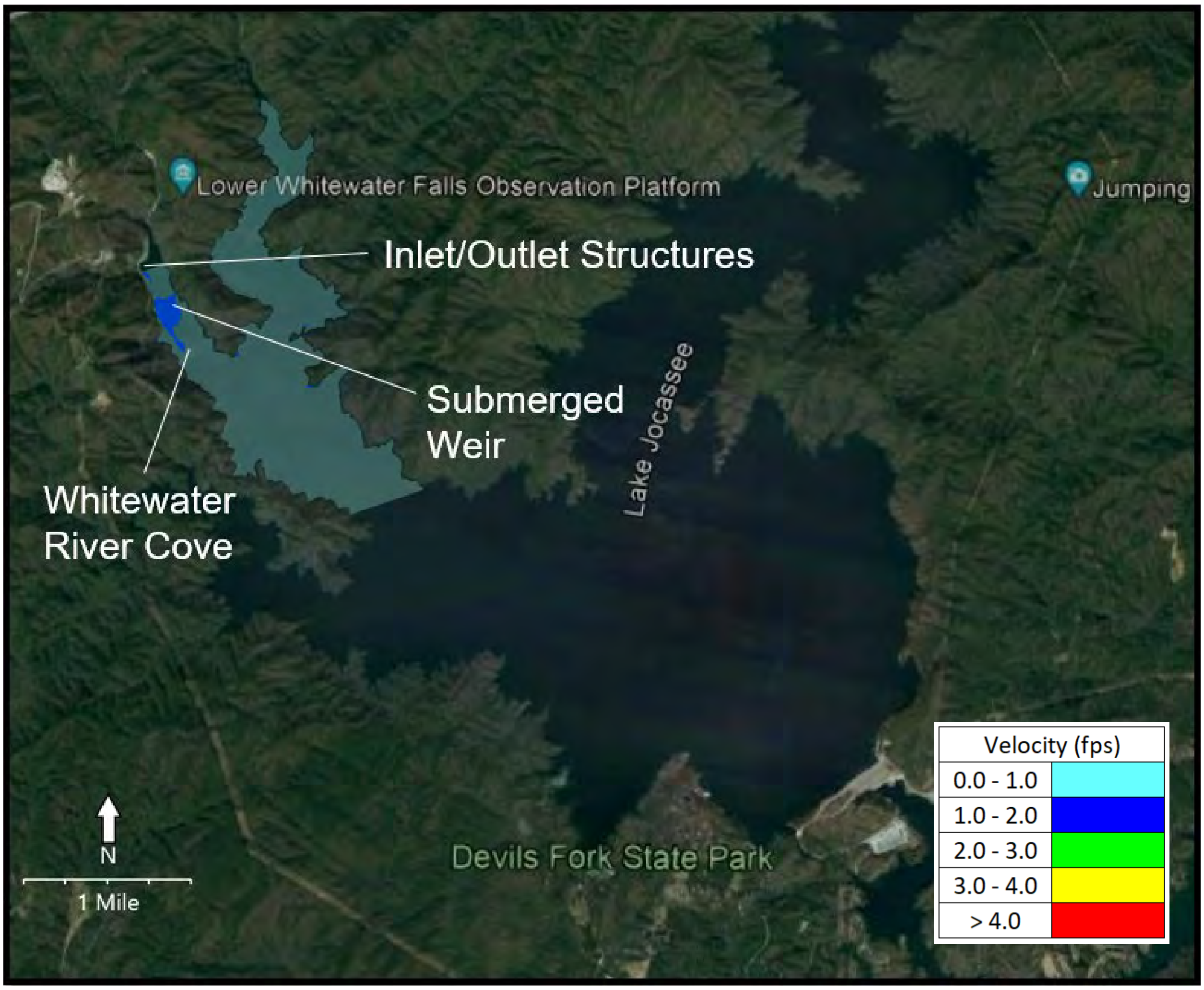


Figure 6-27. Proposed Generation (Expanded Weir) at Full Pond – Velocity Contours

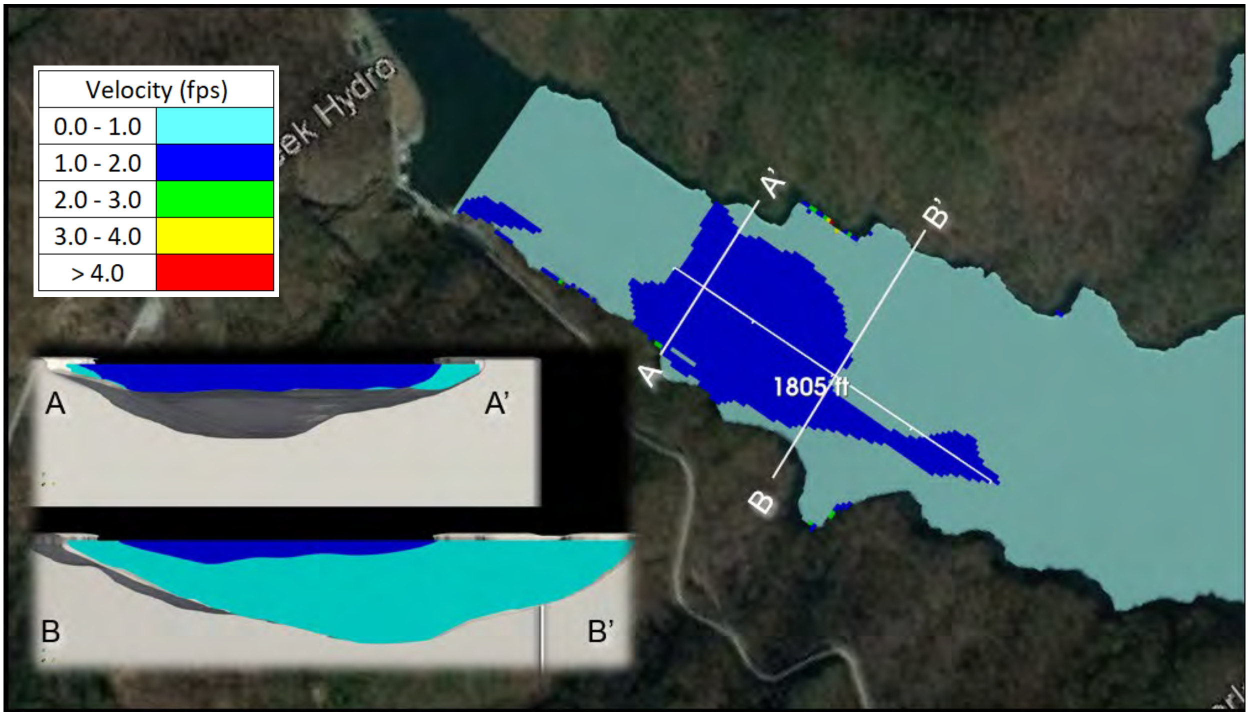


Figure 6-28. Proposed Generation (Expanded Weir) at Full Pond – Velocity Contours in Submerged Weir Vicinity (Flow is Left to Right)

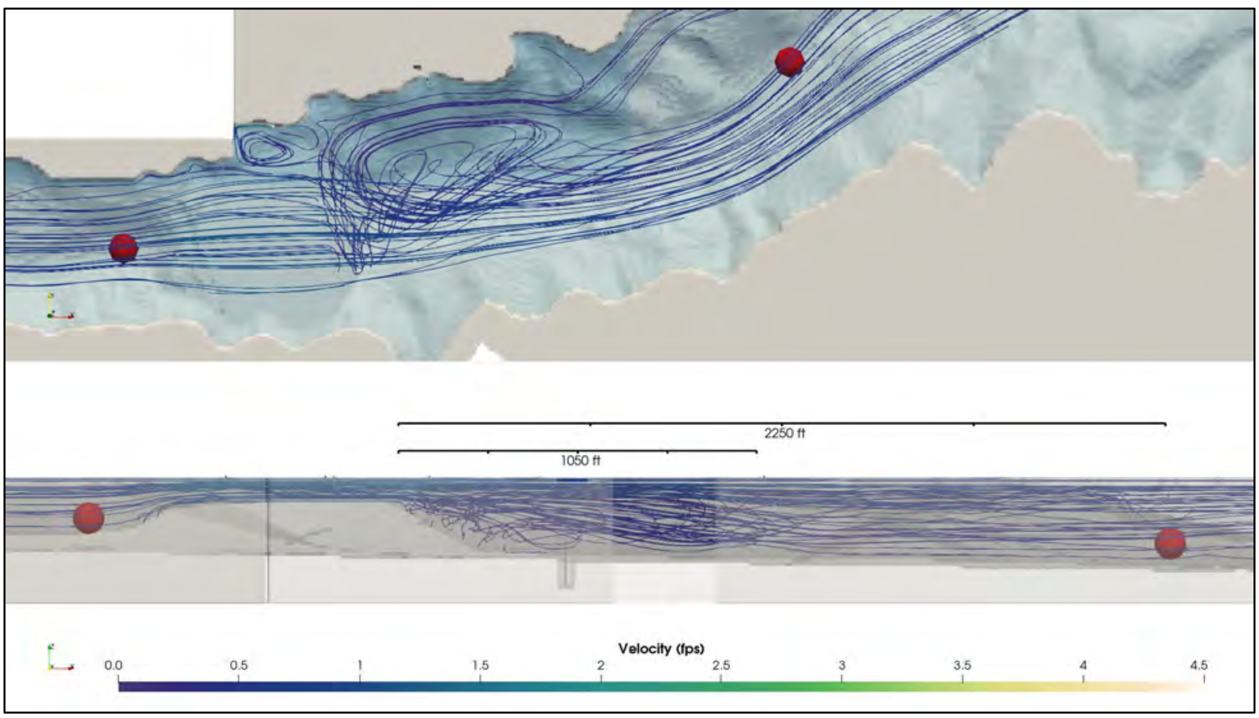


Figure 6-29. Proposed Generation (Expanded Weir) at Full Pond – Whitewater River Cove Streamlines (Flow is Left to Right)

Maximum Drawdown

The scenario with the proposed generating flow and expanded weir at maximum drawdown presents the greatest effect to water velocities and flow patterns in Whitewater River cove. With the lowered pond level, expanded weir geometry (in the downstream direction) and higher flowrate, the effect of the expanded weir is the most pronounced. Contours of surface velocity show an area of elevated velocity in the immediate vicinity of the weir. This area of slightly elevated velocity extends approximately 2,500 ft from the weir crest and peaks at 4.5 fps. For context, 4.5 fps is approximately 3.0 miles per hour or roughly the average adult walking speed.

The area of elevated velocity is shown on Figure 6-30 and Figure 6-31. Vertical slices A-A' and B-B' on Figure 6-31 indicate the area of higher velocity is present through the majority of the water column across the top of the weir, but as flow expands into the downstream section of the Whitewater River cove, flow is concentrated on the right descending bank and near the surface. Velocities in the Whitewater River cove are between 2.0-3.0 fps approximately 1,500 ft downstream of the submerged weir but are concentrated at the surface indicating little downstream mixing potential.

Figure 6-32 shows velocity streamlines that have a similar flow pattern as Figure 6-29 (full pond streamlines), however the effect of the weir is more pronounced. At lower pond levels, water velocities are accelerated across the top of the weir and flows are forced to the surface. This results in an area of slightly higher surface velocities, and a significantly reduced potential mixing length downstream of the weir.

As with the full pond scenario, because of the low velocities within the water column downstream of the weir at water quality monitoring location 564.0, it can be reasonably expected that flow conditions would not inhibit thermal stratification.

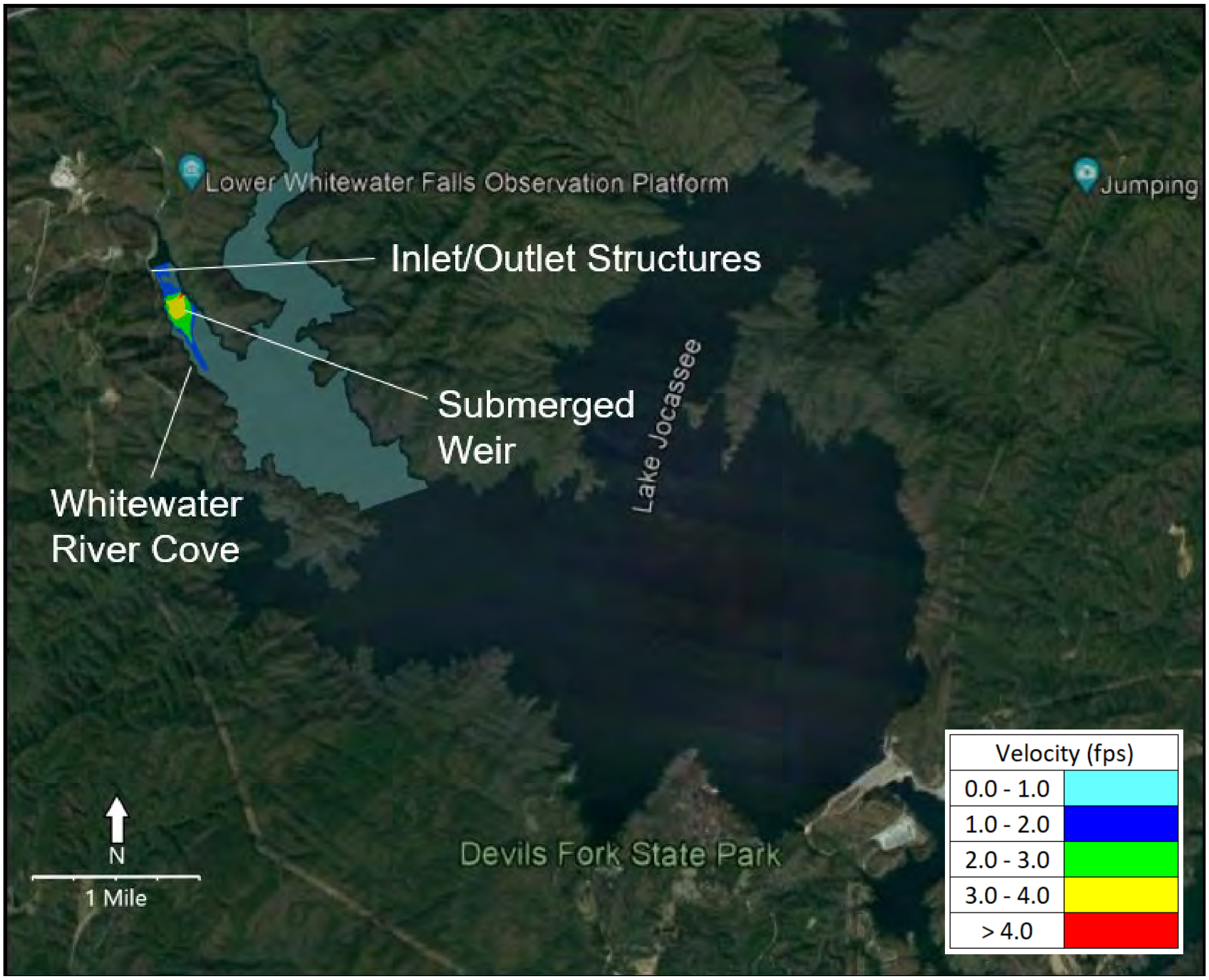


Figure 6-30. Proposed Generation (Expanded Weir) at Maximum Drawdown – Velocity Contours

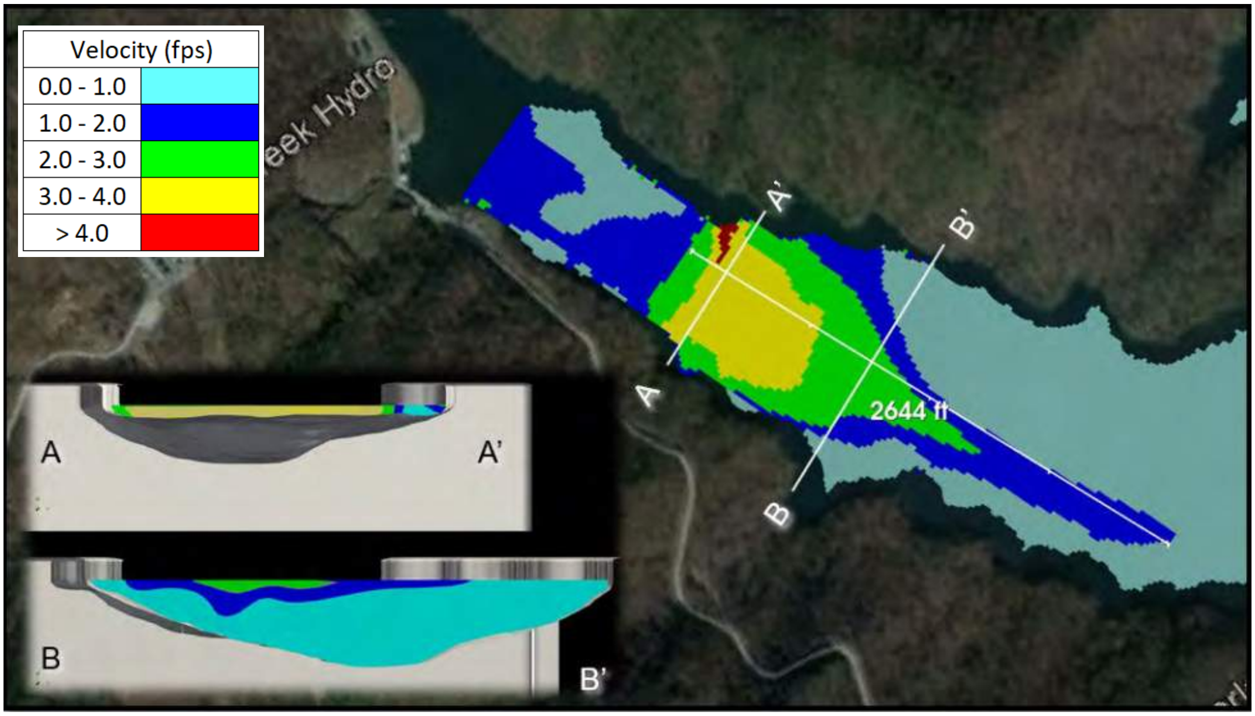


Figure 6-31. Proposed Generation (Expanded Weir) at Maximum Drawdown – Velocity Contours in Submerged Weir Vicinity (Flow is Left to Right)

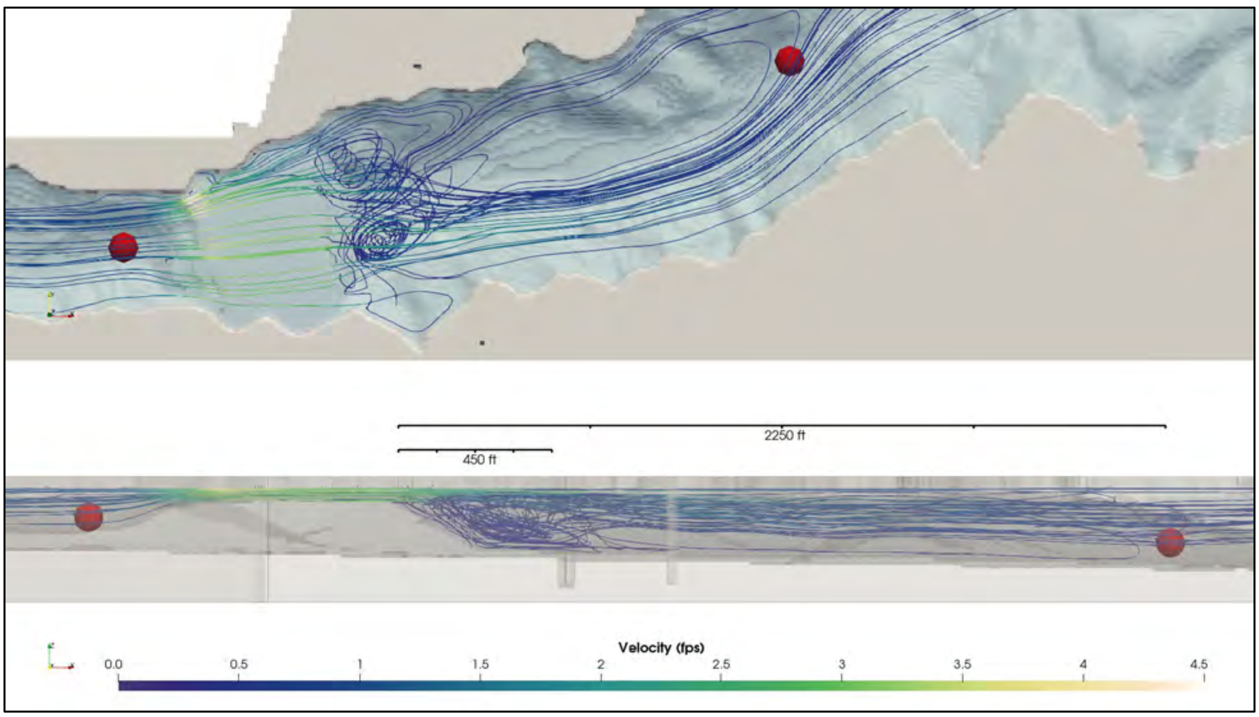


Figure 6-32. Proposed Generation (Expanded Weir) at Maximum Drawdown – Whitewater River Cove Streamlines (Flow is Left to Right)

6.4.2 Pumping

Full Pond

The expanded weir has a slightly stronger effect of accelerating flow across the top of the weir and upstream into the upper Whitewater River cove. Full pond pumping hydraulic conditions in the Whitewater River cove under the proposed flow with the expanded weir geometry are still characterized by relatively low velocities. Flow velocities peak across the top of the submerged weir at approximately 1.1 fps. Figure 6-33 shows contours of velocity in an aerial view. Figure 6-34 shows the surface velocity contours in the vicinity of the submerged weir, as well as two vertical slices showing vertical velocity profiles in the Whitewater River Arm. Slice B-B' indicates little to no elevated velocities downstream of the submerged weir. The area of slightly elevated velocity (1-2 fps) extends 200 ft upstream of the submerged weir.

Figure 6-35 presents hydraulic flow paths with velocity magnitudes identified by color in the Whitewater River cove. There is little to no vertical mixing downstream of the submerged weir under pumping operations. As flow is pumped to Bad Creek Reservoir, it is gradually pulled from Lake Jocassee across the top of the submerged weir resulting in a very uniform, laminar flow regime downstream of the weir. Flow patterns at monitoring location 564.0 extending upstream to the weir are uniform and have velocities less than 0.2 fps indicating stratification would be present throughout the reservoir downstream of the weir. When comparing to Figure 6-26, expanding the weir geometry results in flow patterns and magnitudes that are similar to the flow patterns and magnitudes of the existing submerged weir geometry, which limits downstream vertical mixing.

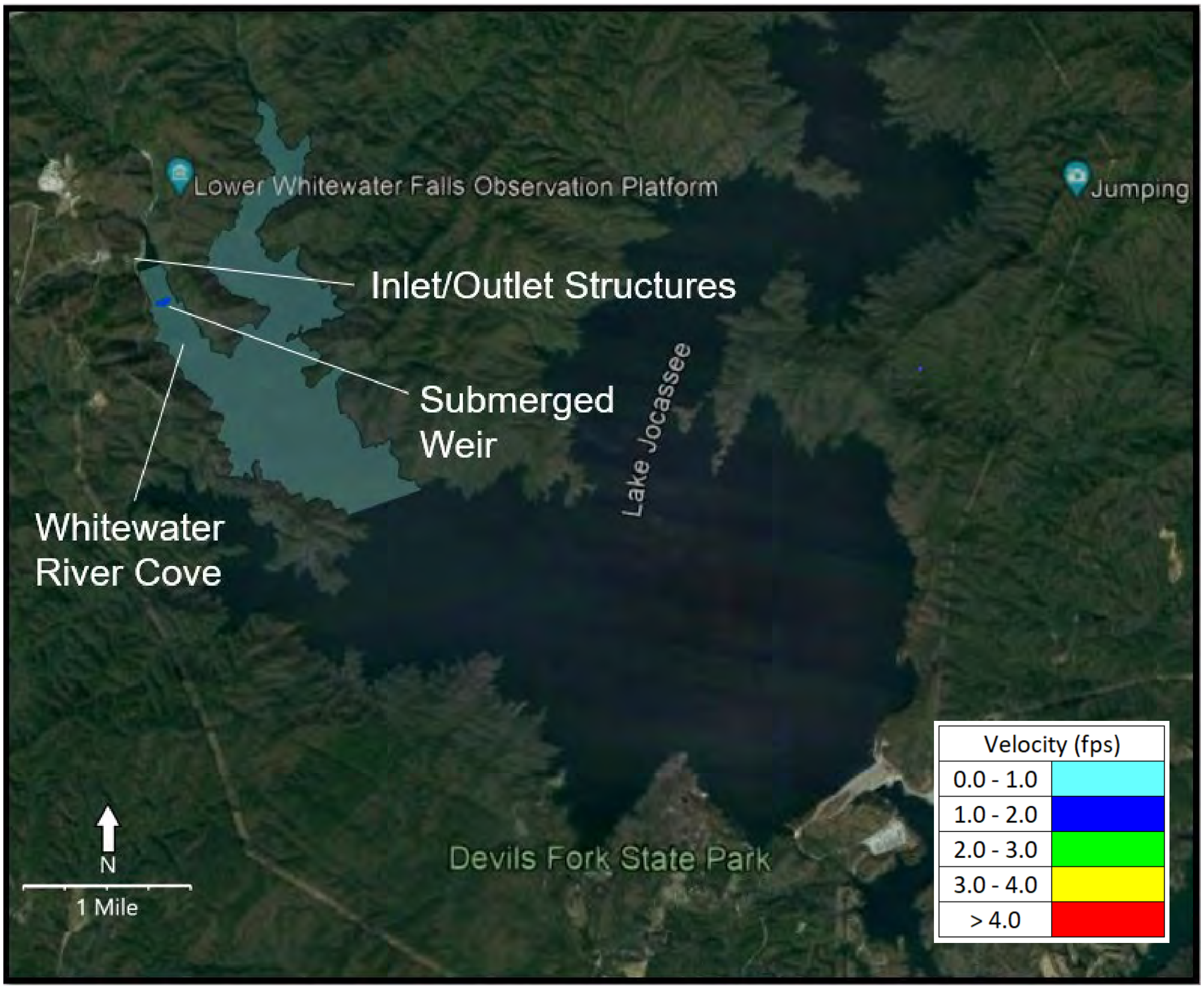


Figure 6-33. Proposed Pumping (Expanded Weir) at Full Pond – Velocity Contours

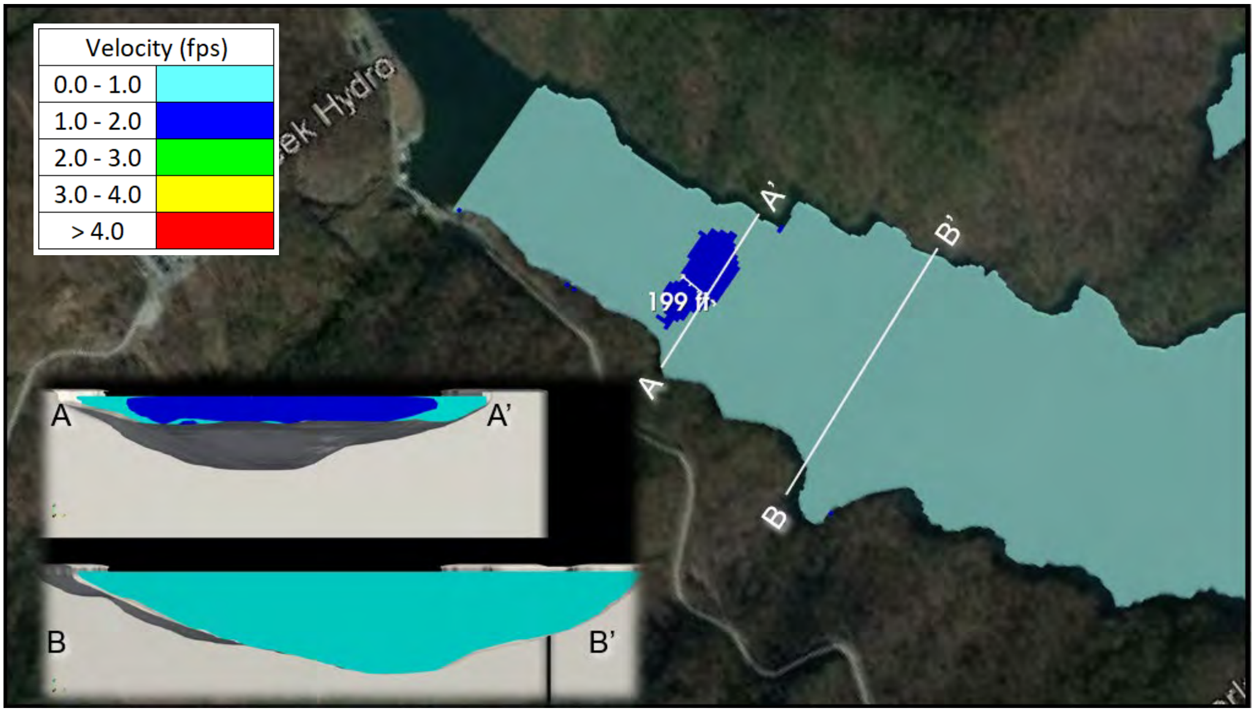


Figure 6-34. Proposed Pumping (Expanded Weir) at Full Pond – Velocity Contours in Submerged Weir Vicinity (Flow is Right to Left)

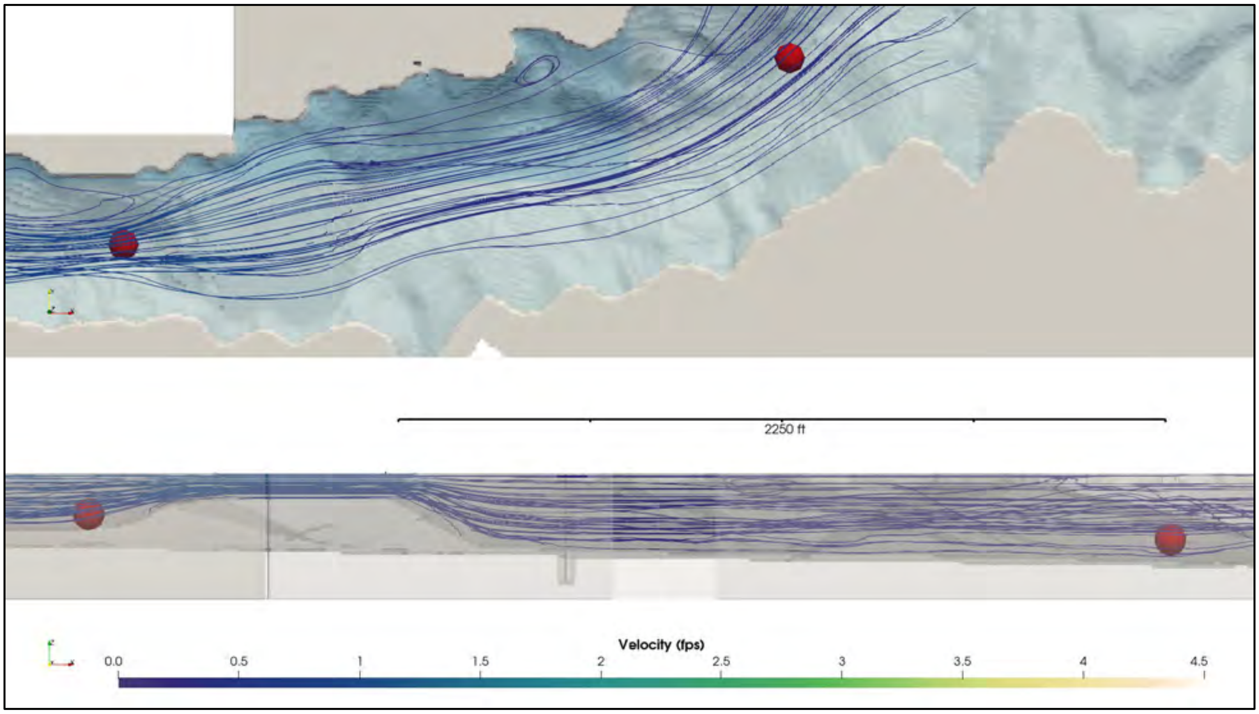


Figure 6-35. Proposed Pumping (Expanded Weir) at Full Pond – Whitewater River Cove Streamlines (Flow is Right to Left)

Maximum Drawdown

Similar to generating at maximum drawdown, pumping at maximum drawdown increases the effect of the submerged weir. An area of higher velocity extends approximately 1,800 ft upstream of the submerged weir peaking at 3.3 fps. Surface velocities for pumping at maximum drawdown are shown in Figure 6-36 and Figure 6-37. Vertical slices in Figure 6-37 indicate minimal vertical mixing effects are observed downstream of the submerged weir. Velocity streamlines in the Whitewater River cove shown on Figure 6-38 are uniform and slow moving, indicating stratification would be present downstream of the weir. As flow is pulled across the top of the weir it is accelerated into the upstream section of the Whitewater River cove.

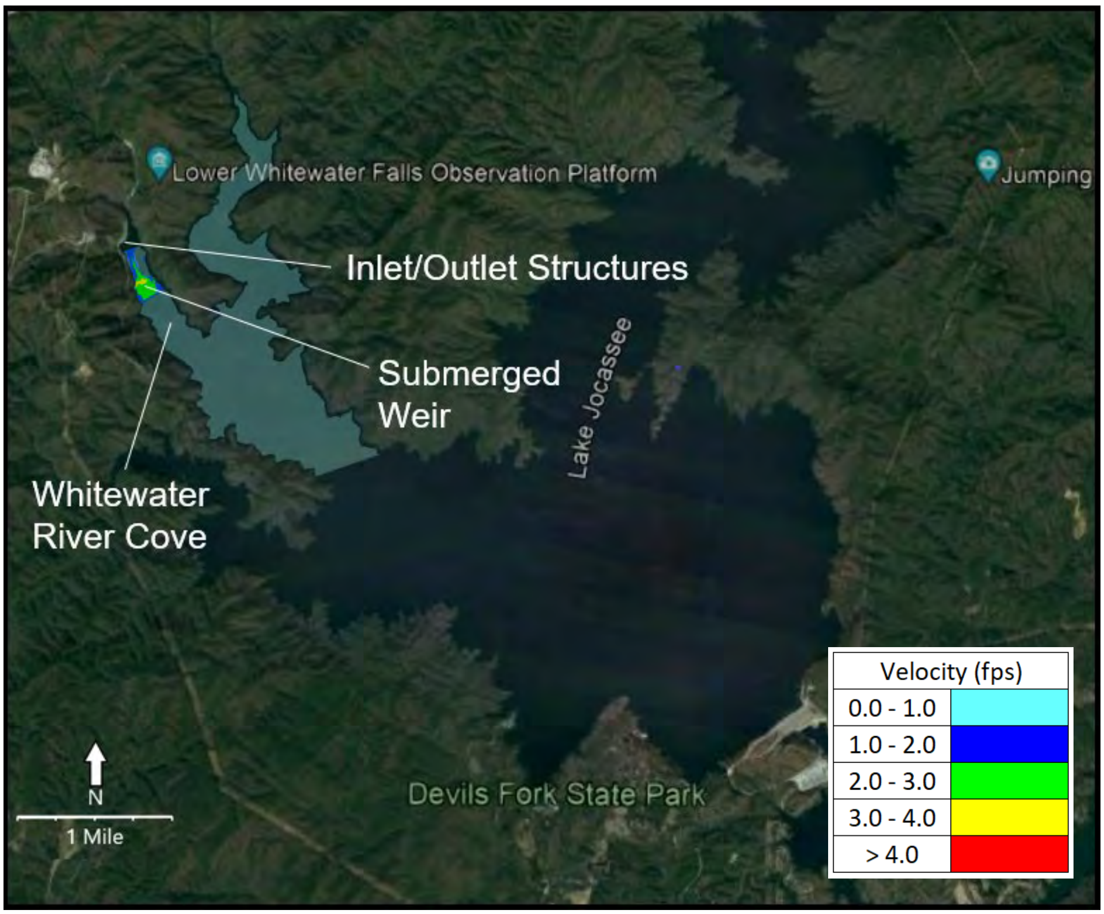


Figure 6-36. Proposed Pumping (Expanded Weir) at Maximum Drawdown – Velocity Contours

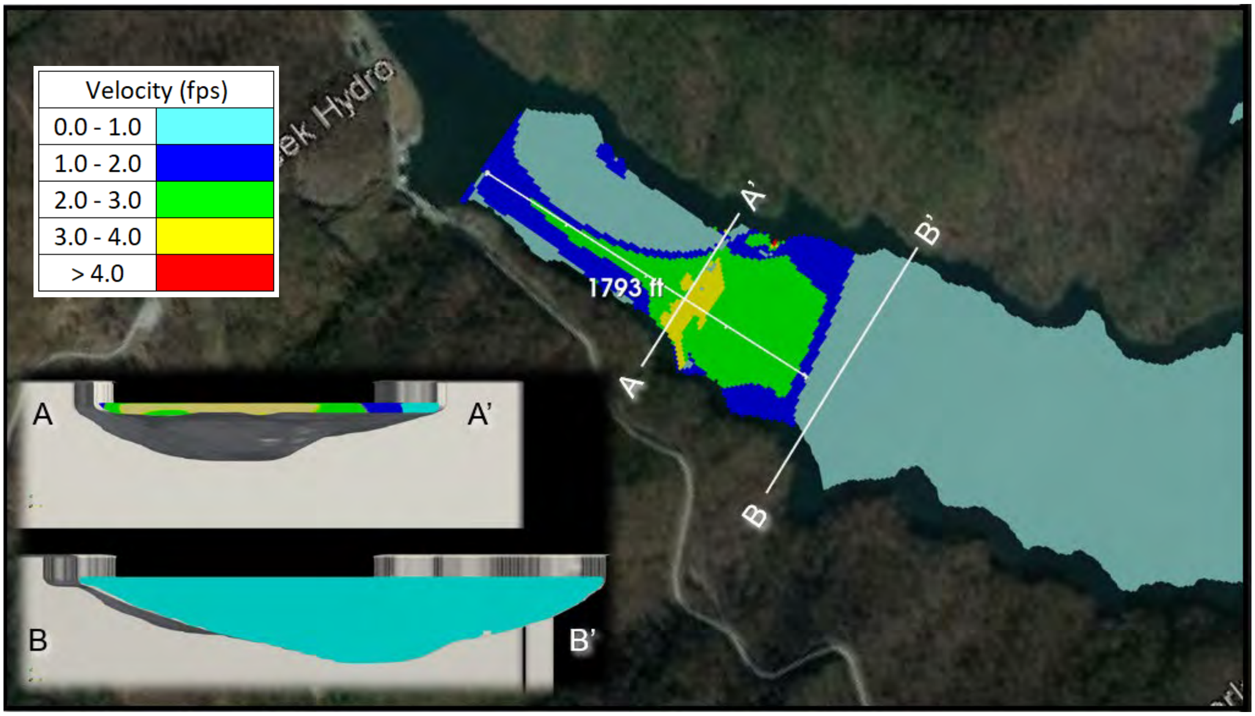


Figure 6-37. Proposed Pumping (Expanded Weir) at Maximum Drawdown – Velocity Contours in Submerged Weir Vicinity (Flow is Right to Left)

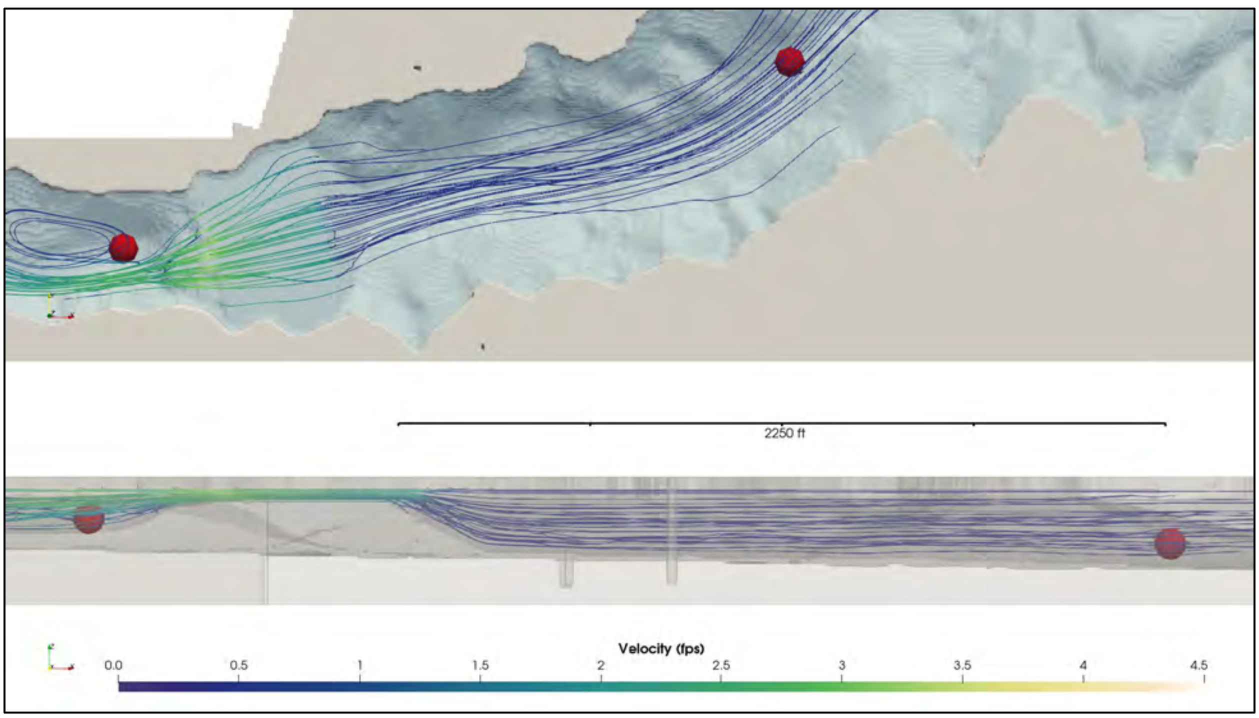


Figure 6-38. Proposed Pumping (Expanded Weir) at Maximum Drawdown – Whitewater River Cove Streamlines (Flow is Right to Left)

6.5 Effect of Submerged Weir Geometry

As previously stated, the expanded weir geometry results in a small increase in flow acceleration as water flows over the crest of the weir (when compared to the existing weir geometry). Comparison of Figure 6-19 and Figure 6-31 shows similar magnitudes of velocity increases, but the area of elevated surface velocity are slightly larger with the expanded weir geometry. Comparison of streamlines downstream of the weir in Figure 6-20 and Figure 6-32 indicate the flow patterns are very similar, and it can be reasonably expected to result in similar stratification patters at water quality monitoring location 564.0.

Comparison of the pumping scenarios leads to the same conclusion. Flow is accelerated over the expanded weir and the increased velocity has a slightly larger footprint compared to the existing weir (Figure 6-25 vs Figure 6-31). However, expanding the weir geometry results in flow patterns and magnitudes that are similar to the flow patterns and magnitudes of the existing submerged weir geometry, which limits downstream vertical mixing. (Figure 6-26 vs Figure 6-38).

7 Conclusions

Each CFD model scenario was run at full pond and maximum drawdown. These two elevations were selected to bookend the potential operating conditions of the existing and proposed powerhouse configurations. Over the last 45 years, Lake Jocassee elevation has been above the minimum pond level 100 percent of the time.

The CFD model domain was appropriately sized to evaluate the hydraulic effects of Bad Creek and Bad Creek II. Results indicate hydraulic effects in Lake Jocassee due to operations are limited to the model domain (i.e., the area upstream of the Devil's Fork arm and Whitewater River arm confluence) and water conditions to maintain natural stratification downstream of the weir exist under all modeled scenarios.

In generation mode, the energy of the water discharged from Bad Creek is dissipated as it is forced across the top of the existing submerged weir. Similar vertical mixing patterns result from the existing and proposed expanded weir geometries under existing and proposed generation flows. Model results indicate Bad Creek II powerhouse operations will not alter existing stratification patterns observed at Station 564.0 (downstream of weir) or further downstream into Lake Jocassee.

In pumping mode, hydraulic effects due to Bad Creek II operations are limited to the Whitewater River cove upstream of the submerged weir and in the upper water column across the top of the weir. No modeled configuration of pumping operations creates mixing downstream of the submerged weir. Water quality profile data (current and historic) also support CFD model results, indicating stratification is preserved downstream of the submerged weir. As discussed in Section 4.2.7.1, the CFD model will be verified with new computational runs simulating field conditions at the time of data collection. Preliminary verification model runs indicate good agreement between CFD results and velocity data collected in the Whitewater River arm.

8 Future Work

Model verification will be completed in fall 2023 and results will be provided in an addendum to the final study report.

9 Variances from FERC-approved Study Plan

There were no variances from the FERC-approved RSP.

10 Germane Correspondence and Consultation

Germane correspondence and consultation documentation will be included with the Water Resources Study Report to be filed with the ISR in January, 2024.

11 References

Chow, V.T. 1959. Open Channel Hydraulics. McGraw-Hill, Incorporated, New York, New York.

Environmental Systems Research Institute (ESRI). 2021. ArcGIS Pro, Release 2.8.8 Redlands, CA: Environmental Systems Research Institute.

Flow Science, Inc. (Flow Science). 2023. User Manual: FLOW-3D Documentation, release 23.1.0.12. Albuquerque: Flow Science, Inc.

HDR Engineering, Inc. (HDR). 2022. Bad Creek II Power Complex Feasibility Study. Volume 5: Lower Reservoir CFD Flow Modeling Report. September 1, 2022. Prepared for Duke Energy Carolinas, LLC.

Hirt, C. W. 2000. Implicit Vs. Explicit Numerical Methods. Santa Fe: Flow Science.

Hirt, C. W. and Nichols, D. B. 1981. Volume of Fluid (VOF) Method for the Dynamics of Free Boundaries. Journal of Computational Physics, 201-225.

Innovyze Infoworks Integrated Catchment Model (Innovyze). 2023. Version 2023.2; Software 2022.

Larsen, J., and White, D. K. 1986. Letter Report Bad Creek Discharge Structure Model Study Phase II. Worcester Polytechnic Institute Alden Research Laboratory.

Yakhot, V and Orszag, S.A. 1986. Renormalization Group Analysis of Turbulence. I. Basic Theory. Journal of Scientific Computing, 1, 3-51.

This page intentionally left blank.

Appendix A

Appendix A – Upgraded Unit Figures

List of Figures

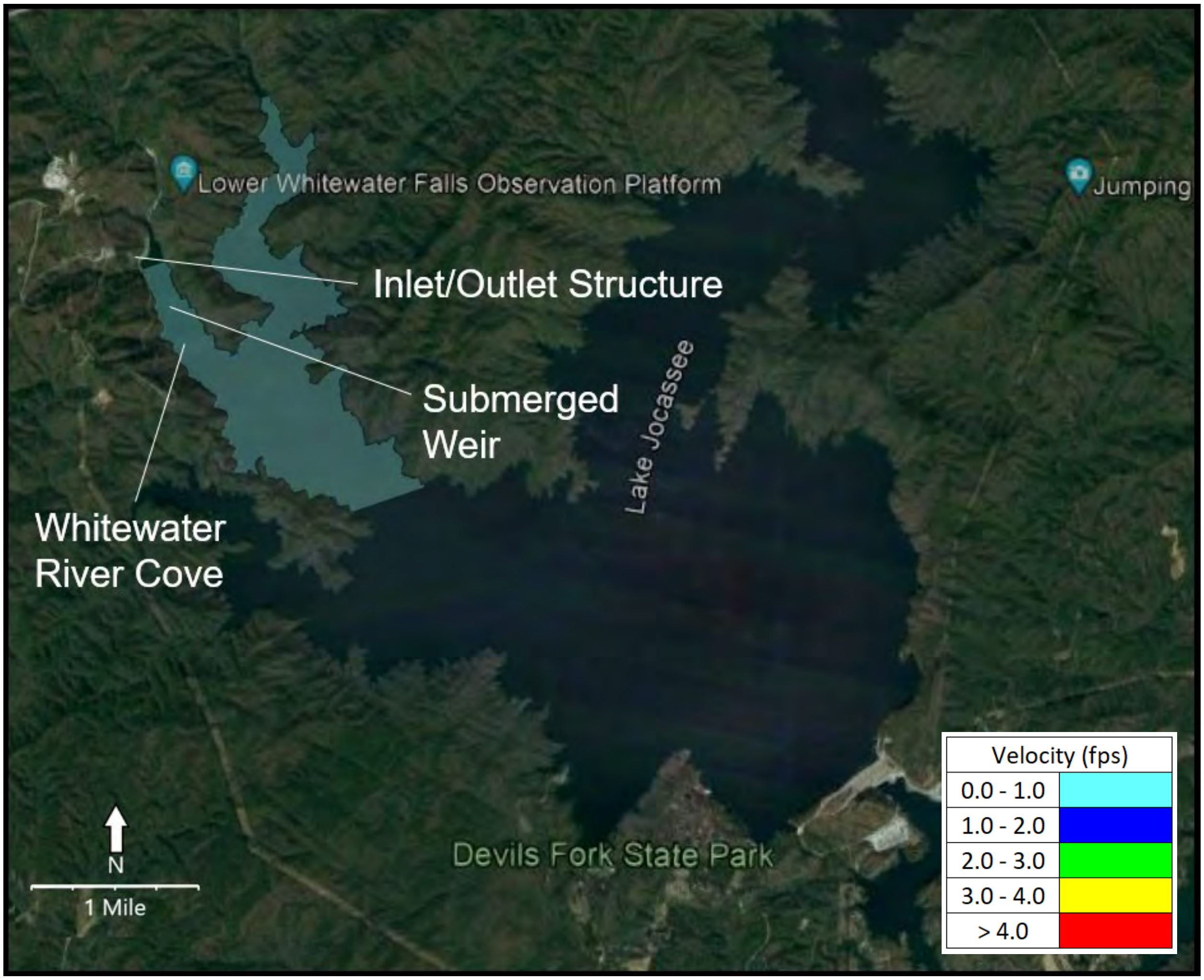


Figure A-1. Upgraded Generation at Full Pond – Velocity Contours

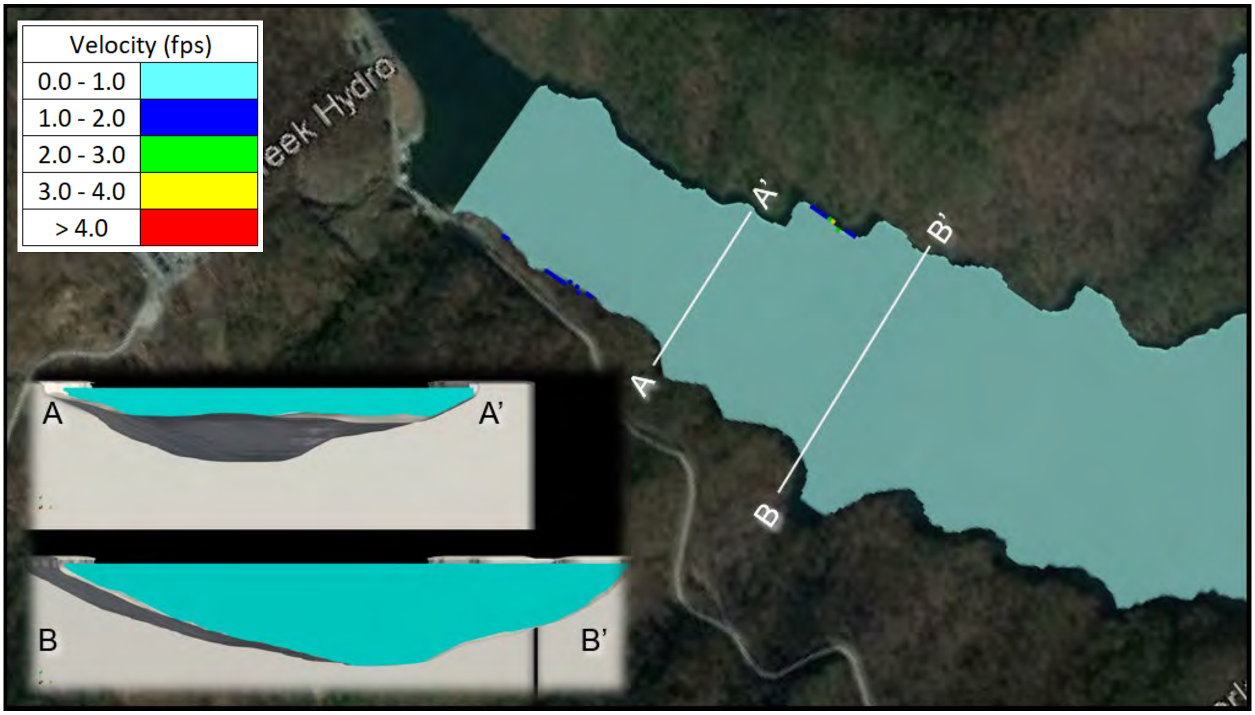


Figure A-2. Upgraded Generation at Full Pond –Velocity Contours in Submerged Weir Vicinity (Flow is Left to Right)

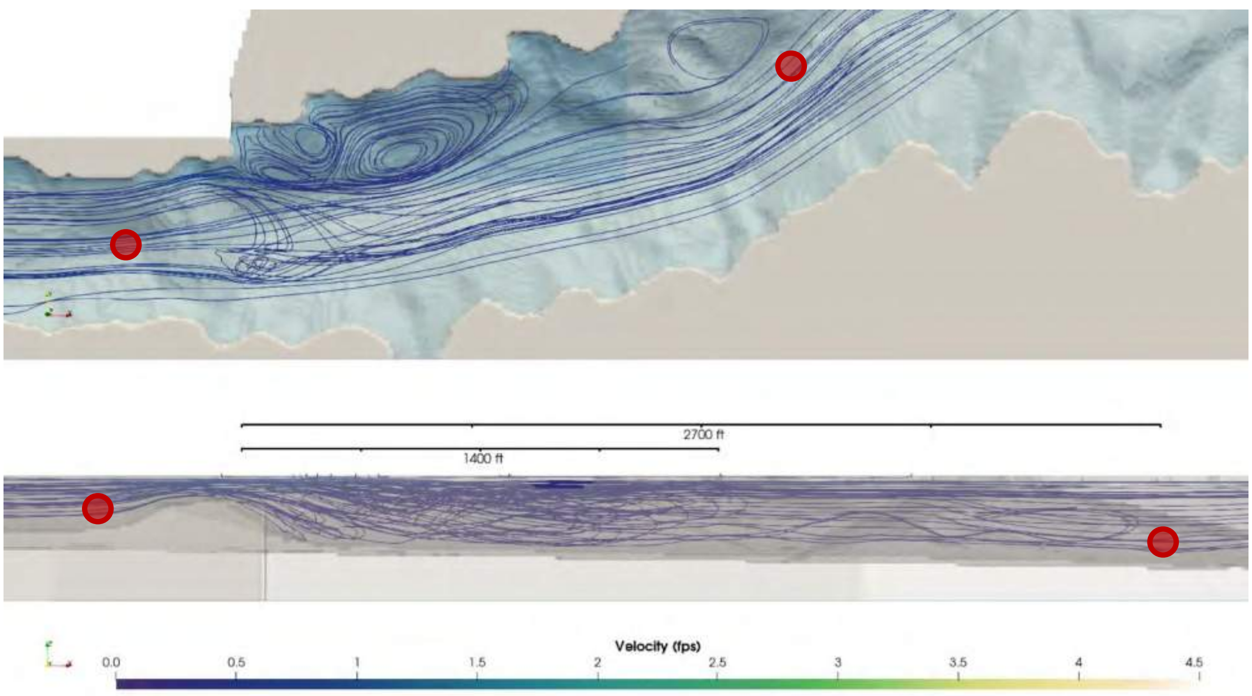


Figure A-3. Upgraded Generation at Full Pond – Whitewater River Cove Streamlines (Flow is Left to Right)

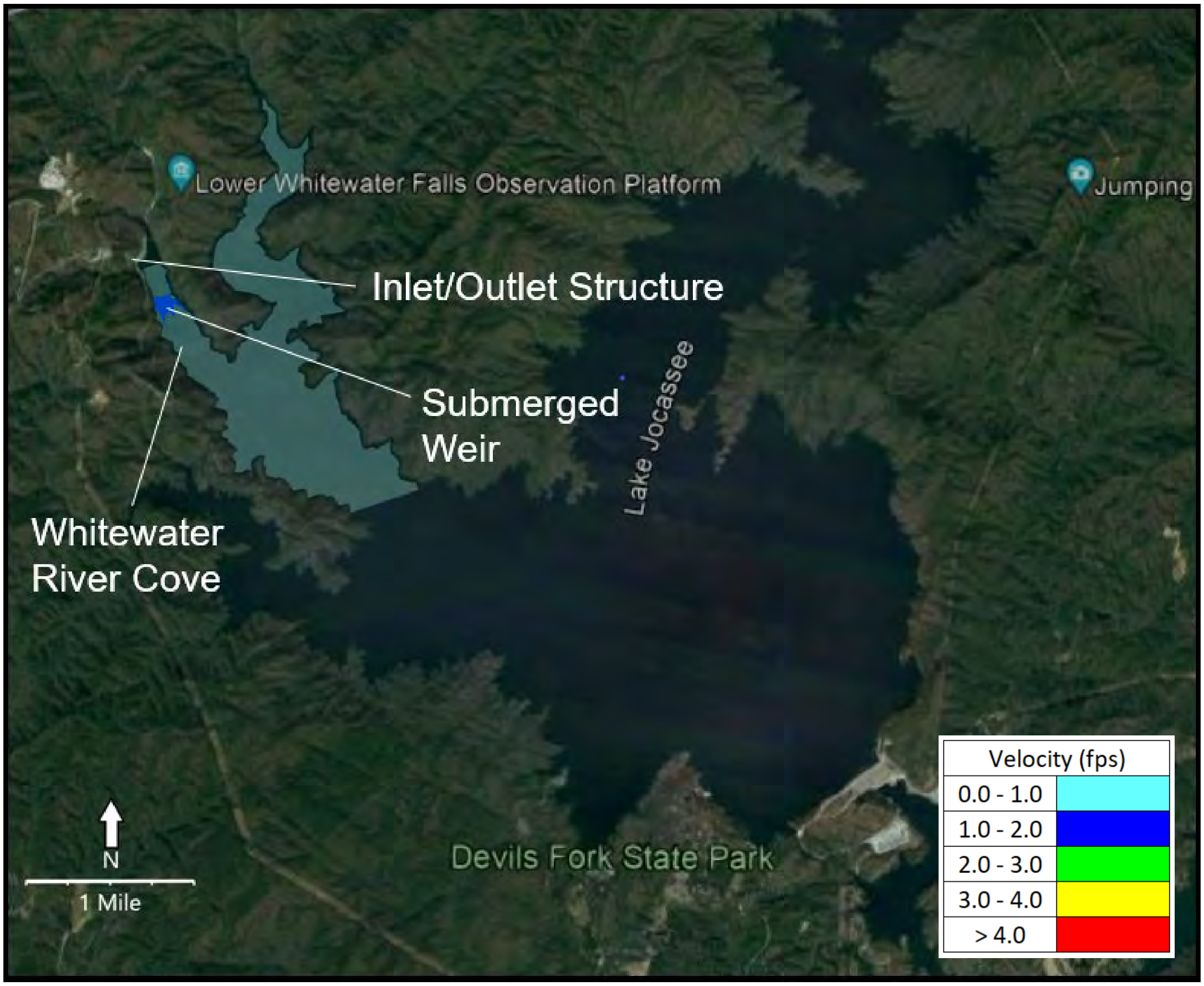


Figure A-4. Upgraded Generation at Maximum Drawdown – Velocity Contours

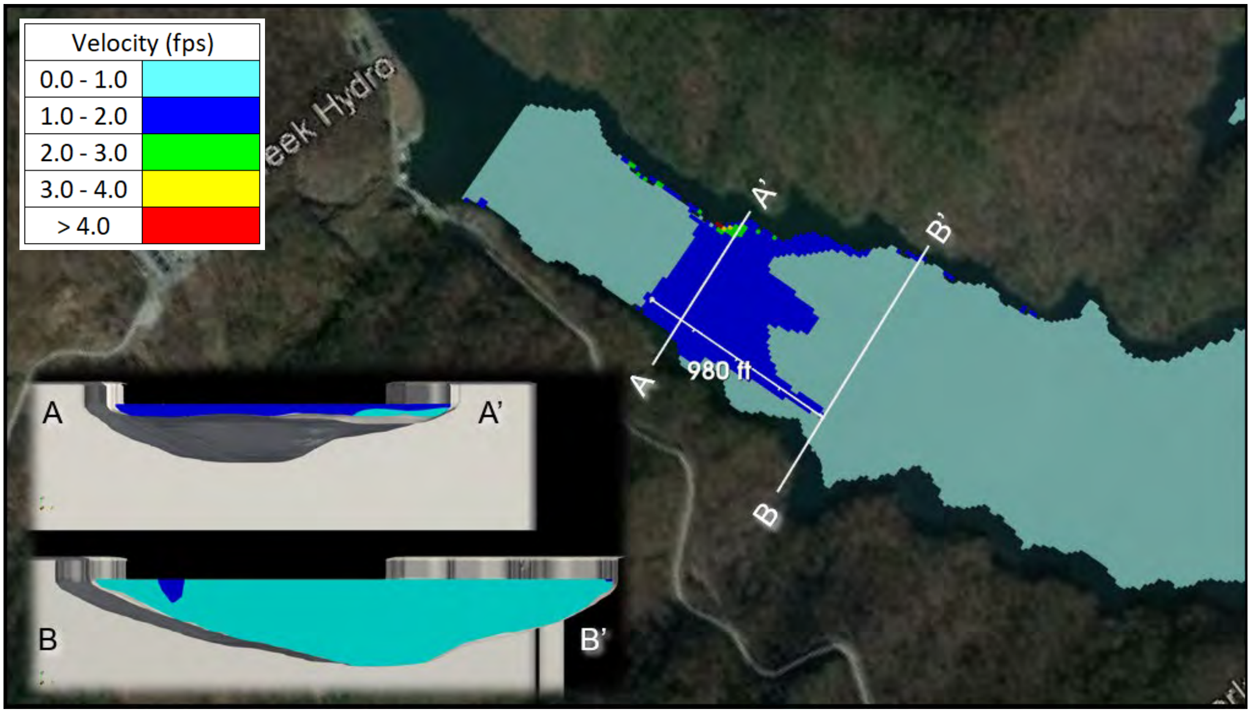


Figure A-5. Upgraded Generation at Maximum Drawdown –Velocity Contours in Submerged Weir Vicinity (Flow is Left to Right)

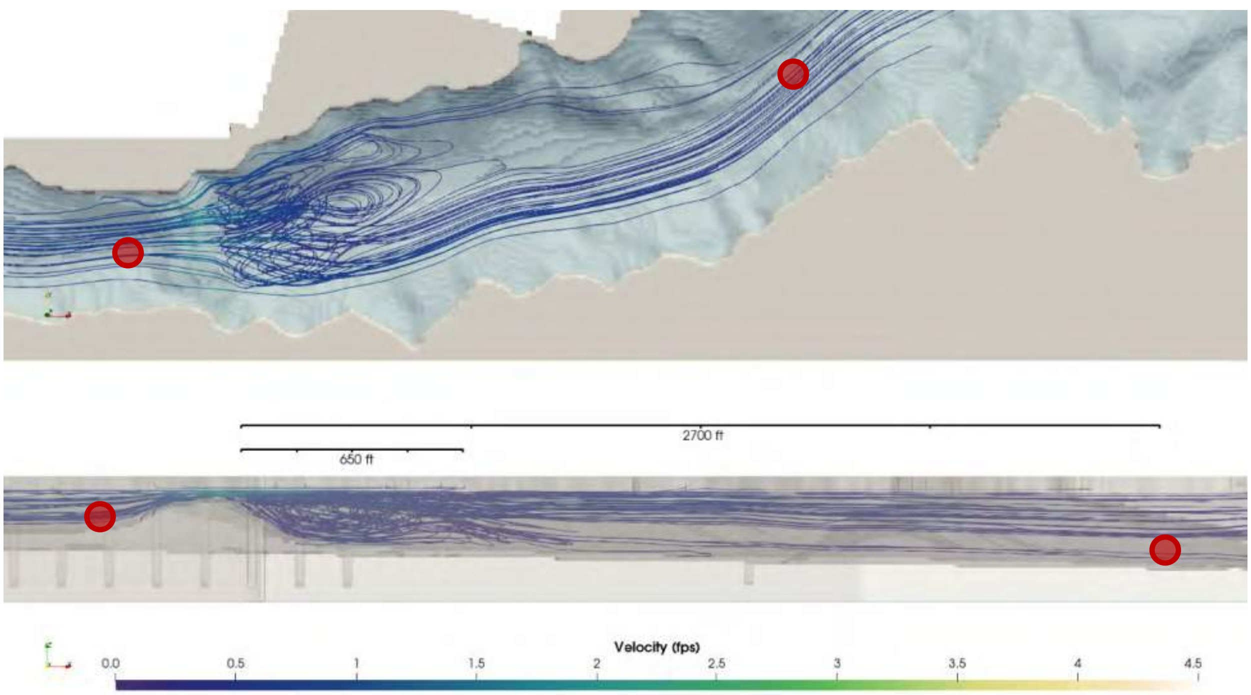


Figure A-6. Upgraded Generation at Maximum Drawdown – Whitewater River Cove Streamlines (Flow is Left to Right)

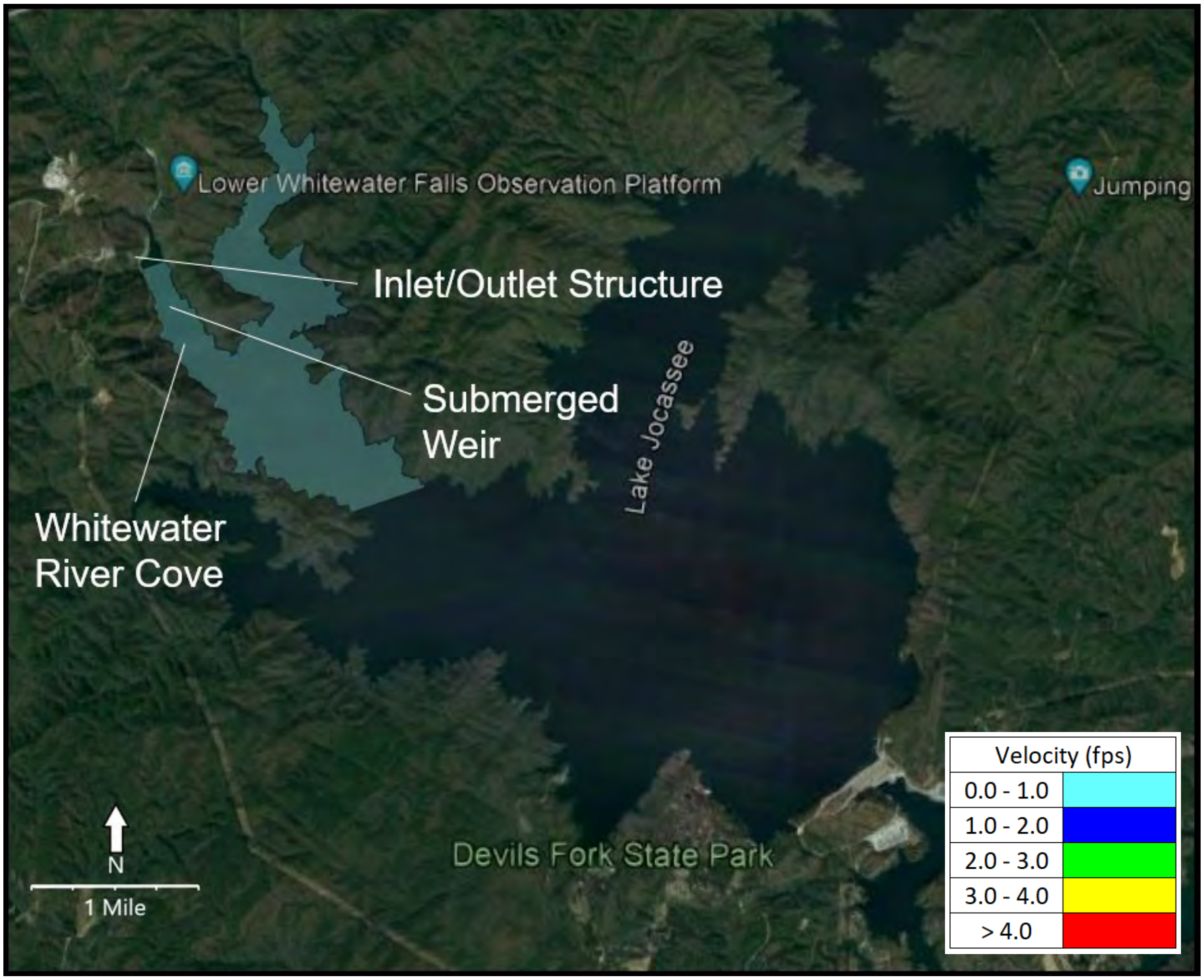


Figure A-7. Upgraded Pumping at Full Pond – Velocity Contours

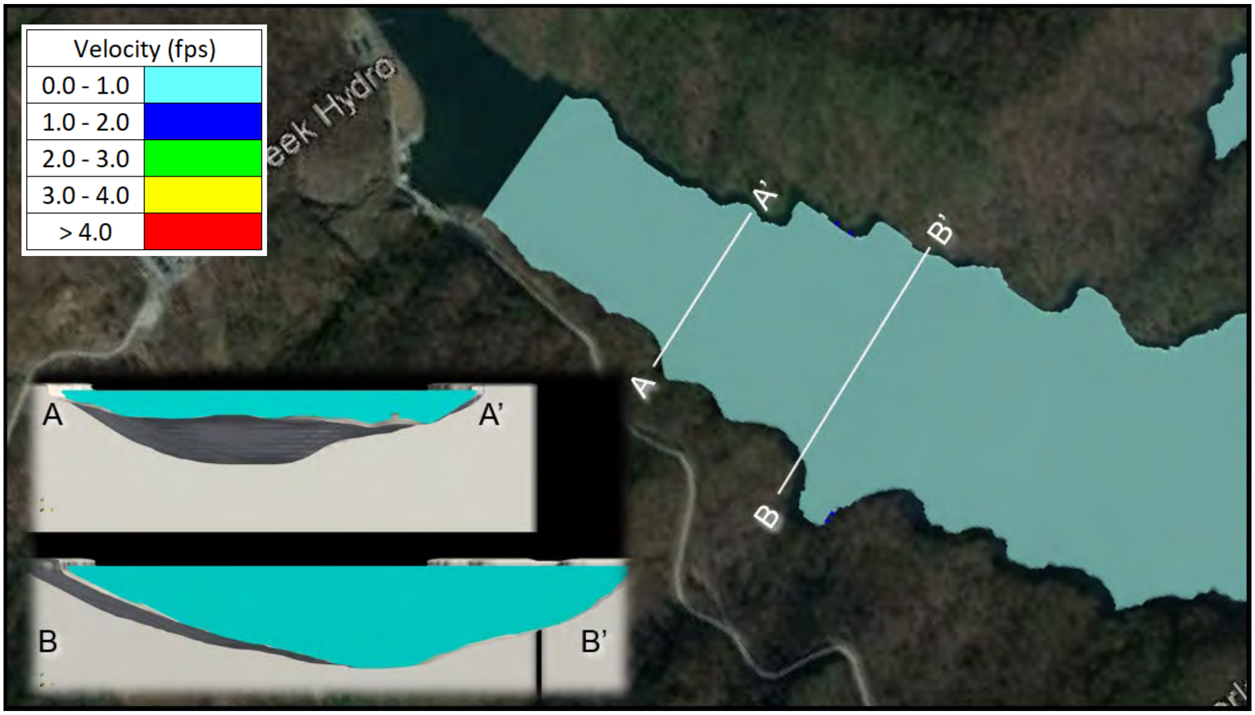


Figure A-8. Upgraded Pumping at Full Pond –Velocity Contours in Submerged Weir Vicinity (Flow is Right to Left)

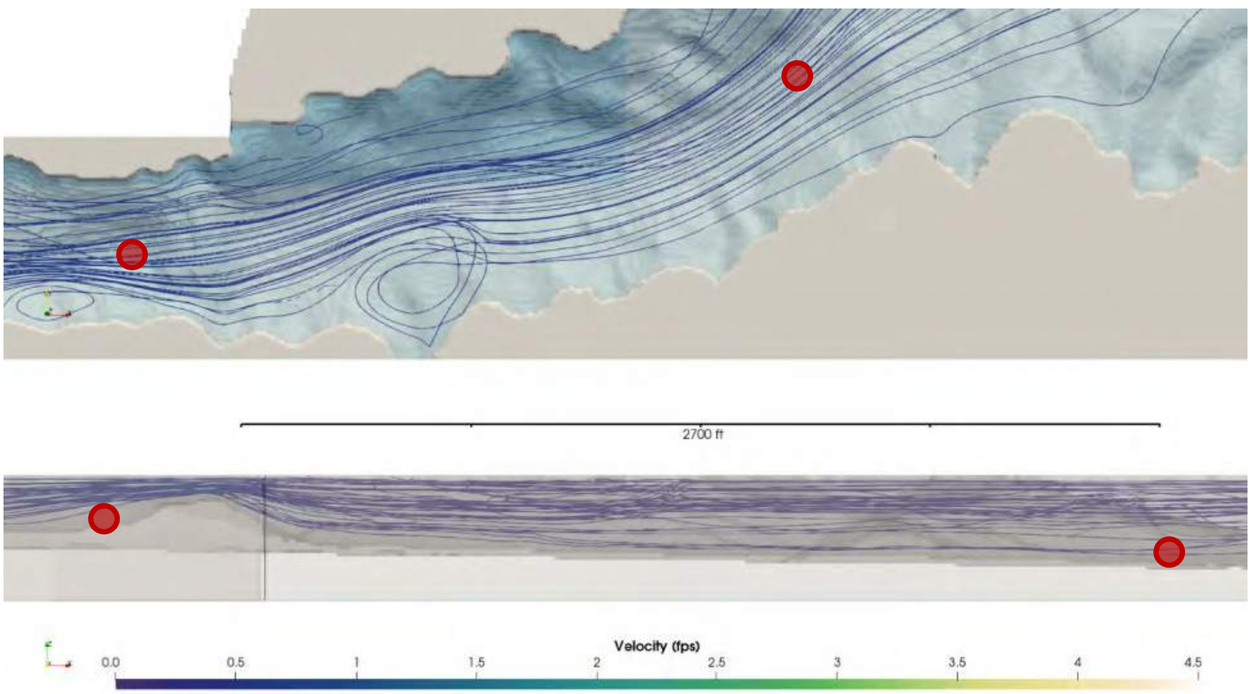


Figure A-9. Upgraded Pumping at Full Pond – Whitewater River Cove Streamlines (Flow is Right to Left)

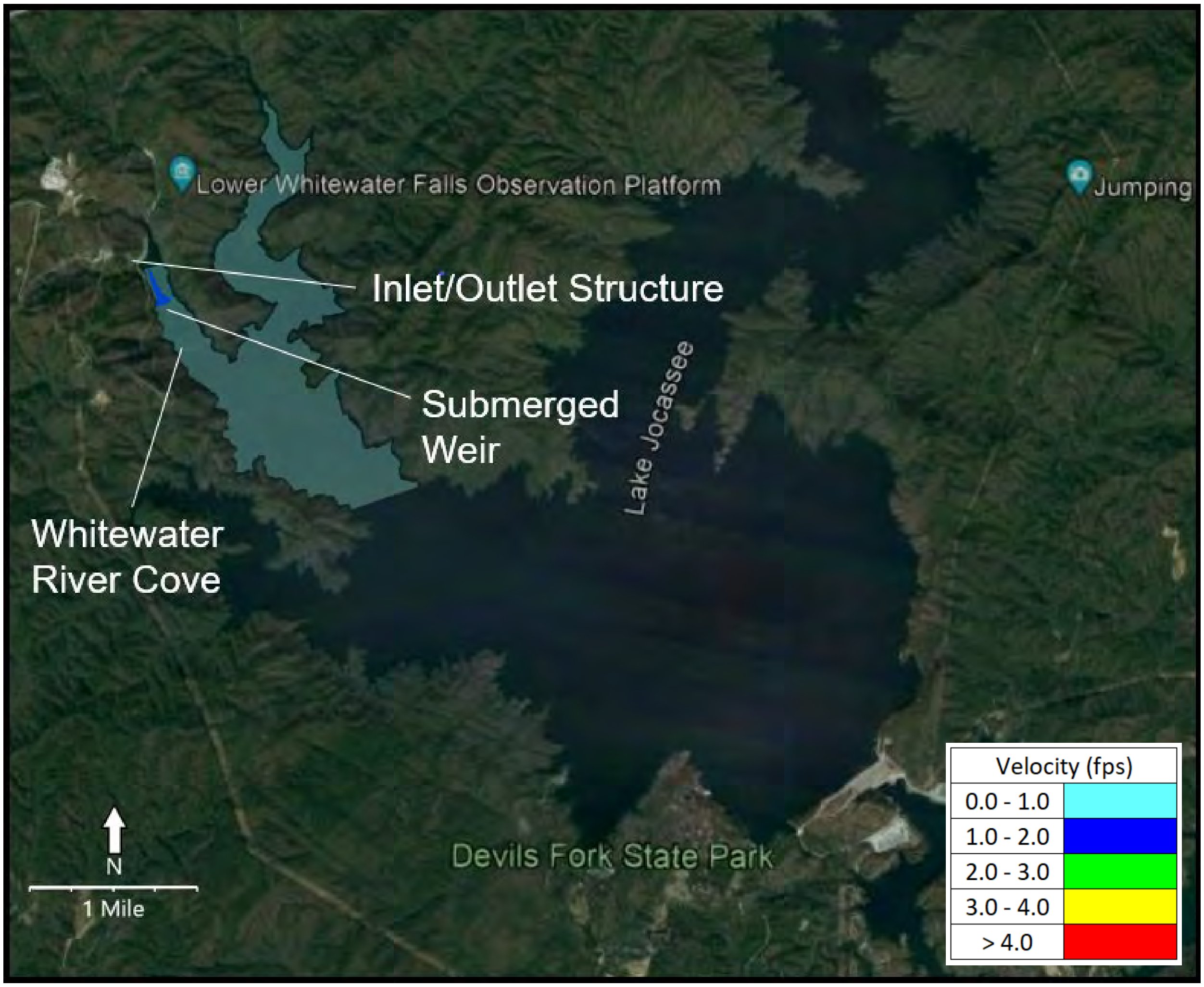


Figure A-10. Upgraded Pumping at Maximum Drawdown – Velocity Contours

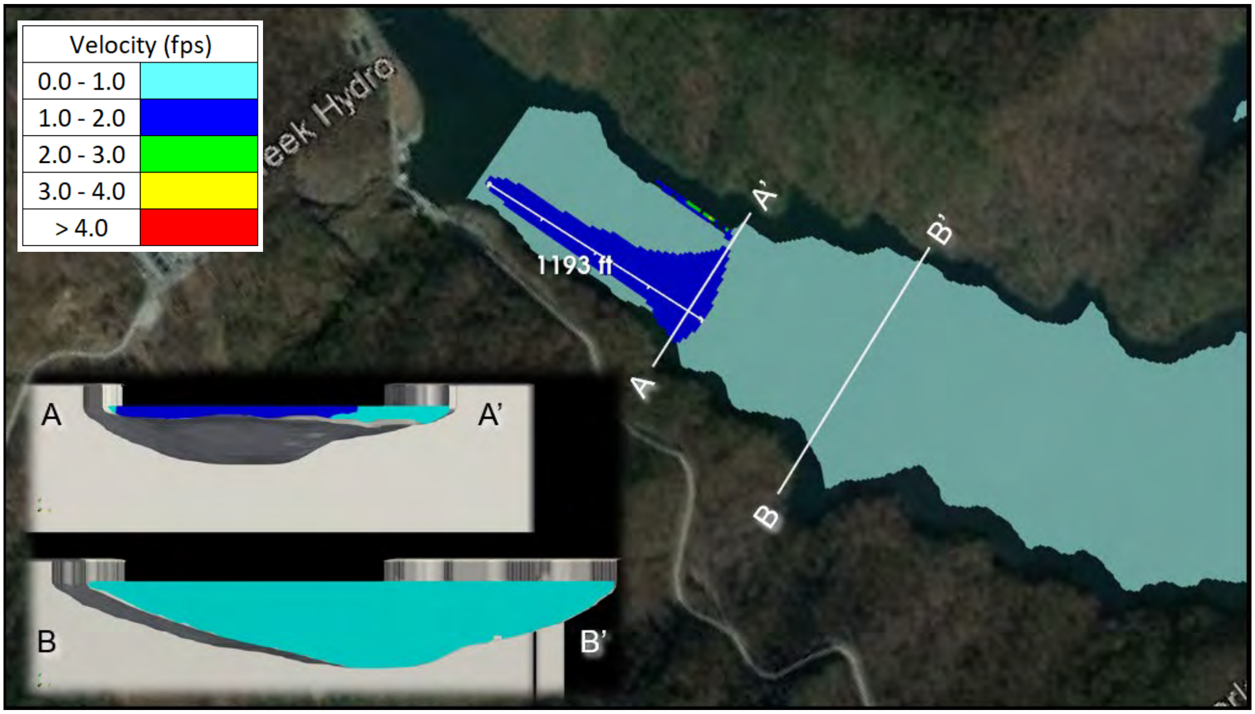


Figure A-11. Upgraded Pumping at Maximum Drawdown –Velocity Contours in Submerged Weir Vicinity (Flow is Right to Left)

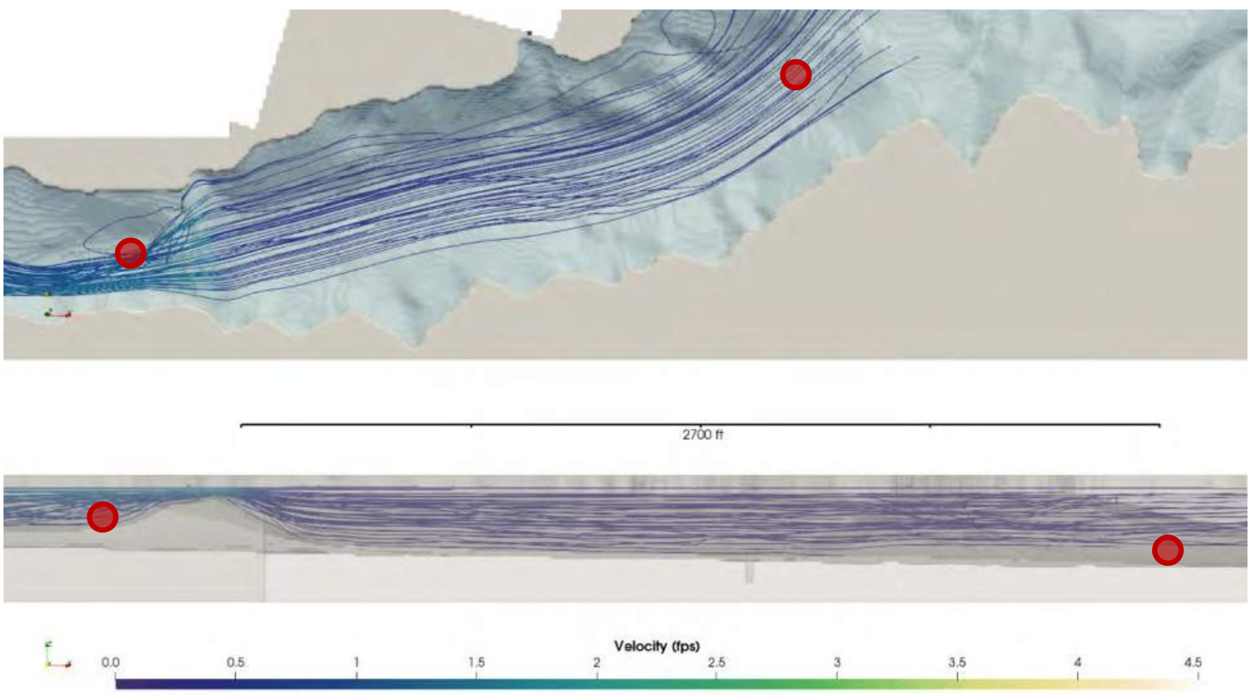


Figure A-12. Upgraded Pumping at Maximum Drawdown – Whitewater River Cove Streamlines (Flow is Right to Left)

BAD CREEK CFD MODEL VERIFICATION

ADDENDUM

WATER RESOURCES STUDY

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

November 6, 2023

This page intentionally left blank.

BAD CREEK CFD MODEL VERIFICATION
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
TABLE OF CONTENTS

Section — Title — Page No.

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

3-D	3-dimensional
ADCP	Acoustic Doppler Current Profiler
Bad Creek II Complex	Bad Creek II Power Complex
Bad Creek Reservoir	upper reservoir
CFD	computational fluid dynamics
CFD Model Report	Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse report
cfs	cubic feet per second
Duke Energy or Licensee	Duke Energy Carolinas, LLC
fps	feet per second
ft	feet
ft msl	feet above mean sea level
FERC or Commission	Federal Energy Regulatory Commission
Project	Bad Creek Pumped Storage Project
RiverRay	Teledyne© RD Instruments, Inc. RiverRay ADCP
Sentinel	Teledyne© RD Instruments, Inc. Workhorse Sentinel ADCP
Teledyne RDI	Teledyne© RD Instruments, Inc.
USGS	U.S. Geological Survey

1 Project Introduction and Background

Duke Energy Carolinas, LLC (Duke Energy or Licensee) is the owner and operator of the 1,400-megawatt Bad Creek Pumped Storage Project (Project) (FERC 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 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 expiration date of July 31, 2027.

Task 3 of the Water Resources Study (Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse) implemented three-dimensional (3-D) computational fluid dynamics (CFD) to determine flows and extent of vertical mixing in the Whitewater River cove (also called Whitewater River arm) due to the addition of a second powerhouse (Bad Creek II Power Complex [Bad Creek II]). Field verification data for the model were collected during summer 2023; however, results were not available prior to submittal of the Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse draft report (i.e., CFD Model Report) to stakeholders on September 11, 2023. Therefore, Duke Energy is hereby providing enclosed verification results as an addendum to the final CFD Model Report.

2 Objectives

The main objective of Task 3 of the Water Resources Study (i.e., CFD modeling) is to evaluate flow patterns and the extent of vertical mixing in the Whitewater River cove downstream of the submerged weir due to the addition of a second inlet/outlet structure. The purpose of this addendum is to provide a summary of field methods and results of flow and velocity data collected in the Whitewater River cove with the goal of verifying CFD model results, thereby providing confidence in modeled results.

3 Study Area

The study area for the CFD modeling study is shown on Figure 3-1. It encompasses the western portion of Lake Jocassee that includes the Whitewater River arm and the Thompson River arm; this is the extent of the CFD model domain previously presented in the CFD report.

Verification flow data were collected along four transects in the Whitewater River cove as shown on Figure 3-2. Approximate locations of flow transects include Transect 1 (upstream of the weir near water quality monitoring Station 564.1), Transect 2 (across the top of the submerged weir), Transect 3 (downstream of the submerged weir near Station 564.0), and Transect 4 at the confluence of the Whitewater River arm and Thompson Creek arm.

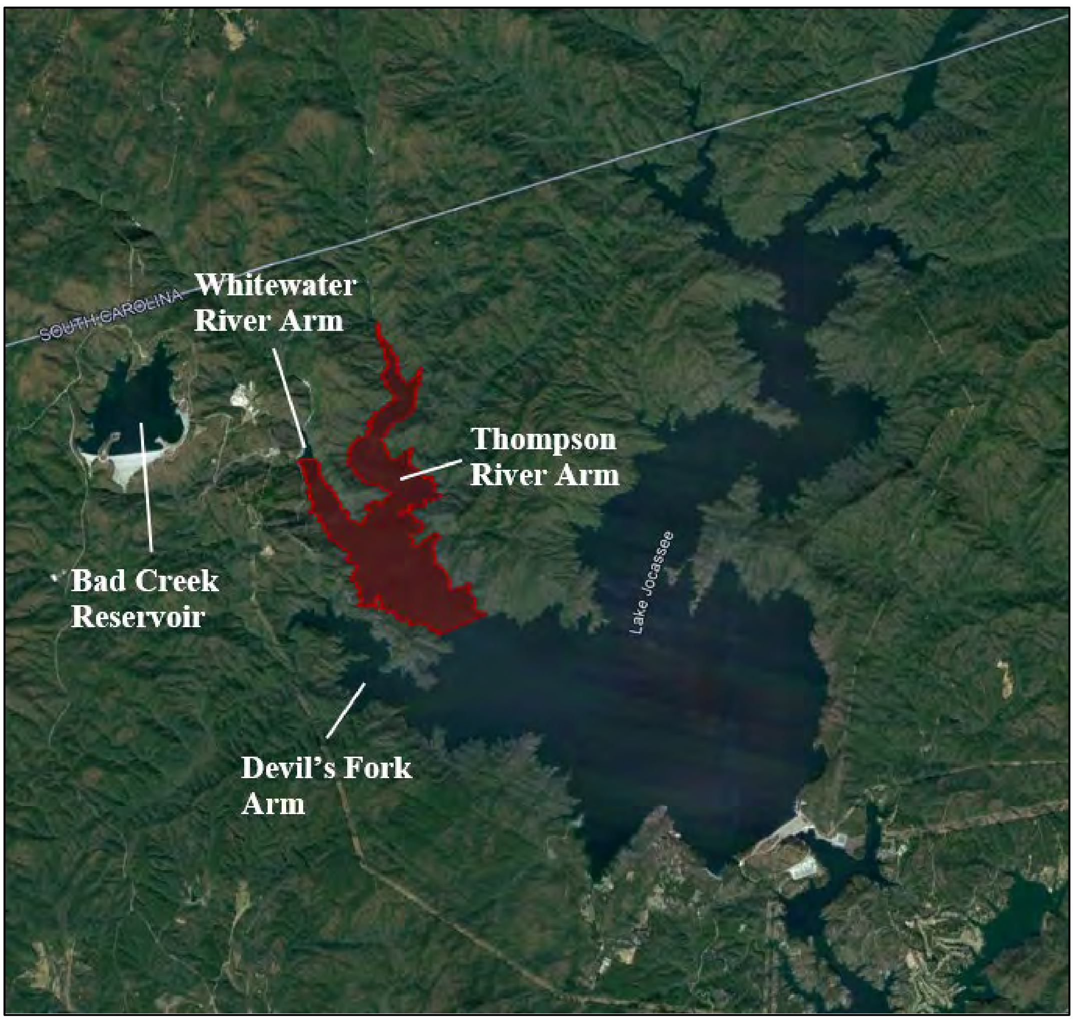


Figure 3-1. CFD Modeling Study Area

Figure 3-2. Transects for CFD Model Verification Data in the Whitewater River Cove

4 Methods

4.1 ADCP Overview

An Acoustic Doppler Current Profiler (ADCP) was used to measure flow velocities along four transects in Whitewater River arm (see Figure 3-2). ADCPs are versatile, widely used instruments for collecting flow measurement profiles in riverine or offshore marine environments; they do not measure the movement of water itself, but instead use sound waves produced by a transducer to measure the speed and direction of currents in the water column. It does this by sending out pulses of sound at a constant frequency and “listening” for echoes (i.e., backscatter) that reflect off particles in the water (typically zooplankton, suspended sediment, or other particles). The echoes have a slightly different frequency than the original sound transmitted, depending on whether the particles are moving towards or away from the device, as well as the speed at which they are moving. Particles moving toward the device will have a higher frequency and particles moving away from the device have a lower frequency. This difference in frequencies is called the Doppler effect, and it allows the ADCP to calculate the velocity of the water along the path of a sound wave (Nortek 2023). A single ADCP beam can only sense the motion of particles that are moving parallel to the beam (i.e., one-dimensional velocity). However, by using multiple beams of sound in different directions, multi-beam ADCPs can measure particles moving in three-dimensional space (i.e., speed and direction) and at different depths (called bins) in the water column.

4.1.1 Low velocity threshold

While the lower limit of velocity detection can vary depending on site-specific conditions, ADCPs are typically not used to measure discharge in areas where velocities are less than approximately 0.3 feet (ft) per second (fps) (Mueller and Wagner 2009).

4.1.2 Homogeneous flow assumption

An ADCP assumes the flow field being measured is homogenous, meaning the particles in each depth cell (bin) are generally moving in the same direction. If the flow field is non-homogenous, errors or data gaps may result when computing velocity components from multiple beams that are receiving backscatter from particles moving in different directions. Multidirectional flows caused by density currents are common in tidally affected areas and have also been observed in freshwater environments where significant temperature gradients create density currents (Garcia et al. 2007).

4.1.3 Interference zone and bottom tracking

ADCP beams are shaped like cones which widen with increasing depth. Acoustic signals reflecting off particles are relatively weak and travel back to the ADCP along the centerline of the cone. However, reflections off hard surfaces (e.g., river or reservoir bottoms) are much stronger and introduce errors in the velocity calculations as some of the acoustic signal travels back to the ADCP along the sides of the cone. Therefore, ADCPs ignore data collected from the portion of the water column near the river or reservoir bottom. This is called the sidelobe interference layer. The depth of this layer is based on the angle of the ADCPs transducer heads and can also vary depending on the hardness of the bottom surface, but typically covers the bottom 6 to 13 percent of the water column (Nortek 2023).

ADCPs also track the bottom of the water column when measuring velocities to determine the overall depth of each data ensemble. A data ensemble is a single profile of the water velocity through the water column consisting of multiple stacked bins (i.e., each bin represents a single depth cell). If the individual transducer beams hit solid surfaces at different depths (for example, lakebed and submerged trees), the ADCP will only calculate velocity for bins that it can resolve. As a result, in addition to the sidelobe interference layer, additional data gaps may occur for bins near the bottom of the transect due to an inconsistent bottom profile. In this case, the ADCP will only calculate velocities for bins that can be resolved based on moving particles (i.e., higher in the water column).

4.1.4 Temperature effects

ADCPs use the speed of sound traveling through the water column to determine the distance to each depth cell (or bin). Sound speed is affected by water temperature, salinity, and depth. Water temperature is the most important of these three variables in calculating sound speed in water (sound speed increases with increasing water temperature and vice versa). As a result, presence of thermal stratification in the water column affects sound speed which in turn affects velocity measurements. For example, a difference of five degrees Celsius will cause a two percent bias error in the measured discharge (Oberg et al. 2005).

4.2 Field Data Collection

Velocity profiles were measured in the Whitewater River cove during three separate field visits on June 12 & 13, August 10 & 11, and September 20 & 21, 2023. Field work was conducted in parallel with regularly scheduled water quality monitoring in the Whitewater River cove in support of Task 2 of the Water Resources Study. Due to varying water depths along the transects, two different ADCPs were used; a deep-water ADCP and a shallow-water ADCP. Instrumentation and specifications for each are described in the following sections.

4.2.1 Instrumentation

4.2.1.1 Deep-water ADCP

The ADCP used for deep-water measurements in the Whitewater River cove was a Teledyne© RD Instruments, Inc. (Teledyne RDI) Workhorse Sentinel ADCP (300kHz) (Sentinel); this model is ideally suited for a wide variety of applications (e.g., seafloor monitoring, wave data collection, vessel-mounted, buoy-mounted etc.).[1] It has a low-frequency, four-beam convex configuration (see Figure 4-1), a standard depth rating of 200 meters, and can be deployed upward or downward looking to measure flow velocities in the water column. The signal processing delivers low-noise data, resulting in high resolution data and minimal power consumption; Table 4-1 provides relevant specifications for the Sentinel.

(Photo source: https://www.teledynemarine.com/brands/rdi/workhorse-sentinel-adcp)

Figure 4-1. Photo of Teledyne RDI Workhorse Sentinel ADCP

[1] https://www.uniquegroup.com/wp-content/uploads/2022/08/Teledyne_RDI_Workshorse_Sentinel_ADCP.pdf

Table 4-1. Teledyne RDI Workhorse Sentinel ADCP Relevant Specifications

Component	Attribute	Specification
Water Profiling	Operating Mode	Broadband
	Max profiling range	160 m
	Vertical Resolution	1m
	Range	83 m
	Stdev	14 cm/s
	Frequency	300 kHz
Profile Parameters	Velocity accuracy	0.5% of the water velocity relative to ADCP ±0.5cm/s
	Velocity resolution	0.1cm/s
	Velocity range:	±5m/s (default) ±20m/s (max)
	Number of depth cells	1–255
	Ping rate	Up to 10Hz (2 Hz typical)
Echo Intensity Profile	Vertical resolution	Depth cell size, user configurable
	Dynamic range	80dB
	Precision	±1.5dB
Transducer and Hardware	Beam angle	20°
	Configuration	4-beam, convex
	Internal memory	Two PCMCIA card slots; one memory card included
	Communications	RS-232 or RS-422; ASCII or binary output at 1200-115,200 baud
Power	DC input	20–50VDC
	Number of batteries	1 internal battery pack
	Internal battery voltage	42VDC (new) 28VDC (depleted)
	Battery capacity @ 0°C	450 watt hours
Sensors	Temperature	Range -5° to 45°C, Precision ±0.4°C, Resolution 0.01°
	Tilt	Range ±15°, Accuracy ±0.5°, Precision ±0.5°, Resolution 0.01°
	Compass	Accuracy ±2°5 , Precision ±0.5°5 , Resolution 0.01°, Maximum tilt ±15°
Environmental	Standard depth rating	200m; optional to 500m, 1000m, 6000m
	Operating temperature	-5° to 45°C
	Weight in water	4.5kg
	Weight in air	13.0kg
Software	TRDI's WindowsTM-based software included: WinSC—Data Acquisition System; WinADCP—Data Display and Export	

4.2.1.2 Shallow-water ADCP

The ADCP used for shallow-water measurements in the Whitewater River cove was a Teledyne RDI RiverRay ADCP (RiverRay). The RiverRay is primarily for riverine applications and can sample continuously from bank to bank from rivers as shallow as 0.4 meters to rivers as deep as 40 meters.[2] The trimaran float (designed by OceanScience© specifically for use with this ADCP) provides reduced drag and less disturbance in shallow waters. A photo of the RiverRay is included on Figure 4-3 and Table 4-2 provides relevant specifications for the RiverRay ADCP.

[2] https://www.comm-tec.com/prods/mfgs/RDI/brochures/riverray_ds_lr.pdf

Table 4-2. Teledyne RDI RiverRay ADCP Relevant Specifications

Component	Attribute	Specification		
Water Profiling Profile Parameters	Operation Mode	Broadband / pulse-coherent; automatic / manual		
	Velocity range	±5m/s (default), ±20m/s max		
	Profiling range	0.4m to 60m		
	Accuracy	±0.3% of water velocity relative to ADCP, ±2mm/s		
	Resolution	1mm/s		
	Number of cells	automatic, 25 typical, 200 max		
	Cell size:	automatic, 10cm min.		
	Surface cell range	25cm[2]		
	Data output rate	1-2 Hz (typical)		
Bottom Tracking	Operation mode	Broadband		
	Velocity range	±9.5m/s		
	Depth Range	0.4-100m[1]		
	Maximum depth	70m (@15°C, fresh water)		
	Accuracy	±0.25% of bottom velocity relative to ADCP, ±2 mm/s		
	Resolution	1mm/s		
Depth Measurement	Range	0.3m to 100 (@15°C, fresh water)[1]		
	Accuracy	1% (with uniform water temperature and salinity profile)		
	Resolution	1mm		
Vertical Beam	Range	20 cm to 120 m		
	Accuracy	±1% (with uniform water temperature and salinity profile)		
	Resolution	1 millimeter		
Transducer and Hardware	Frequency	600Hz		
	Configuration	Phased array (flat surface), Janus four beams at 30° beam angle		
	Internal memory	16mb		
	Communications	RS-232, 1200 to 115,200 baud. Bluetooth,115,200 baud, 200m range.		
Power	Input voltage	10.5–18VDC		
	Power consumption	1.5W typical		
	Transmit Power	8W		
	Battery (inside float)	12V, 7A-hr lead acid gel cell (rechargeable)		
	Battery capacity	>40 hours continuous operation		
Standard Sensors		**Temperature**	**Tilt (solid state)**	**Compass (solid state)**
	Range	-5° to 45°C	± 15°	0-359.99°
	Accuracy	± 0.4°C	± 0.5°	± 2°
	Resolution	0.01°C	0.01°	0.01°
Float	Configuration	Three hulls (trimaran)		
	Material	Polyethylene		
	Dimensions	Length 120 cm, width 80 cm, height 20 cm		
	Weight	10 kg bare; 17 kg with instrument and battery		
Software	WinRiver II (standard) for moving-boat measurement			

[1] Assumes fresh water; actual range depends on temperature and suspended solids concentration.

(Source: https://cclynch.com/wp-content/uploads/2020/09/Teledyne-RDI-RiverRay-Datasheet.pdf

Figure 4-2. Photo of Teledyne RDI RiverRay ADCP

4.2.2 Data Collection Methods

Proper field procedures are critical to obtaining high quality discharge measurements using ADCPs. For all transects, the ADCP was mounted to a flotation device and attached to a lead line which was held parallel to the boat as the boat motored along the transects. The deep-water ADCP (Sentinel) was mounted to a flotation device retrofitted with sections of high-density foam attached to the bottom and back of the float for additional vertical stability and to reduce backward tilt of the instrument as it was pulled through the water (Figure 4-3). The shallow-water (RiverRay) ADCP was mounted to a trimaran platform (Figure 4-4). Previous studies have shown velocity and discharge measurement errors are directly proportional to the speed of the boat; average boat speed during transect measurements should be less than or equal to the average water speed if possible (Mueller and Wagner 2009), therefore, very slow boat speeds were maintained during field measurements.

Operational data were obtained from Duke Energy for dates of flow data collection. Project operations data information is listed in Table 4-3 and includes pumping, generation, and reservoir elevation for Bad Creek Reservoir and Lake Jocassee. Table 4-3 also provides ADCP measurement details during field data collection.

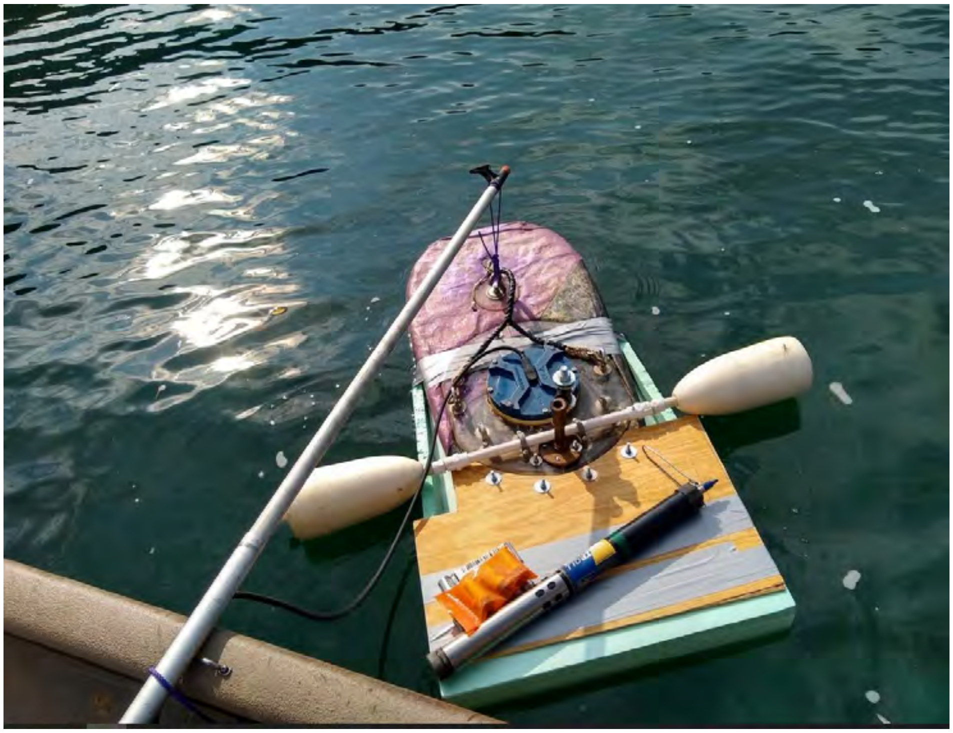


Figure 4-3. Teledyne RDI Workhorse Sentinel and Retrofitted Flotation Device

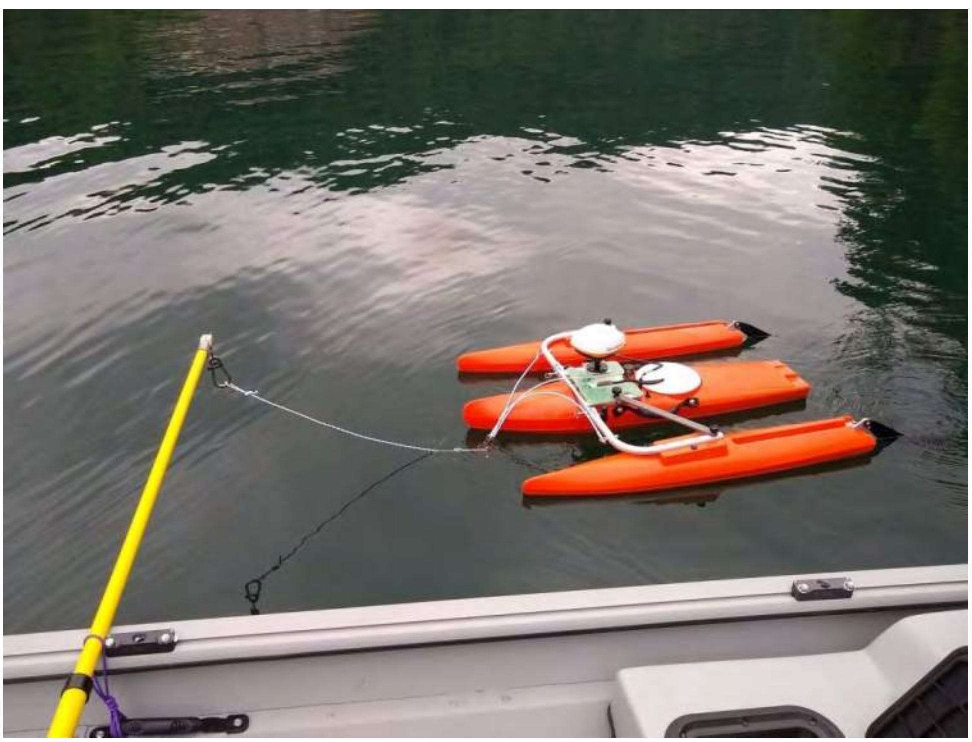


Figure 4-4. Teledyne RDI RiverRay ADCP and Trimaran

Table 4-3. Operations and Measurement Details

Transect	Date	Time	Measured Flowrate (cfs)	Lake Jocassee Reservoir Elevation (ft above mean sea level [msl])	Maximum Depth (ft)	Transect Width (ft)	Operations	Measurement Details
Transect 1	July 13	08:00	8,800	1,107.5	143	716	3 Units Pumping	1.1 Ensemble/ft
Transect 2	August 10	18:00	8,500	1,107.7	53	934	2 Units Generating	1.7 Ensemble/ft
Transect 3	Sept 20	16:40	12,400	1,107.2	208	1,146	2 Units Generating	4.4 Ensemble/ft
Transect 4	Sept 21	17:00	13,000	1,107.0	234	1,352	2 Units Generating	1.7 Ensemble/ft

4.2.3 Data Collection Challenges

There are many well-documented data collection challenges when measuring flows with an ADCP in the field; some of these were listed in Section 4.1 associated with ADCP assumptions. The U.S. Geological Survey (USGS) recommends the following guidelines for properly measuring flow velocities with an ADCP (Mueller and Wagner 2009).

- The cross section of a stream should be within a straight reach, and streamlines are parallel to each other. Flow should be relatively uniform and free of eddies, slack water, and excessive turbulence (Rantz et al. 1982).
- Desirable measurement sections should be roughly parabolic, trapezoidal, or rectangular. Asymmetric channel geometries should be avoided, if possible (Simpson 2002), as should cross sections with abrupt changes in channel bottom slope.
- The streambed cross section should be as uniform as possible and free from debris and vegetation or plant growth.
- Depth at the measurement site should allow for the measurement of velocity in two or more depth cells at the start and stop points near the left and right edges of the measurement section.
- Measurement sections with mean velocities less than 0.3 fps should be avoided if an alternative measurement location is available (Oberg et al. 2005). If maintaining a slow boat speed is not possible, maintain the slowest speed that allows smooth boat operation. (Additional transects may be needed to average turbulence and instrument noise.)
- Sites with non-uniform flow lines should be avoided. This condition is often indicative of non-homogenous flow, which is a condition that violates one of the assumptions required for accurate ADCP velocity and discharge measurements.

Several of the data collection challenges listed above are relevant to Lake Jocassee measurements. Additionally, turbidity in the water column and temperature affect measurements in the lake. Lake Jocassee is a very clear, oligotrophic reservoir with low concentrations of nutrients and thus, relatively sparse growth of algae and other organisms. Chlorophyll a concentrations collected in the Whitewater River cove are typically in the upper 105 ft of the water column (i.e., from full pond [1,110 ft msl] down to approximately 1,005 ft msl) with sporadic (both spatial and temporal) concentrations deeper than 105 ft. This is likely a combination light penetration through the upper layers of the water column and the depth of the thermocline (below which water temperatures are cooler and dissolved oxygen concentrations are lower compared to the upper surface layers). As a result, zooplankton densities are also likely to be relatively sparse (as they use plankton as a primary food source) and mostly present in the upper 105 ft of the water column. Lake Jocassee also has very low turbidity levels, typically less than 1.0 NTU[3]. Because ADCP technology measures particles moving in the water column, lack thereof results in an insufficient amount of acoustic energy reflected back to the transducer to allow the ADCP to measure the Doppler shift; thus resulting in data gaps, particularly in deeper areas that are devoid of both organisms and turbidity.

Additionally, the Whitewater River arm of Lake Jocassee is deep with most of the flow on the downstream side of the submerged weir contained in the upper portion of the water column. Deeper areas have very slow-moving water (less than 0.3 fps) and coupled with areas that may have non-homogenous flow (due to density currents near the thermocline) and/or very few particles to measure, therefore, it is reasonable to expect bins where the velocity cannot be resolved.

Finally, the area that was flooded to form Lake Jocassee was not cleared prior to filling, therefore, it is reasonable to expect submerged trees that are either still standing and/or have fallen but have not yet decomposed. As a result, bottom tracking is challenging in some areas as the ADCP beams backscatter off hard objects at different elevations at the same location. This causes decorrelation of the acoustic pulse and results in bins where the velocity cannot be computed.

Erroneous and/or inconsistent data values at lower depths attributed to challenging field conditions in the Whitewater River cove are discussed in Section 4.3.

4.3 Post-Processing and Model Verification

WinRiver II is a real-time discharge data collection software developed by Teledyne RDI for collecting and processing data gathered by an ADCP. To make accurate comparisons between measured and modeled data, ADCP data was post processed using WinRiver II. The number of horizontal readings per transect is provided in Table 4-3 (i.e., ensembles per ft). The density of these readings or ensembles (each of which is comprised of stacked “bins” as described in Section 4.1), ranged from 1.1 to 4.4 ensembles/ft. The CFD model mesh used for this study was 20-ft x 20-ft x 10-ft (X,Y,Z directions). To match the CFD model output, the ADCP data was

[3] Nephelometric turbidity unit

horizontally averaged into 20-ft ensembles. WinRiver II does not have a method for averaging data in the vertical direction.

4.4 Modeling Assumptions

The CFD model is a numerical approximation of the hydraulics in the Whitewater River arm of Lake Jocassee. Because of the slow-moving nature of the flow patterns in the Whitewater River arm, the model mesh size (i.e., 20-ft x 20-ft x 10-ft) is appropriate to model the velocity magnitudes and direction and mixing / recirculation patterns associated with existing and proposed Bad Creek Project operations.

Inflows to the model were assumed to be constant and uniform in the horizontal and vertical directions. In reality, properties of the water such as temperature (which affects the density of water in thermally stratified waterbodies like Lake Jocassee) play a role in the distribution of flow across a given transect; however, only hydraulics were modeled with the CFD model. Potential hydraulic effects of temperature gradients, flow bulking and buoyancy, or wind-driven vertical mixing were not included. Given these assumptions and model limitations, it is not expected that the CFD model results will exactly replicate real-world conditions within the model domain. However, the CFD model configuration is suitable for purposes of determining potential Project-related operational impacts to flow patterns and vertical mixing in the Whitewater River arm of Lake Jocassee.

5 Verification Results

As described above, two different ADCPs were used to collect velocity data in the Whitewater River arm as part of the CFD model verification effort. The Sentinel and RiverRay transducer heads are mounted with a 20-degree and 30-degree offset from vertical, respectively. This equates to a minimum sidelobe interference zone along the bottom of the reservoir of 5 percent and 8 percent of total depth, respectively. This interference zone is visible as a well-defined band of varying vertical thickness with no data along the bottom of each transect shown on Figure 5-1 through Figure 5-4 (all figures displaying transects are oriented looking in the upstream direction).

As discussed in Section 4.1, there are several assumptions and limitations associated with ADCP data collection. When data collection occurs outside of these assumptions and limitations, erroneous data can occur in the transects, generally in the form of blank cells or artificially high velocity measurements. Data resolution errors in velocity measurements will show up as velocity spikes when compared with the neighboring valid velocity measurements. Mueller and Wagner describe five causes for erroneous or invalid ensembles (Mueller and Wagner 2009):

1 Invalid bottom tracking, which would provide no boat reference from which to compute the velocity,

2 Decorrelation of the acoustic pulse (from turbulence, high shear, submerged debris, or fish) which would not permit an accurate measurement of the Doppler shift,

3 Low backscatter, which results in an insufficient amount of acoustic energy reflected back to the ADCP to measure the Doppler shift,

4 The blocking of acoustic pulses by air entrainment, and

5 User-specified data quality criteria.

Velocities depicted on Figure 5-1 were measured along Transect 1 which is the furthest upstream transect near water quality monitoring station 564.1. Velocity data shown on Figure 5-1 were collected with the Project in pumping mode to evaluate velocity magnitudes and flow patterns in the area most affected by pumping operations (i.e., near the Project’s inlet/outlet structure). Velocities shown on Figure 5-1 are generally moving in the upstream direction towards the Project inlet/outlet structure. The overall measured velocity magnitude is < 0.5 fps from top to bottom (upper panel on Figure 5-1) indicating flows in this area are generally slow moving, but well mixed throughout the water column, which also matches the CFD model results (lower panel on Figure 5-1). Both historic and current water quality profiles at this location also indicate the water column in this area is well-mixed due to Project operations.

Velocities shown on Figure 5-2 were measured across the top of the submerged weir (Transect 2) with the Project in generation mode. The maximum depth along Transect 2 is 53 ft; it is the shallowest of the ADCP transects which range from 53 to 234 ft deep. Due to the smaller cross-sectional area for discharged water to pass through, the area across the top of the weir is also well mixed and exhibits higher velocities compared to the other transects. Maximum measured velocities across the top of the weir with the Project in generation mode were close to 1.0 fps while the majority of Transect 2 had velocities < 0.5 fps (upper panel on Figure 5-2). The CFD model results for Transect 2 were similar to the measured data and also exhibited areas with higher velocities up to approximately 0.7 fps (lower panel on Figure 5-2).

Transects 1 and 2 exhibited complete datasets with no obvious invalid cell measurements or erroneous data, as many of the challenges and limitations associated with ADCP data collection (described above) were not a factor at these two transects.

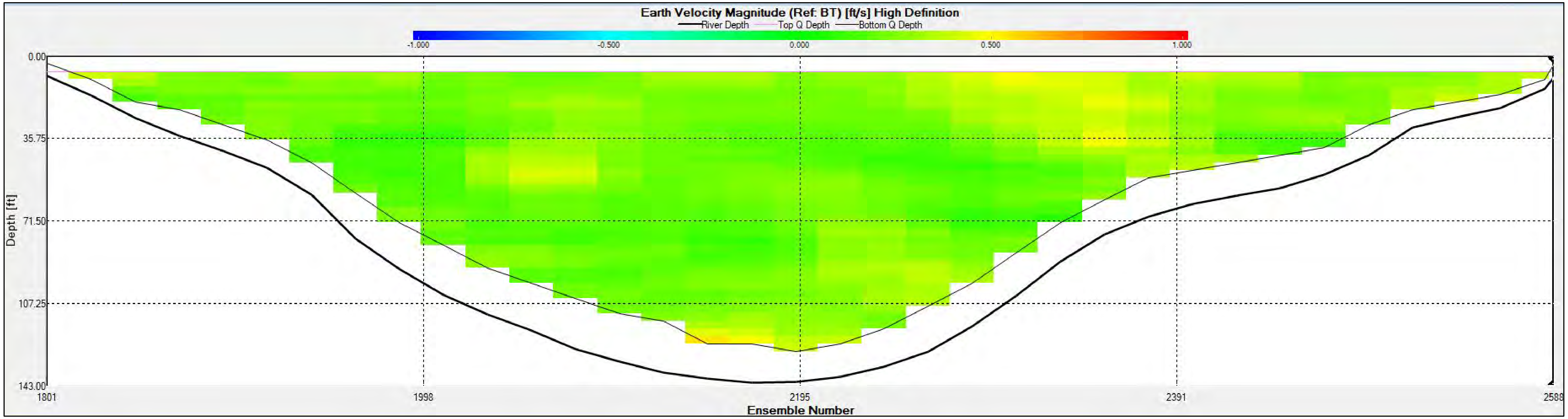
Figure 5-3 and Figure 5-4 show results of the two downstream transects (Transects 3 and 4). These transects are deeper and the velocities are slower at these two locations compared to Transects 1 and 2. There are numerous invalid ensembles and velocity spikes for both of these transects, indicated by white cells (no data) and artificially high velocities (yellow/orange/red colors at depth or near invalid cells). A review of the ADCP bottom tracking data shows continuous black lines along the bottom of each transect indicating that there were no issues with bottom tracking. Air entrainment (typically due to turbulence) was also not an issue at Transects 3 and 4 and no specific user quality criteria were used in the measurements. This means the invalid ensembles displayed on Figure 5-3 and Figure 5-4 were likely the result of decorrelation of the acoustic pulse and/or low backscatter due to lack of moving particles in the water column (particularly at deeper depths).

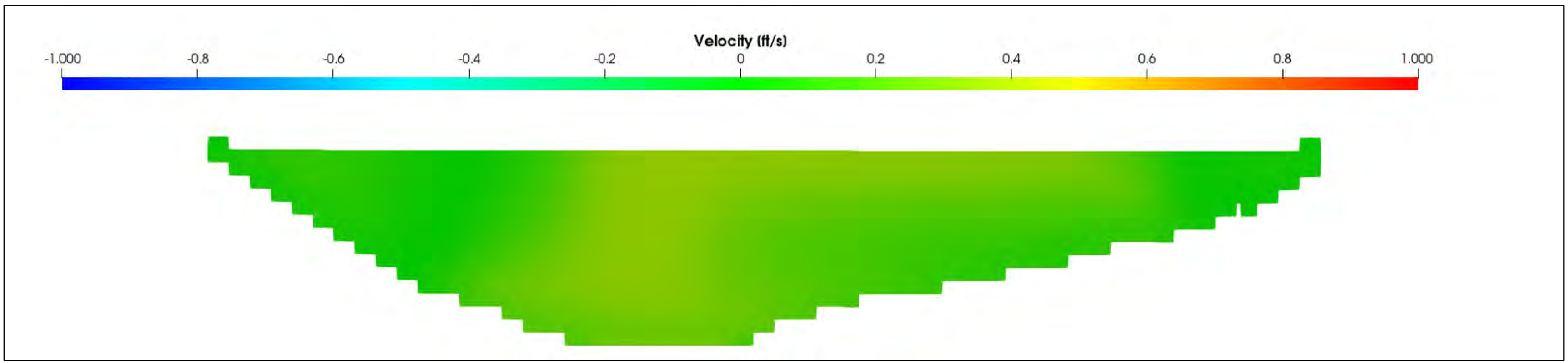
Transect 3 (Figure 5-3) is located between the submerged weir and water quality monitoring location 564.0. This location has slightly elevated velocities near the surface which is carry-over from the higher velocities across the top of the submerged weir. Most of the velocities at this location are generally < 0.5 fps which is consistent with the CFD model results. There are several areas along the left-hand side of Figure 5-3 with missing or erroneous data at depth. The first is a series of blank bins around an erroneously high velocity spike (i.e., >1.0 fps) to the left of ensemble 3854. The second is an area of missing data just to the right of ensemble 3854. And the third is an area of missing area approximately halfway between ensembles 3854 and 2625.

As previously discussed in Section 4.2.3, Lake Jocassee has very low turbidity and sparse growth of algae and other organisms. These two factors increase the likelihood of low backscatter, especially at depth. Additionally, because trees and other debris were not cleared before Lake Jocassee was filled, there are likely many areas where trees are still standing, which can cause decorrelation of the acoustic pulse. The invalid cells farthest to the left of Figure 5-3 appear to be caused by either standing trees and/or low backscatter. The bottom tracking is continuous at the second area, however there is an abrupt change in bottom elevation likely caused by submerged debris. The third location (to the right) is in the deepest part of the transect and the blank cells there are likely caused by low backscatter.

Transect 4 **(**Figure 5-4) is located just upstream of the confluence of the Whitewater River arm and Thompson River arm. It is the deepest of the four transects (maximum 234 ft) and velocities are very low (<0.50 fps) from the surface to the bottom. There are numerous areas along Transect 4 with either blank cells and/or erroneous high velocities at depth. The combination of low back scatter and submerged debris interrupting the acoustic pulse are feasible explanations for these areas of invalid data; most of the invalid data points are below depths of 100 feet, where there is little turbidity or organic growth present to reflect the acoustic energy back to the ADCP.

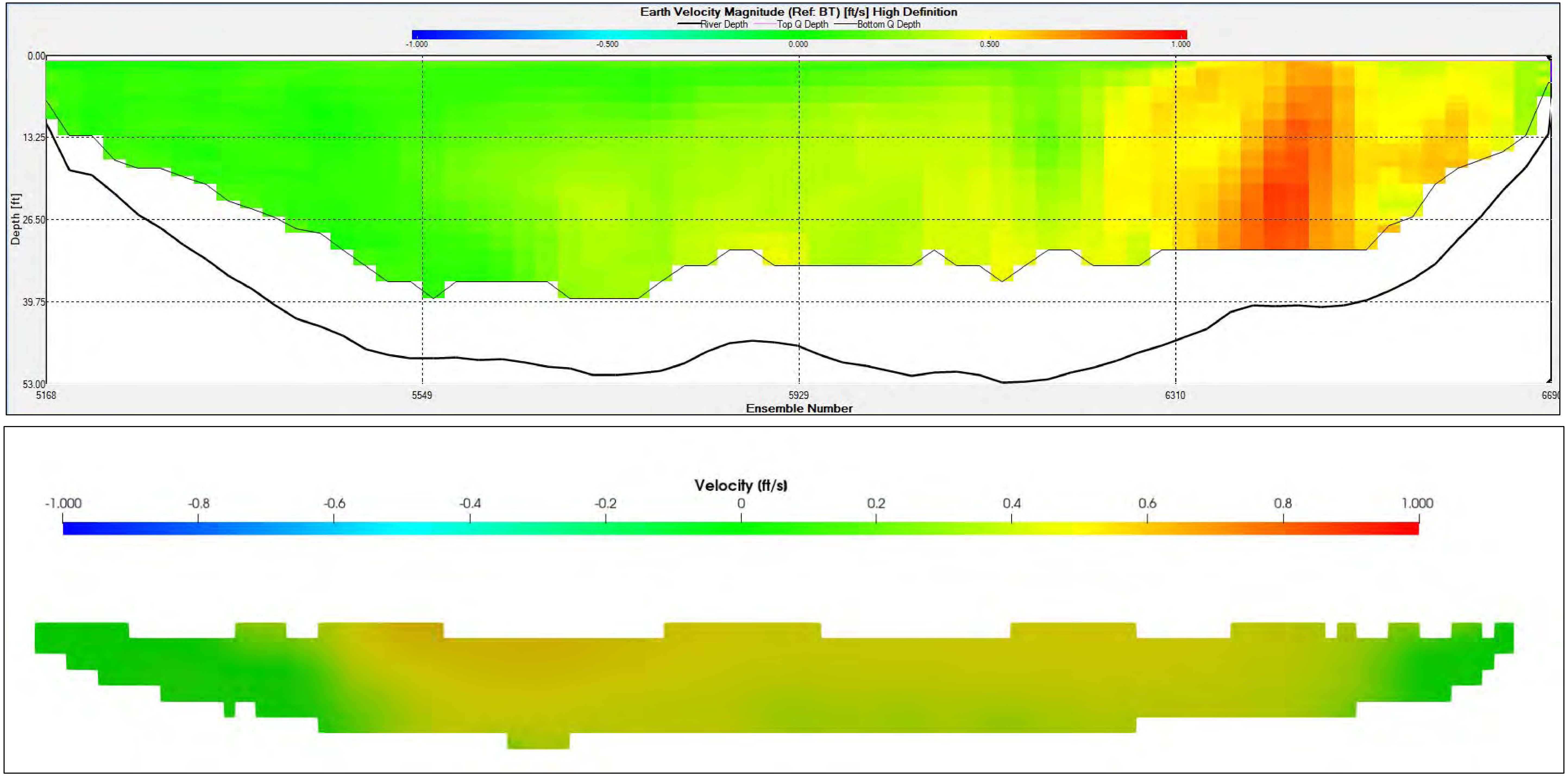
While Transects 3 and 4 exhibit some blank cells and erroneous data, this is to be expected when measuring velocities in deep, clear water with very low velocities (i.e., < 0.3 fps). Knowing that data collection would be a challenge at these two locations, extra time was taken in the field to collect a higher density of data ensembles, including hovering in place over areas where data gaps occurred in an attempt to minimize those gaps. Most of the data ensembles at these two locations are complete and a comparison of measured velocities in the upper panels of Figure 5-3 and Figure 5-4 is consistent with the CFD model results shown in the lower panels of these two figures.





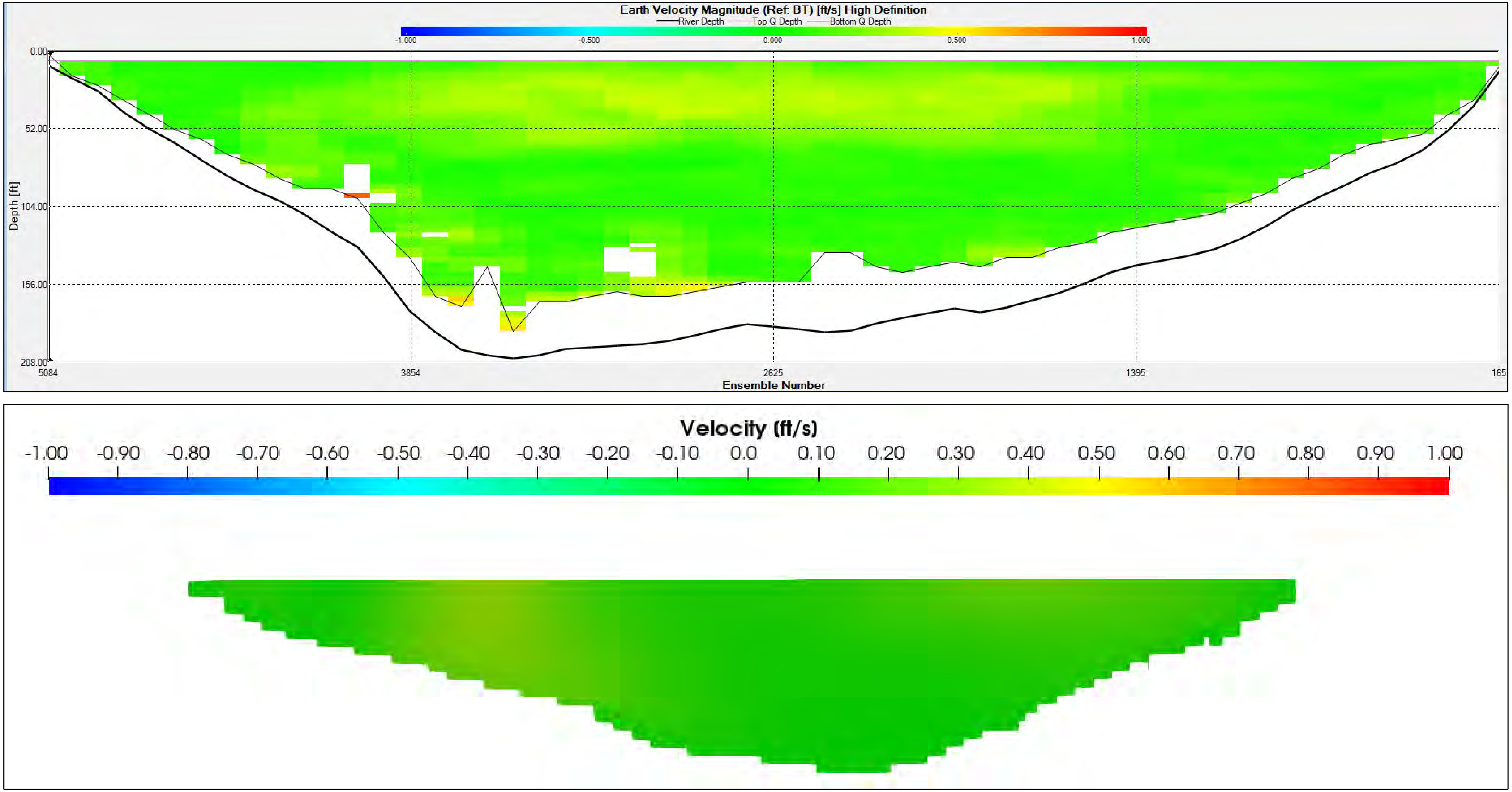
Notes: Pumping mode. Approximate Measured Flow: 13,150 cfs. Modeled Flow: 13,780 cfs

Figure 5-1. Measured Velocity (top) vs Modeled Velocity (bottom) Transect 1 (Station 564.1)



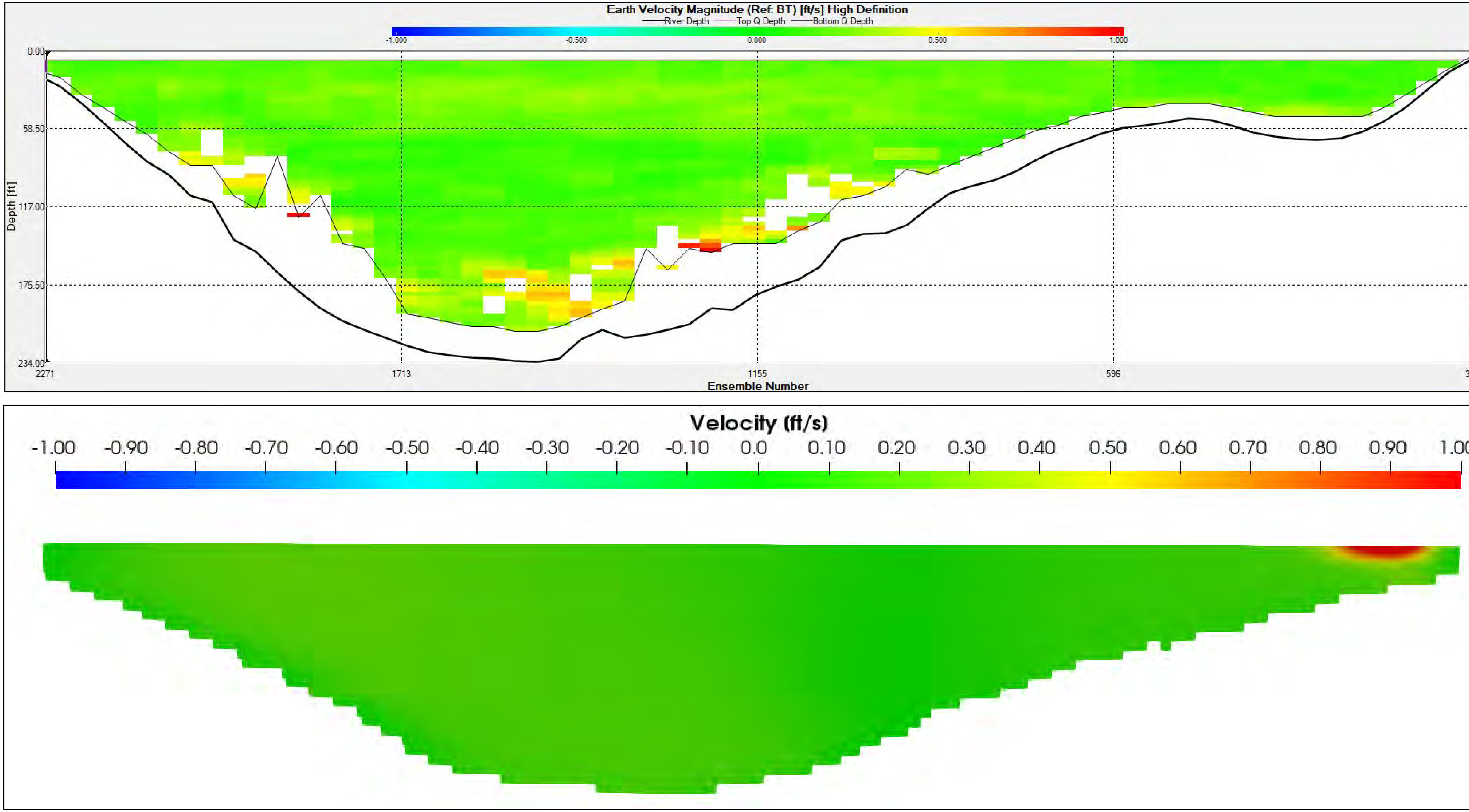
Notes: Generation mode. Approximate Measured Flow: 11,800 cfs. Modeled Flow: 16,000 cfs.

Figure 5-2. Measured Velocity (top) vs Modeled Velocity (bottom) Transect 2 (Top of Weir)



Notes: Generation mode. Approximate Measured Flow: 12,400 cfs. Modeled Flow: 16,000 cfs.

Figure 5-3. Measured Velocity (top) vs Modeled Velocity (bottom) Transect 3 (Station 564.0)



Notes: Generation mode. Approximate Measured Flow: 13,000 cfs. Modeled Flow: 16,000 cfs.

Figure 5-4. Measured Velocity (top) vs Modeled Velocity (bottom) Transect 4 (Upstream of Thompson River-Whitewater River Confluence)

6 Conclusions

ADCP velocity measurements at the four transects located in the Whitewater River arm of Lake Jocassee generally corroborate the CFD model results at these locations. Velocity magnitudes and directions and overall flow patterns are consistent with CFD model results which show a mixed water column on the upstream side of the submerged weir (Transect 1), and area of slightly higher velocities across the top of the submerged weir (Transect 2) and deeper, slower moving water (i.e., < 0.50 fps) towards the Whitewater River arm / Thompson River arm confluence.

As discussed in Section 4.1, there are several assumptions and limitations associated with ADCP data collection that can make velocity data resolution challenging, especially in deep, clear, slow-moving water such as the Whitewater River arm of Lake Jocassee. In particular, the lack of moving particles in the lower portions of the water column, coupled with very slow-moving water (i.e., <0.30 fps) in many areas resulted in data gaps and erroneous velocity spikes. Even with these challenges, a robust velocity dataset was collected at each of the four transect locations and results are consistent with the CFD model results in both pumping and generation mode.

Overall, velocities predicted with the CFD model compare well with measured velocities across each transect. Modeled velocities are generally within 0.1-0.3 fps of valid measured velocities and accurately represent actual flow dynamics. This study is considered appropriate and sufficient to provide confidence in the CFD model results used to carry out Task 3 of the Water Resources Study.

7 References

Garcia, Carlos, M., Oberg, K., and Garcia, M.H., 2007. ADCP Measurements of Gravity Currents in the Chicago River, Illinois. Journal of Hydraulic Engineering. ASCE December 2007. DOI: 10.1061/

Nortek Group (Nortek). 2023. Understanding ADCPs: A guide to measuring currents, waves and turbulence using acoustic sensors. [URL] https://www.nortekgroup.com/knowledge-center/wiki/guide-to-understanding-adcps#7-how-the-surface-or-bottom-affects-adcp-data. Accessed Oct 3, 2023.

Oberg, K.A., Morlock, S.E., and Caldwell, W.S. 2005. Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers. U.S. Geological Survey Scientific Investigations Report 2005-5183. [URL]: https://pubs.usgs.gov/sir/2005/5183/SIR_2005-5183.pdf. Accessed October 3, 2023.

Mueller, D.S. and Wagner, C.R. 2009. Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat. U.S. Geological Survey, Techniques and Methods 3–A22. [URL]: http://pubs.water.usgs.gov/tm3a22)

Rantz, S.E., and others, 1982, Measurement and computation of streamflow, volume 1, Measurement of discharge: U.S. Geological Survey Water-Supply Paper 2175, 631 p.

Simpson, M.R., 2002, Discharge measurements using a broadband acoustic Doppler current profiler: U.S. Geological Survey Open-File Report 01–01, 123 p., accessed June 22, 2007, at http://pubs.usgs.gov/of/2001/ofr0101/

BAD CREEK CFD MODEL
UPDATED PUMPING RATES

ADDENDUM

WATER RESOURCES STUDY

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

September 10, 2024

This page intentionally left blank.

BAD CREEK CFD MODEL UPDATED PUMPING RATES ADDENDUM
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Section	Title	Page No.

ATTACHMENTS

ACRONYMS AND ABBREVIATIONS

3-D	3-dimensional
Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II Complex or Bad Creek II	Bad Creek II Power Complex
CFD	computational fluid dynamics
cfs	cubic feet per second
Duke Energy or Licensee	Duke Energy Carolinas, LLC
fps	feet per second
ft	feet
ft msl	feet above mean sea level
FERC or Commission	Federal Energy Regulatory Commission
HDR	HDR Engineering, Inc.
ISR	Initial Study Report
I/O	inlet/outlet
WWRC	Whitewater River cove

1 Project Introduction and Background

Duke Energy Carolinas, LLC (Duke Energy or Licensee) is the owner and operator of the 1,400-megawatt Bad Creek Pumped Storage Project (Project) (FERC 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 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]

Given the need for additional significant 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 would 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-megawatt Bad Creek II Power Complex (Bad Creek II Complex or Bad Creek II) is an alternative relicensing proposal presently being evaluated by Duke Energy.

During the feasibility study phase for Bad Creek II, a three-dimensional (3-D) computational fluid dynamics (CFD) model was developed by HDR Engineering, Inc (HDR) to evaluate impacts under combined operation of the existing and proposed projects on water velocities in the Whitewater River cove (WWRC) of Lake Jocassee downstream of the inlet/outlet (I/O) structures. Results from the CFD feasibility modeling study are presented in the Feasibility Study Report as Volume 5 (*Bad Creek II Power Complex Feasibility Study Lower Reservoir CFD Flow Modeling Report*; HDR 2022). This report was also included in the Revised Study Plan

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

submitted to FERC on December 5, 2022. During studies for relicensing in 2023, a second CFD model was developed under Task 3 of the Water Resources Study (*Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse)* to determine flow patterns and extent of vertical mixing in the WWRC due to the addition of a second powerhouse. Findings from that study were provided in Appendix A of the Initial Study Report (ISR) submitted to the Commission on January 4, 2024 (Duke Energy 2024).

After filing the ISR, Duke Energy provided updated hydraulic capacities, provided by the preferred Original Equipment Manufacturer, for proposed variable speed pump-turbines for Bad Creek II. Based on this information, additional CFD modeling was conducted using the updated proposed hydraulic capacities. This report includes the results of updated CFD modeling and is being provided as an addendum to the Task 3 study report for the Bad Creek relicensing Water Resources Study.

2 Objectives

Increased hydraulic capacities associated with Bad Creek II could affect flow patterns and velocities in the WWRC near the I/O structures. The purpose of this addendum is to provide results of additional CFD model runs carried out to incorporate updated hydraulic capacities associated with Bad Creek II that were not available during original CFD modeling. Updated generating capacity resulted in similar flows as originally estimated (i.e., less than 2 percent difference), so this report's focus is to present the effects of updated pumping capacities on WWRC flows.

3 Study Area

The study area for this assessment includes the area of the WWRC from the immediate vicinity of the Project’s existing and proposed I/O structures to the upstream end of the submerged weir (see Figure 3-1; blue rectangle defines study area). Previous CFD modeling results carried out under Task 3 of the Water Resources Study showed the submerged weir limits effects of operations downstream of the weir, therefore, updated modeling focused on the area upstream of the weir only.

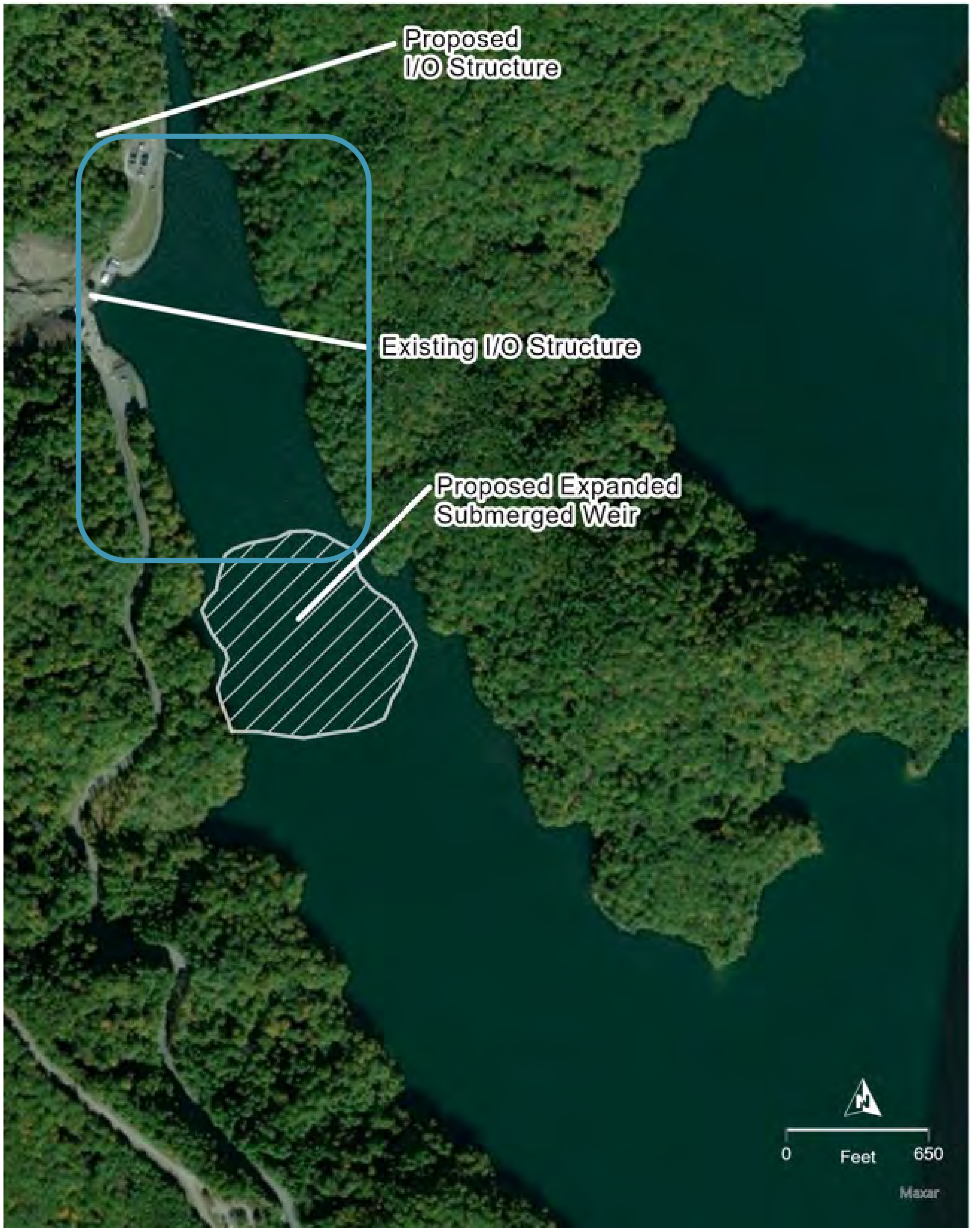


Figure 3-1. CFD Updated Modeling Study Area: Whitewater River Cove

4 Hydraulic Capacities

Existing hydraulic capacities for the Bad Creek Project are included in Table 1. This table shows as-constructed and previously licensed Project capacities and upgraded unit capacities (as amended). On April 23, 2018, Duke Energy filed a Non-Capacity License Amendment Application to upgrade and refurbish the four Francis-type pump-turbines in the powerhouse, replace existing runners with Francis-type pump-turbine runners, and rehabilitate and/or upgrade the remaining components of the pump-turbine runners at the Bad Creek Project. Authorized installed and maximum hydraulic capacities for the Project were increased to 1,400 megawatts (based upon the definition provided by 18 CFR §11.1[i])[2] and 19,760 cubic feet per second (cfs), respectively. The upgrades were approved by FERC in an amendment order dated August 6, 2018 and modifications for Units 1 – 3 were completed by March 2023 and Unit 4 was completed in February 2024. The upgraded Project is the baseline for the relicensing and upgraded unit capacities were used for (CFD) modeling existing conditions.

Hydraulic capacities at the Project under previously licensed and upgraded (i.e., as amended in 2018) conditions are included in Table 4-1. Results of CFD modeling incorporating upgraded capacities are presented as existing conditions in Volume 5 of the Feasibility Study Report (HDR 2022) upstream of the submerged weir and in the CFD Task 3 report in the ISR (Duke Energy 2024) for downstream of the submerged weir.

Table 4-1. As-Constructed (Original) and Upgraded (Amended) Project Hydraulic Capacities

Bad Creek (Existing Project)				
Unit	**Generation**		**Pumping**	
	Original (cfs)	**Upgraded/Existing (cfs)**	**Original (cfs)**	**Upgraded/Existing (cfs)**
Unit 1	4,000	4,940	3,690	4,060
Unit 2	4,000	4,940	3,690	4,060
Unit 3	4,000	4,940	3,690	4,060
Unit 4	4,000	4,940	3,690	4,060
Total	**16,000**	**19,760**	**14,760**	**16,240**

Prior CFD modeling for proposed conditions followed the assumption that Bad Creek II would be constructed with four reversible pump-turbine units similar to the configuration at the existing Project with the same generation and pumping capacities (see Table 4-1). However, during recent (2023) optimization studies for the Bad Creek II Complex, variable speed pump-turbine

[2] *Authorized installed capacity* means the lesser of the ratings of the generator or turbine units. The rating of a generator is the product of the continuous-load capacity rating of the generator in kilovolt-amperes (kVA) and the system power factor in kW/kVA. If the licensee or exemptee does not know its power factor, a factor of 1.0 kW/kVA will be used. The rating of a turbine is the product of the turbine's capacity in horsepower (hp) at best gate (maximum efficiency point) opening under the manufacturer's rated head times a conversion factor of 0.75 kW/hp. If the generator or turbine installed has a rating different from that authorized in the license or exemption, or the installed generator is rewound or otherwise modified to change its rating, or the turbine is modified to change its rating, the licensee or exemptee must apply to the Commission to amend its authorized installed capacity to reflect the change.

units were selected as the chosen configuration (instead of fixed-speed), which resulted in an increase in proposed hydraulic capacities for Bad Creek II as show in Table 4-2.

Table 4-2. Updated Bad Creek II Hydraulic Capacities

Bad Creek II				
Unit	**Generation**		**Pumping**	
	Previously Proposed (cfs)	**Updated Proposed (2023) (cfs)**	**Previously Proposed (cfs)**	**Updated Proposed (2023) (cfs)**
Unit 1	4,940	5,000	4,060	4,890
Unit 2	4,940	5,000	4,060	4,890
Unit 3	4,940	5,000	4,060	4,890
Unit 4	4,940	5,000	4,060	4,890
Total	**19,760**	**20,000**	**16,240**	**19,560**

In consideration of the recent 2023 updated capacities, total generation capacity with both projects operating would be 39,760 cfs (19,760 + 20,0000 cfs). Modeled (CFD) versus updated generation capacity is similar (39,200 cfs vs. 39,760 cfs), resulting in a less than 2 percent difference. It is anticipated this difference would not substantially affect existing results (as reported in the ISR); therefore, generation capacity was not assessed further.

Total pumping capacity (with both projects) would be 35,800 cfs (16,240 + 19,560 cfs), resulting in a 9 percent increase (i.e., 32,720 cfs vs. 35,800 cfs); therefore, additional model runs were performed under proposed configurations for pumping operations under full pond and minimum normal pond elevations in Lake Jocassee.

5 Lake Jocassee Lake Levels

The lower reservoir has a licensed operating band between 1,110 ft msl (full pond) and 1,080 (minimum pond or maximum drawdown). Results under full pond and maximum drawdown provide potential upper and lower limits of hydraulic effects of Bad Creek II operations. Figure 5-1 provides an exceedance plot of the Lake Jocassee pond level from 1975 to 2020. This plot shows the percentage of time the reservoir is at or above a given elevation. Lake Jocassee operates within 5 ft of the full pond elevation of 1,110 ft roughly 50 percent of the time, and in the 45-year period of record Lake Jocassee has never reached the maximum drawdown elevation.

For this evaluation, unit operations in pumping mode were simulated with the existing and proposed structures at reservoir levels 1,110 ft msl, 1,096 ft msl, and 1,080 ft msl. The elevation of 1,096 ft msl was selected as an intermediate lake elevation operating scenario because it is roughly halfway between full pond and maximum drawdown, and 1,096 ft msl is the elevation below which fish entrainment becomes elevated at Bad Creek (historically, reservoir elevations were lower than 1,096 ft msl approximately 22 percent of the time).

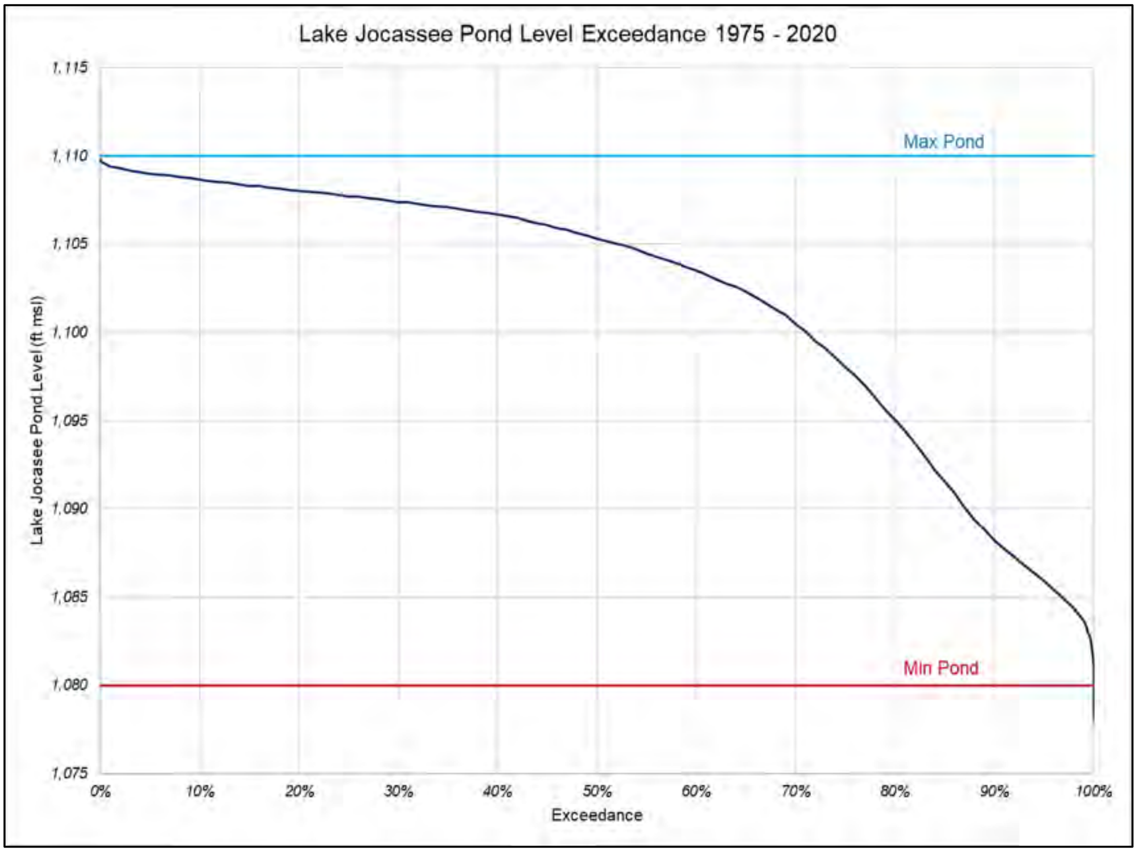


Figure 5-1. Lake Jocassee Pond Level Exceedance

6 Proposed Tunnel Configuration

The Bad Creek II I/O structure will be located in a portal area adjacent to the existing Bad Creek I/O structure (upstream of the existing I/O structure). The proposed location of the new I/O structure portal for Bad Creek II is shown on Figure 6-1.

A schematic of the proposed tunnels extending from the underground powerhouse to the western bank of the WWRC is shown below (Figure 6-2). The proposed I/O structure will be approximately 150 ft wide, 20 ft deep, and 95 ft tall. The location of the structure was selected to minimize the length of the water conveyance tunnel, permit access, and reduce construction-related environmental impacts to the Whitewater River arm of Lake Jocassee. Two tailrace tunnels extending from the underground powerhouse will penetrate the I/O structure at invert elevation 1,012 ft msl. The two tailrace tunnels are divided into a left and right chamber as the tunnels approach the portal opening. Each tunnel has a diameter of 31 ft and the chambers at the outlet are approximately 38 ft tall by 17.5 ft wide. Flows through the center two chambers (Tunnel 1 Right and Tunnel 2 Left) create higher velocities at the tunnel entrances when compared to the outer two chambers (Tunnel 1 Left and Tunnel 2 Right) which is discussed further in Section 8.

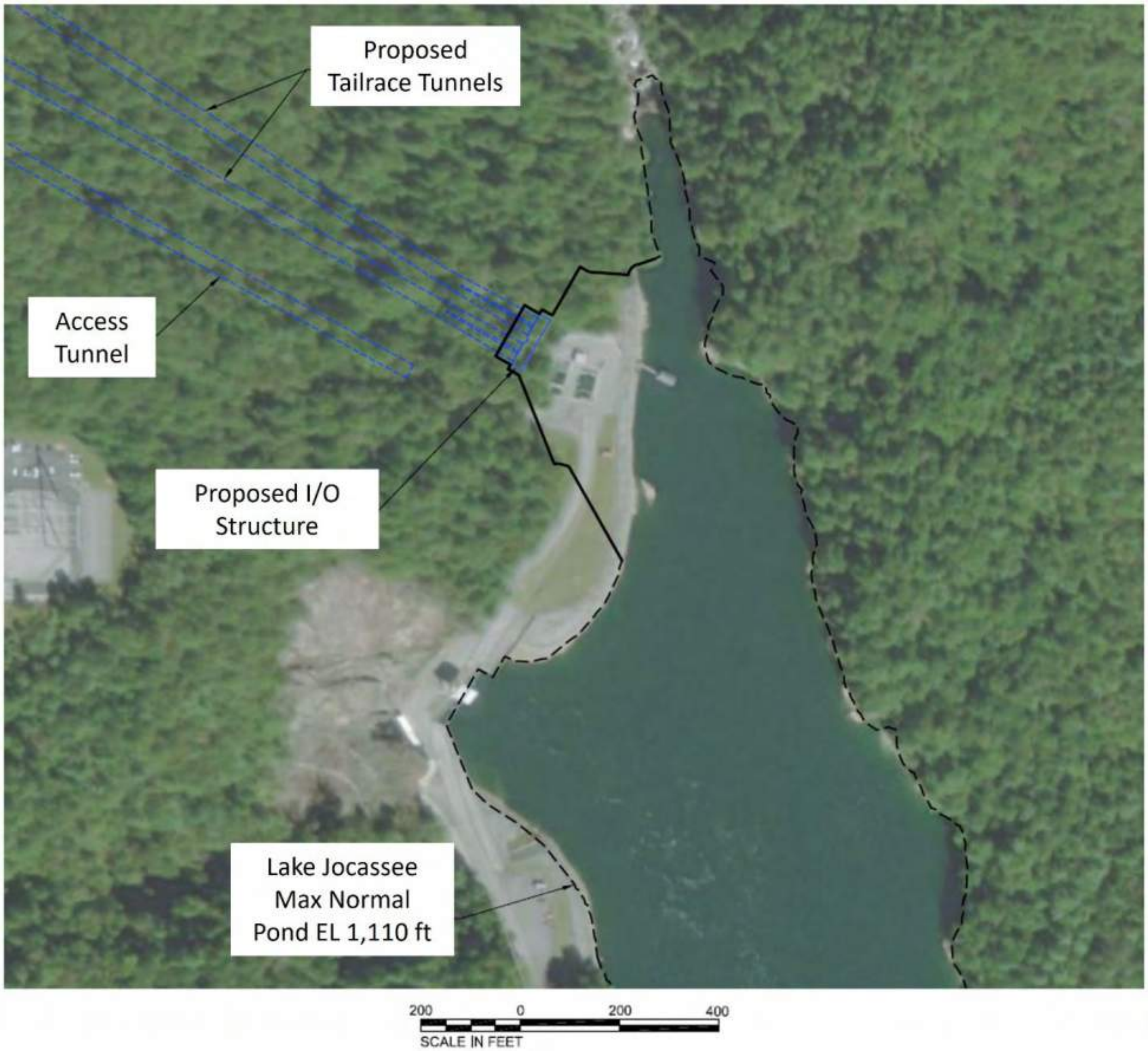
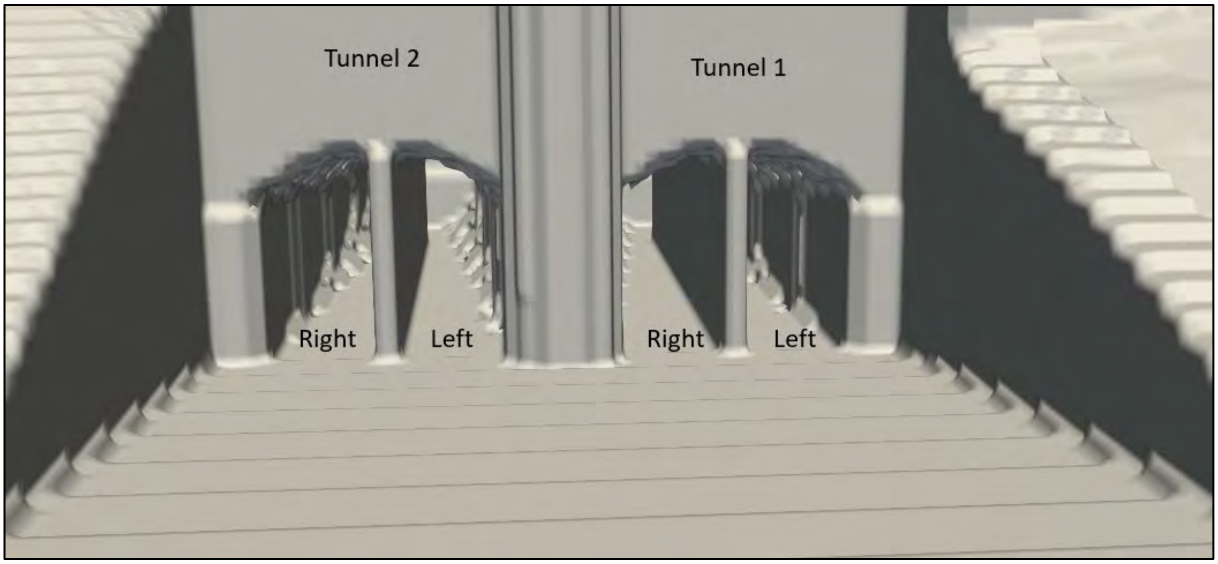


Figure 6-1. Proposed Bad Creek II Lower Reservoir I/O Structure Portal Adjacent to Existing I/O Structure Portal



Note: The left and right tunnel naming convention is based on the direction of flow from the tunnel into Lake Jocassee.

Figure 6-2. Proposed Bad Creek II Powerhouse Tunnel Configuration

7 Methods

7.1 Feasibility CFD Model

As noted in Section 1, two CFD models were previously developed by HDR for the Bad Creek and Bad Creek II projects. The first CFD model was built for the feasibility study (HDR 2022) with the goal of identifying flow velocities and patterns under generation and pumping scenarios with various water level elevations in the WWRC near the I/O structure (upstream of the submerged weir) and to assess the potential for erosion along the opposite (east) shoreline due to increased generation flows from the combined powerhouses. This feasibility model was built with a computational mesh block resolution of 4-ft by 4-ft by 4-ft (length by width by height). Background, methods, and findings of this study are provided in the Bad Creek II Power Complex Feasibility Study Lower Reservoir CFD Flow Modeling Report (HDR 2022) and was also provided in the Revised Study Plan as Appendix I.

7.2 Relicensing CFD Model

The second CFD model was developed for the relicensing study to determine velocity effects and vertical mixing in the WWRC due to operation of a second powerhouse and considering the area downstream of the submerged weir. Inflows to the model were assumed to be constant and uniform in the horizontal and vertical directions approaching the submerged weir. The long-term average flowrate from the Thompson River arm was also included in the model to incorporate flows downstream of the weir. Because this model incorporated a larger (922 acres) and deeper area of Lake Jocassee (with very slow water circulation), a coarser model mesh was appropriate to meet the objectives and a computational mesh block of 20-ft by 20-ft by 10-ft (length by width by height) was used. Background, methods, and findings of this study were included in the ISR as Appendix A, Attachment 3 (Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse) (Duke Energy 2024).

7.3 Updated CFD Model

As described above, recent optimization studies have proposed variable-speed turbines for the Bad Creek II Complex, which will result in increased hydraulic capacities compared to those initially proposed and modeled. Because the objective of this report is to assess near-field hydraulics and changes in velocity in the vicinity of the I/O structures due to increased pumping capacity associated with recently proposed variable speed turbines, the Feasibility CFD Model (described in Section 7.1) was considered the most appropriate model (as opposed to the Relicensing CFD Model) to carry out this evaluation. Model description, geometry, evaluation criteria, and mesh development are described in detail in HDR (2022) and are therefore not provided here.

Modeling with variable speed units did not appreciably increase generation flows, however the effects of increased pumping hydraulic capacity did result in a measurable change (i.e., 9 percent), therefore only updated pumping scenarios are discussed in Section 8. Updated generation flows resulted in a flow difference of less than 2 percent, therefore, the results presented in the original Feasibility CFD Model report (HDR 2022) were not revised.

8 Results

8.1 Existing Pumping Velocity Profiles

Existing pumping conditions (16,240 cfs) at cross-section elevations (i.e., model slices) representing full pond (1,100 ft msl), intermediate (1,096 ft msl), and maximum drawdown

(1,080 ft msl) are shown on Figure 8-1, Figure 8-2, and Figure 8-3, respectively. All estimated velocities are included in the attached results table in Attachment 1.

Under existing pumping conditions at the full pond elevation (Figure 8-1), depth-averaged velocities[3] approaching the I/O structure (i.e., approach velocities) are 1.8 fps approximately 100 ft from the I/O structure with a maximum velocity of 2.1 fps. Maximum velocities in the water column near the face of the I/O structure vary based on tunnel position and the hydrostatic pressure acting on tunnel flows and range from 5.5 fps to 6.2 fps.[4]

Under existing pumping conditions at the intermediate pond elevation (Figure 8-2), depth-averaged approach velocities are 2.2 fps approximately 100 ft from the I/O structure with a maximum velocity of 2.5 fps. Maximum velocities near the face of the I/O structure range from 7.2 fps to 7.7 fps.

Under existing pumping conditions at the minimum pond elevation (Figure 8-3), depth-averaged approach velocities are 4.6 fps approximately 100 ft from the I/O structure with a maximum velocity of 5.2 fps. Maximum velocities near the face of the I/O structure range from 7.9 fps to 8.4 fps.

Under existing pumping conditions, the maximum velocity inside the I/O tunnel chambers near the structure face is approximately 13.3 fps and approximately 23 fps in the tailrace tunnel based on the 31-ft-diameter tunnel and given flowrates.

The width of the WWRC (see Figure 3-1) at the existing I/O structure is approximately 1,110 ft and the extent of velocity effects (as shown on Figure 8-3) extend approximately 230 ft from the I/O structure into the WWRC at the minimum pond elevation.

[3] It is noteworthy that bathymetry of the lake bottom impacts flows as they approach the tunnel openings.

[4] Trashracks on the I/O structure are not considered, therefore velocities at the face of the tunnels would be higher than shown here.

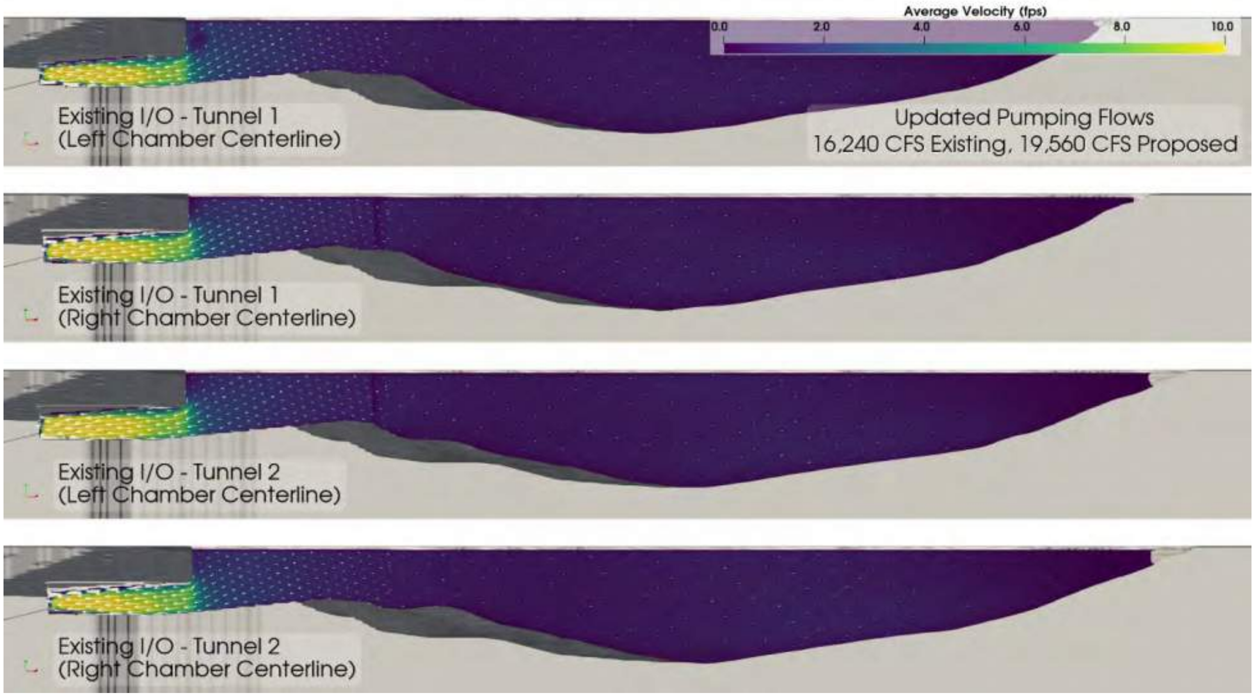


Figure 8-1. Existing Bad Creek I/O Pumping at 1,110 ft msl

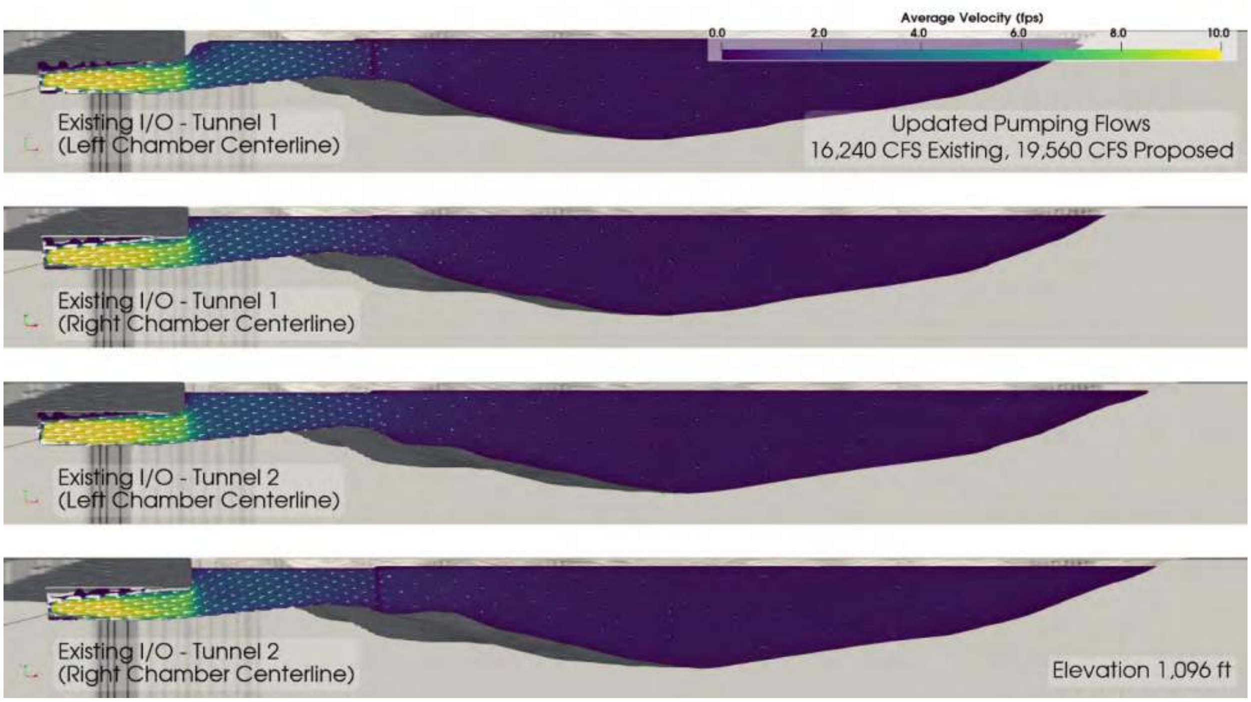


Figure 8-2. Existing Bad Creek I/O Pumping at 1,096 ft msl

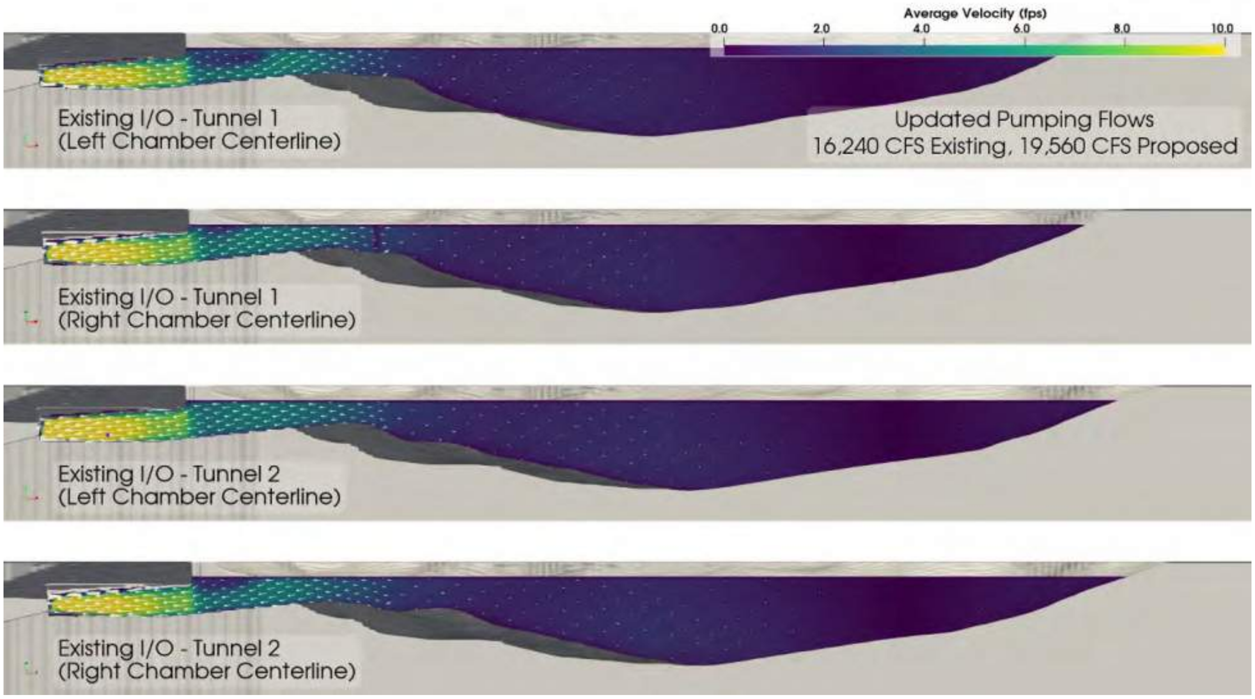


Figure 8-3. Existing Bad Creek I/O Pumping at 1,080 ft msl

8.2 Updated Proposed Pumping Velocity Profiles

As shown on Figure 8-4 through Figure 8-6, the updated increased pumping capacity at Bad Creek II results in higher velocities in the WWRC in the vicinity of the proposed I/O structure when compared to existing velocities at the Bad Creek I/O structure (Figure 8-1 through Figure 8-3). All velocities are included in the attached results table in Attachment 1.

Under updated pumping conditions at the full pond elevation (Figure 8-4), depth-averaged approach velocities for the proposed I/O structure are 1.7 fps approximately 100 ft from the I/O structure with a maximum velocity of 2.0 fps. Maximum velocities in the water column near the face of the I/O structure vary based on tunnel position and hydrostatic pressure and range from 9.6 fps to 10.1 fps.

Under updated pumping conditions at the intermediate pond elevation (Figure 8-5), depth-averaged approach velocities are 2.5 fps approximately 100 ft from the I/O structure with a maximum velocity of 3.1 fps. Maximum velocities near the face of the I/O structure range from 9.2 fps to 9.7 fps.

Under updated pumping conditions at the minimum pond elevation (Figure 8-6), depth-averaged approach velocities are 4.5 fps approximately 100 ft from the I/O structure with a maximum velocity of 8.3 fps. Maximum velocities near the face of the I/O structure range from 7.4 fps to 10.9 fps.

Under updated pumping conditions, the maximum velocity inside the I/O tunnel chambers near the structure face is approximately 16 fps and approximately 28 fps in the tailrace tunnel based on the 31-ft diameter-tunnel and given flowrate.

The width of the WWRC (see Figure 3-1) at the proposed I/O structure is approximately 675 ft and the extent of velocity effects (as shown on Figure 8-6) extend approximately 400 ft from the I/O structure into the WWRC at the minimum pond elevation.

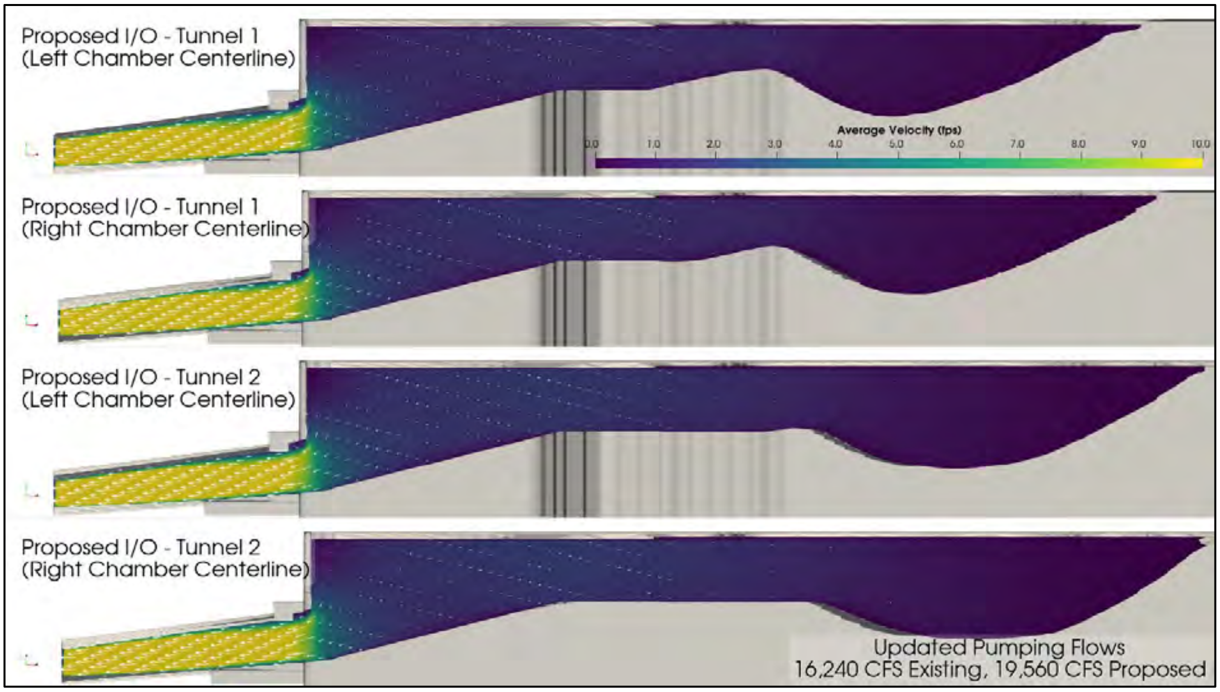


Figure 8-4. Proposed Bad Creek II I/O Updated Pumping at 1,110 ft msl

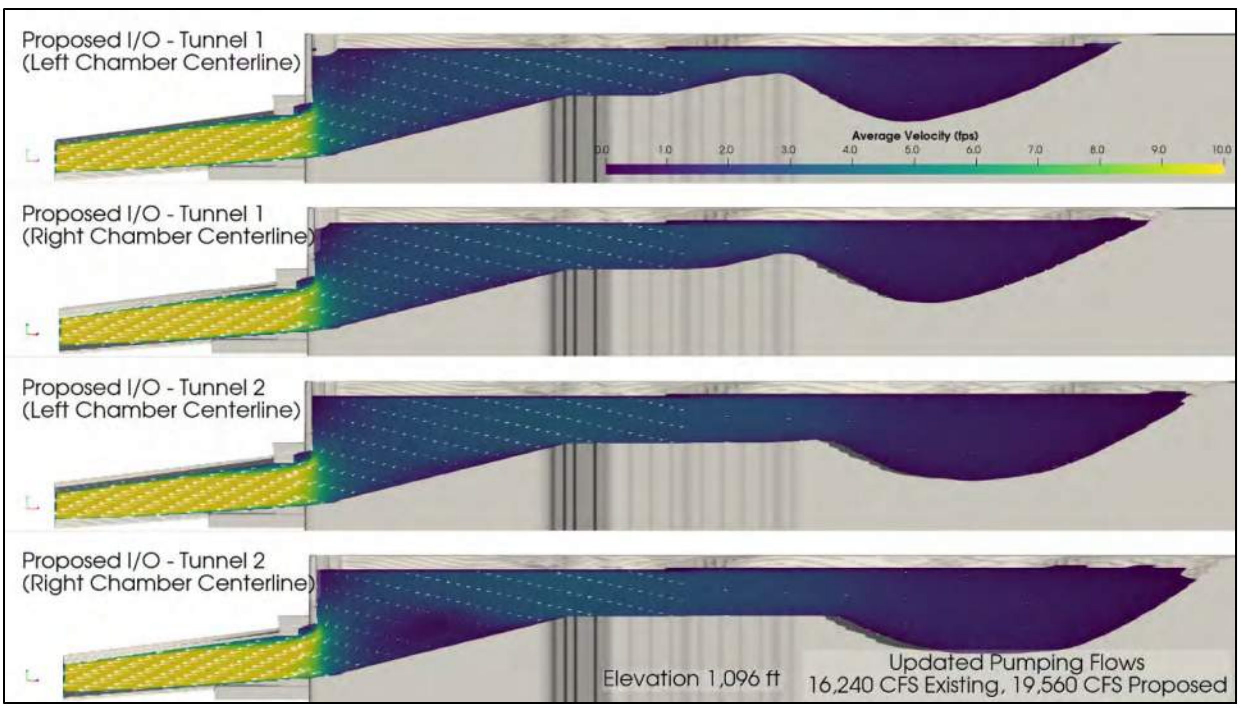


Figure 8-5. Proposed Bad Creek II I/O Updated Pumping at 1,096 ft msl

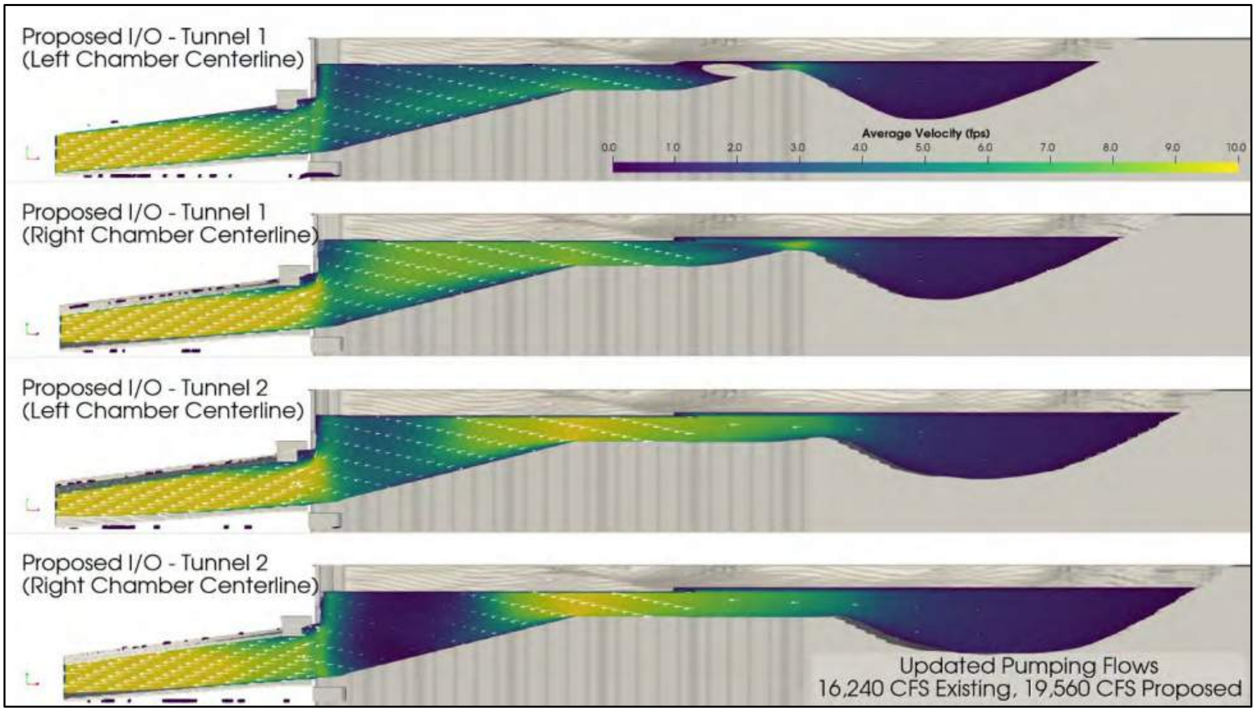


Figure 8-6. Proposed Bad Creek II I/O Updated Pumping at 1,080 ft msl

8.3 Surface Velocities

Plan view flow patterns and velocity vectors at the three reservoir levels (i.e., full, intermediate, and minimum pond) are presented on Figure 8-7, Figure 8-9, and Figure 8-9, respectively. Areas of recirculation occur near the west and east banks under both full pond and minimum pond scenarios, and, similar to the profile figures, velocities increase as reservoir levels decrease and with increased proximity to the proposed I/O structure, as indicated by velocity vectors. Recirculation patterns in the vicinity of the proposed I/O structure under the minimum pond scenario are also indicated on Figure 8-9. These patterns are caused by flow splitting at the tunnel abutments and the restricted flow area near the I/O structure, resulting in increased velocities.

As the pond level decreases, the volume of water decreases and increases the strength of recirculation in the recirculation area. This effect results in concentrated flow through the center of the proposed I/O structure approach channel and center tunnels (Tunnel 1 Right, Tunnel 2 Left) and is more pronounced as the pond level decreases.

Accelerated flows across the weir in the direction of the I/O structure are more pronounced at minimum pond (Figure 8-9). As water is pulled upstream through the WWRC during pumping, flows are spread evenly across the submerged weir before converging into a main center channel in the cove, with localized eddies of slower moving water (i.e., recirculation) on both sides of the main flow path.

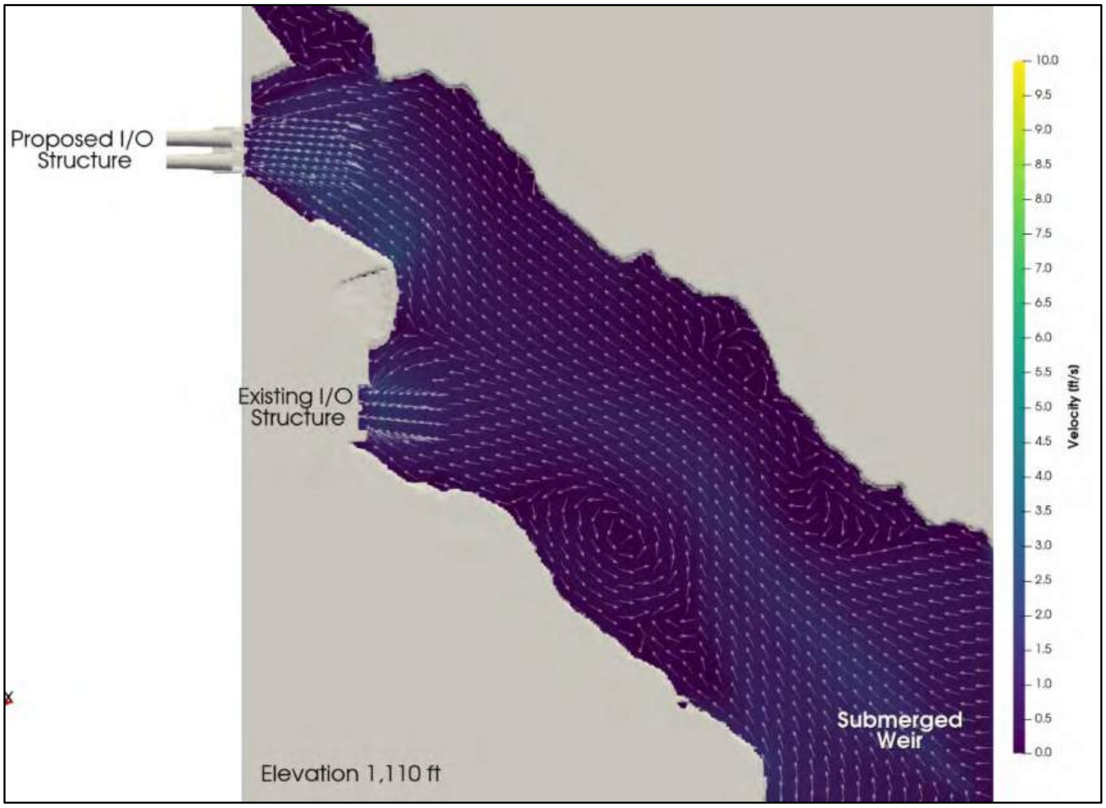


Figure 8-7. Proposed Bad Creek II I/O Updated Pumping Plan View at Elevation 1,110 ft msl

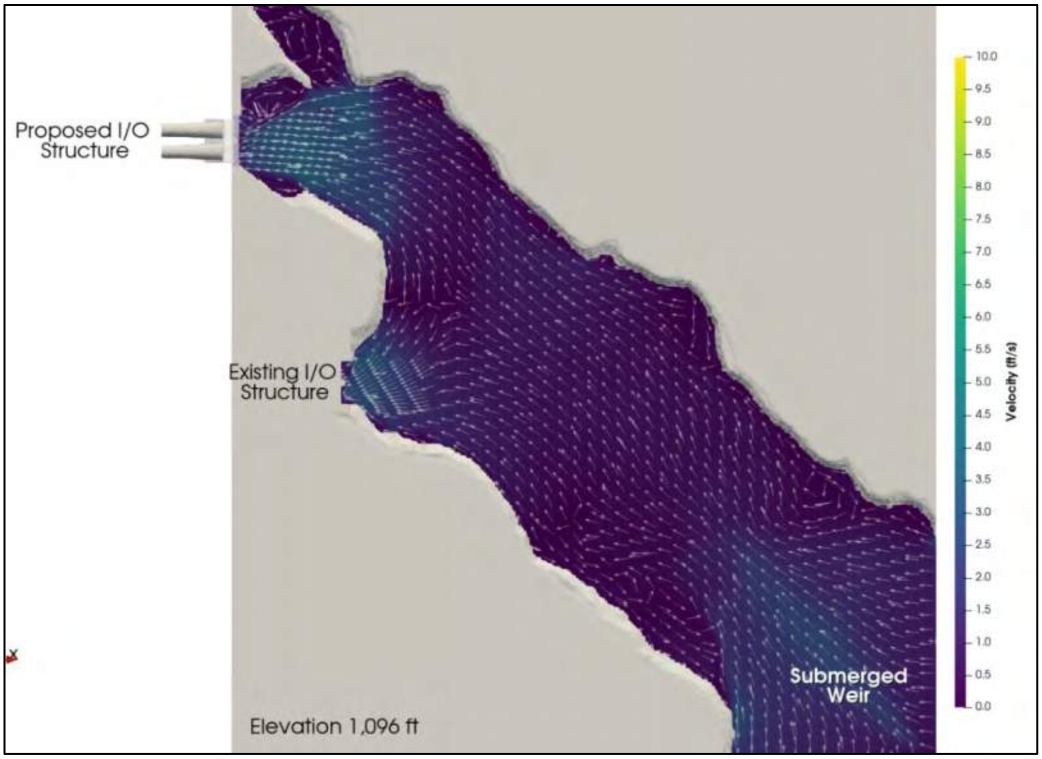


Figure 8-8. Proposed Bad Creek II I/O Updated Pumping Plan View at Elevation 1,096 ft msl

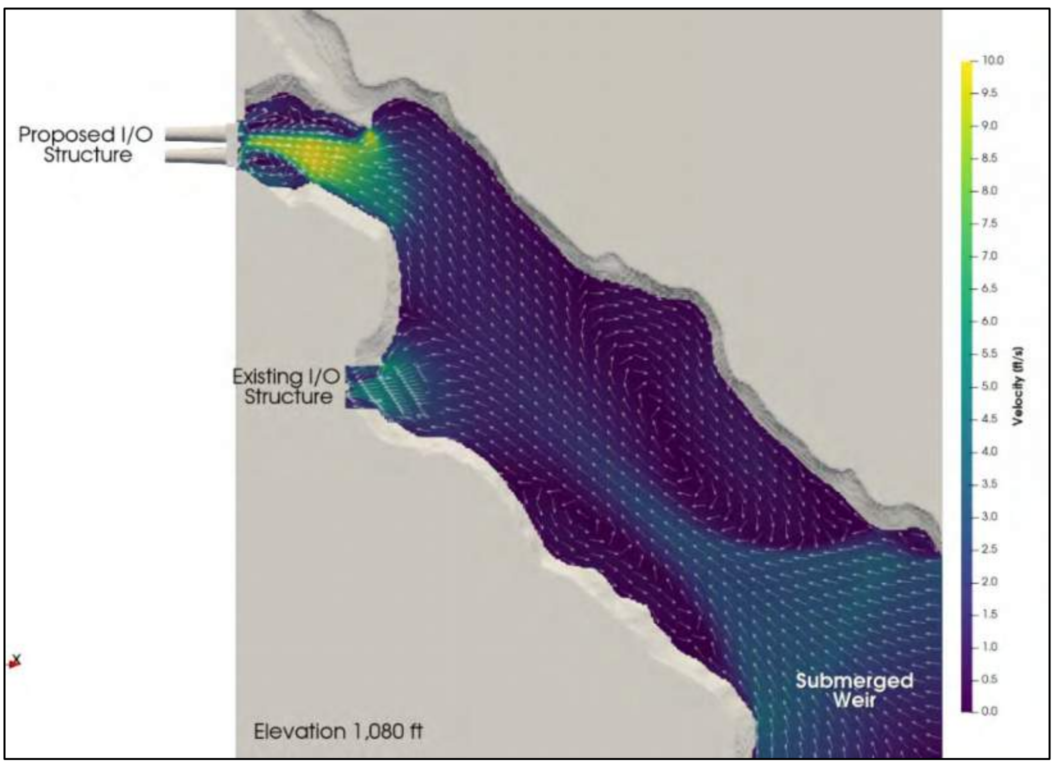


Figure 8-9. Proposed Bad Creek II I/O Updated Pumping Plan View at Elevation 1,080 ft msl

Surface velocity contours are shown on Figure 8-10 and Figure 8-11 for existing conditions[5] and Figure 8-12 and Figure 8-14 for proposed updated pumping conditions under full, intermediate, and minimum pond levels.

Under existing pumping conditions and full pond levels, surface velocities do not exceed 2.0 fps in the WWRC and are on average below 1.0 fps. At minimum pond, existing maximum surface velocities across the weir could reach 3.0 fps and up to 5.0 fps directly in front of the existing I/O structure.

Under full pond conditions for proposed updated pumping operations, velocities are very similar to existing conditions with maximum velocities of 1.5 fps near the existing and proposed I/O structures. Under proposed updated pumping at the minimum pond level, surface velocities could reach 10.0 fps near the proposed I/O structure (see Figure 8-14 and Figure 8-9); however, these higher velocities are localized and constrained within the small area adjacent to the I/O structure in a recessed alcove. As part of Bad Creek II construction, expansion of the submerged weir (in the downstream direction) is being considered; maximum velocities over the proposed expanded weir are 3.5 fps, which are consistent with maximum velocities over the existing submerged weir.

As indicated above, surface velocities under minimum pond could reach 10.0 fps, which could have implications for non-motorized boats moving northward through WWRC, however, the high flows are constrained to the area immediately adjacent to the I/O structure within the recessed area of the shoreline where the proposed I/O will be constructed. Additionally, as shown on Figure 8-9, at minimum pond the area upstream of the proposed I/O is largely dewatered and therefore would not support boating activities regardless of Bad Creek II operations. It should be noted that Lake Jocassee has never been at the licensed maximum drawdown since its creation; maximum drawdown scenarios in this evaluation provide the most conservative hypothetical condition.

[5] A surface velocity map was not generated for the existing intermediate pond level as this scenario was not evaluated as part of the feasibility study; however, it is expected that the results would be similar to Figure 8-13.

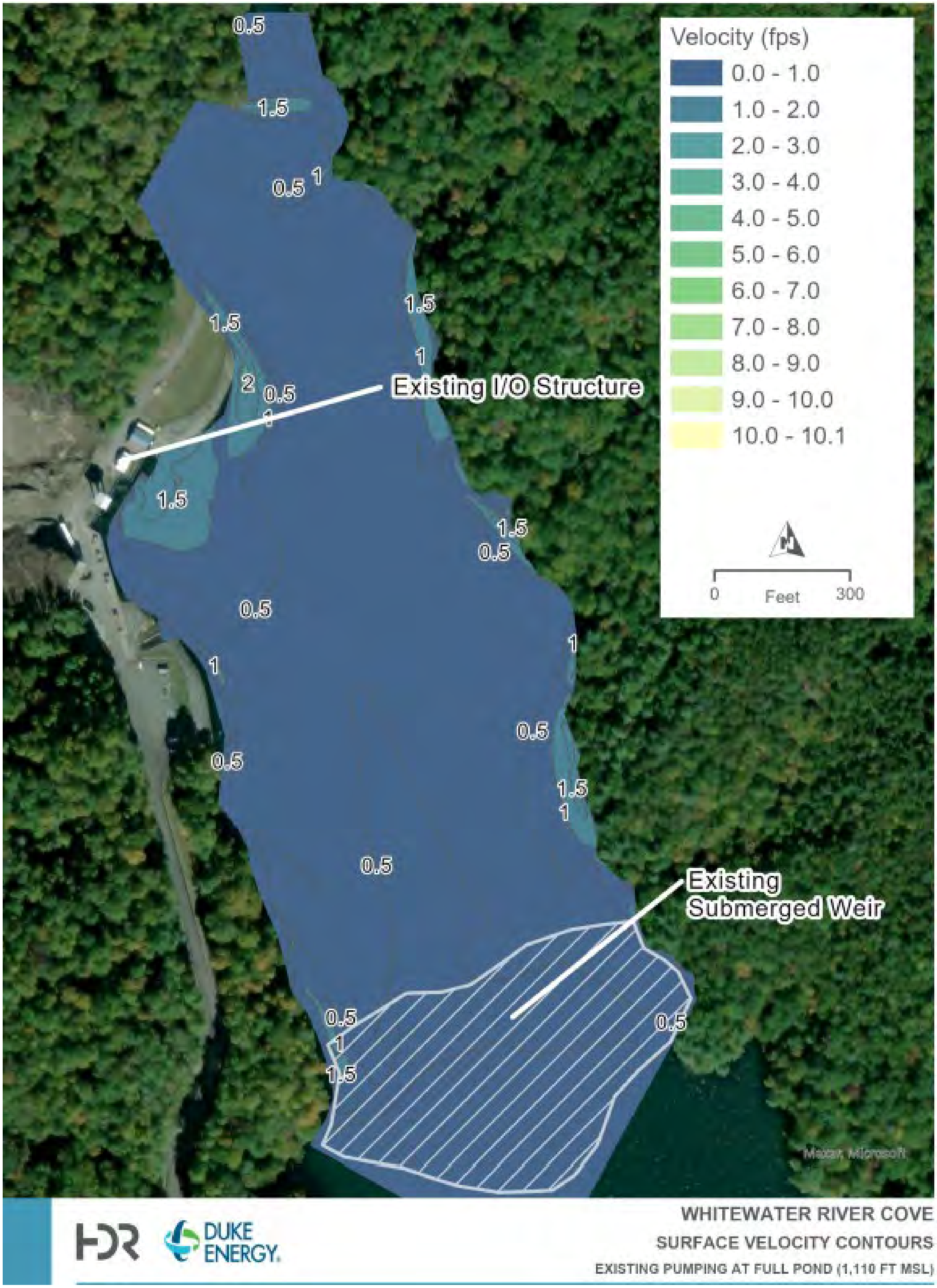


Figure 8-10. Existing Pumping at Full Pond

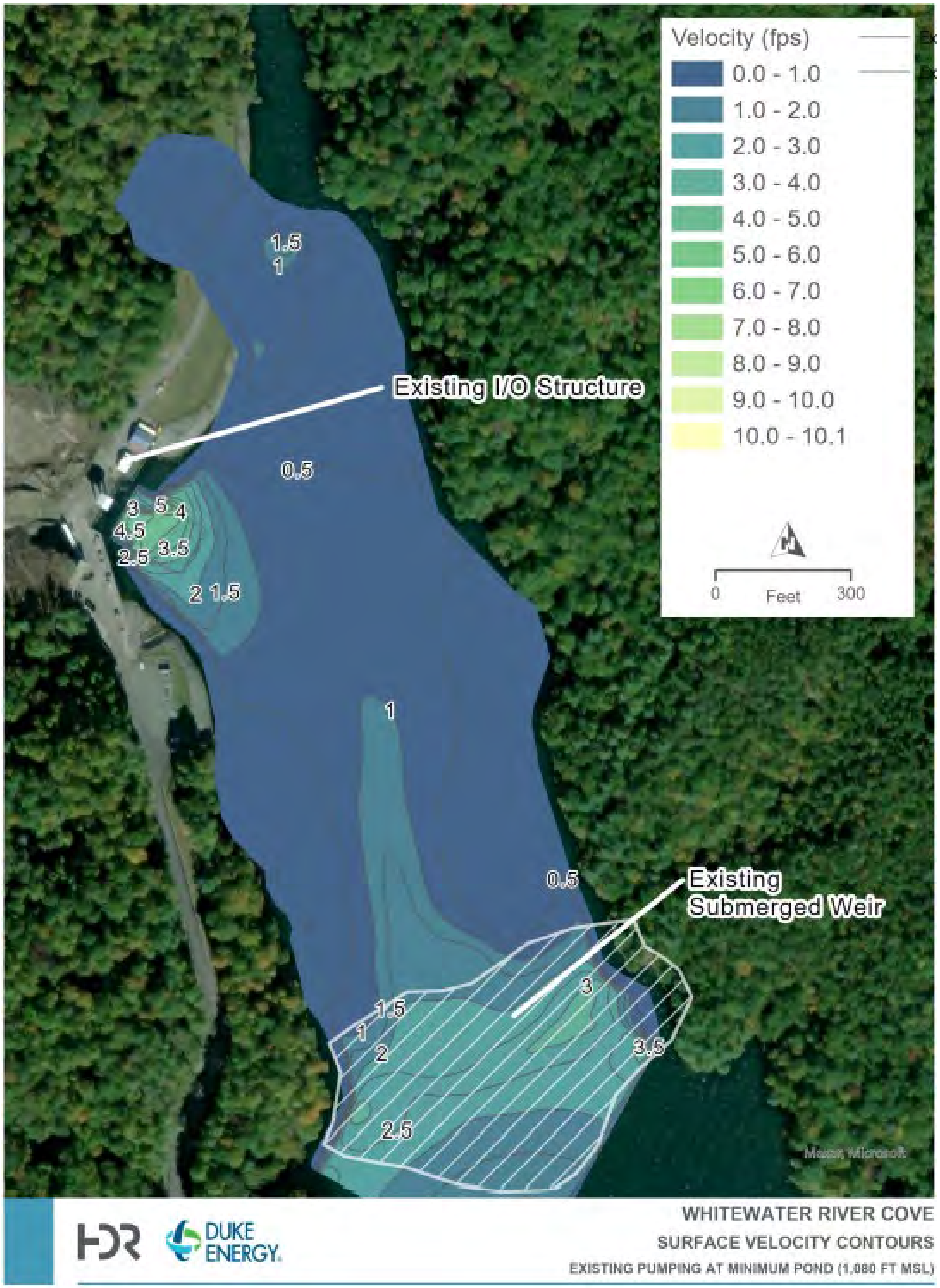


Figure 8-11. Existing Pumping at Minimum Pond

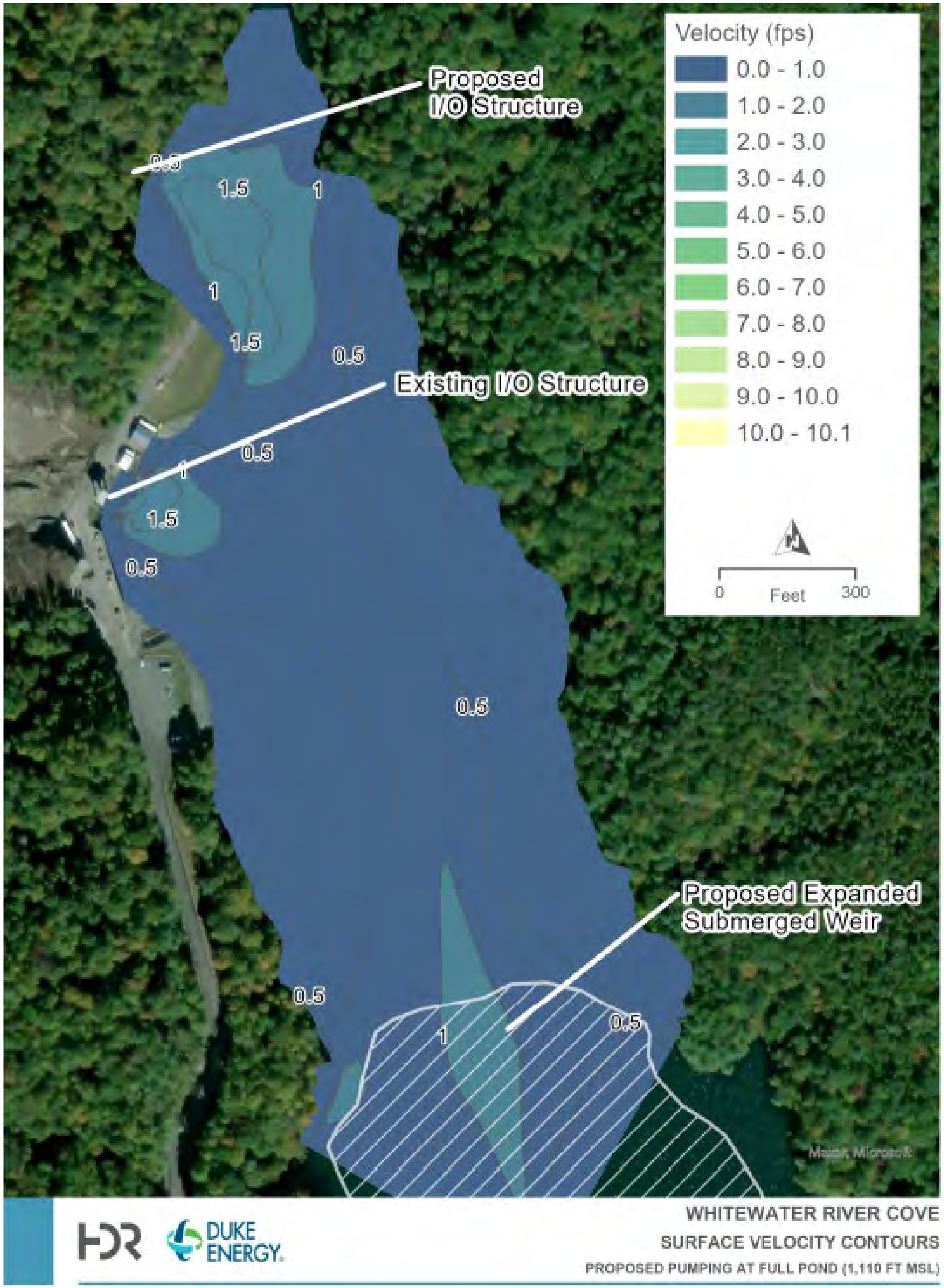


Figure 8-12. Proposed Updated Pumping at Full Pond

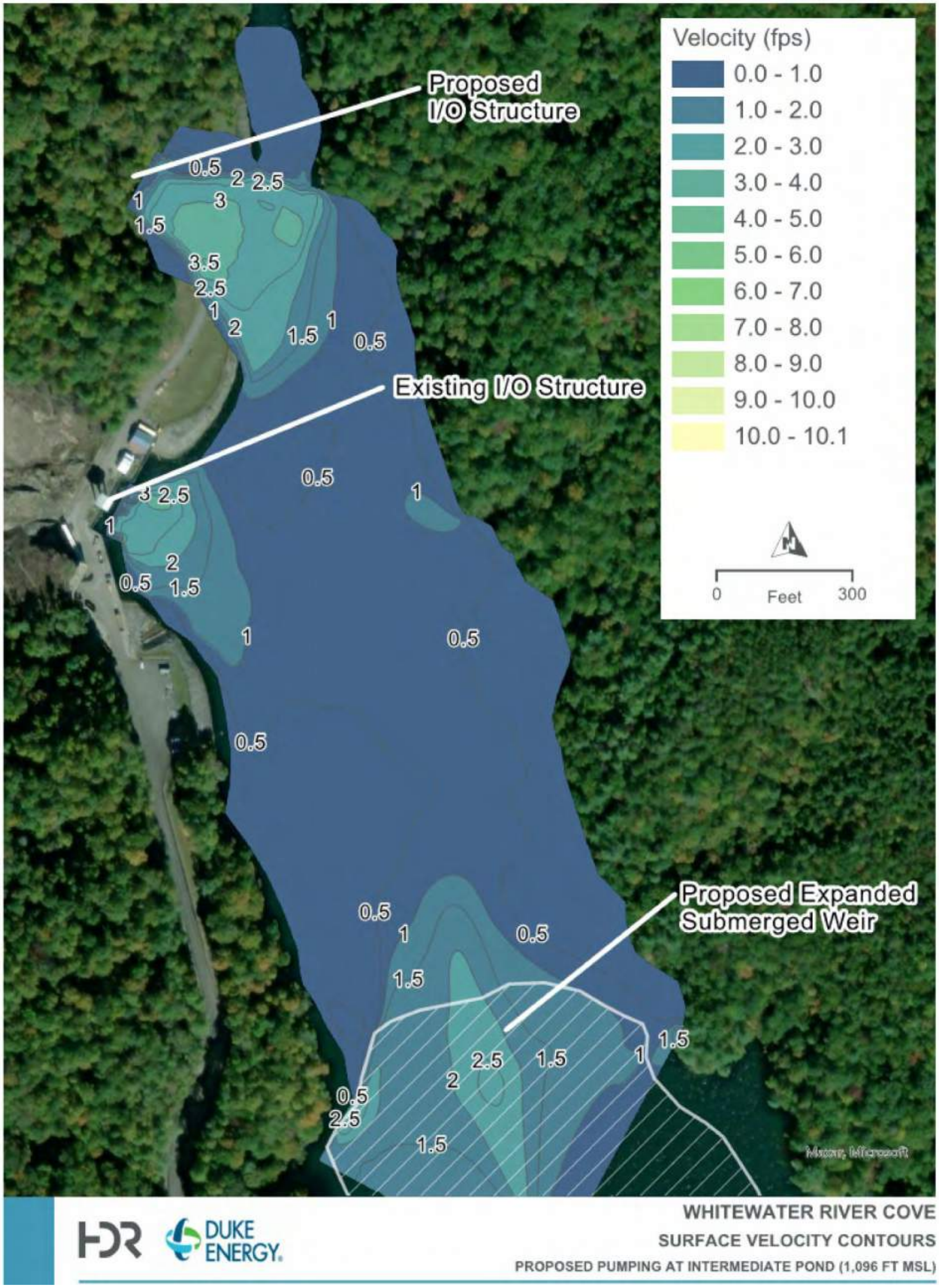


Figure 8-13. Proposed Updated Pumping at Intermediate Pond

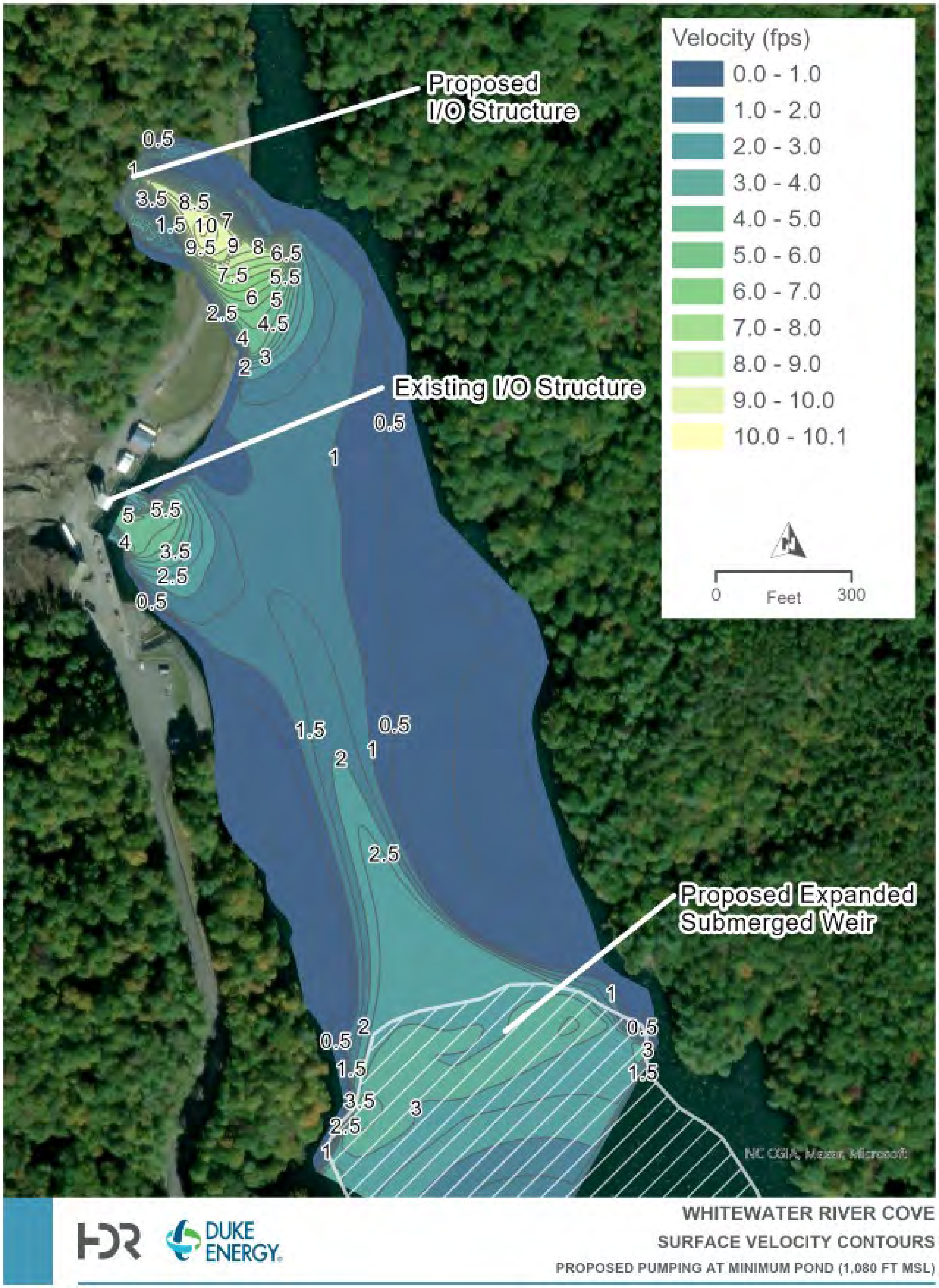


Figure 8-14. Proposed Updated Pumping at Minimum Pond

9 Conclusions

As expected, velocities in the WWRC under all operational scenarios increase with decreased reservoir elevations. As stated in Section 5, Lake Jocassee has never been at the licensed maximum drawdown since its creation and it is worth noting Bad Creek II would likely not operate at maximum hydraulic capacities in the unlikely event of a drawdown (licensed minimum pond level). Therefore, maximum drawdown scenarios with maximum pumping evaluated in this study provide the most conservative results.

As indicated in Section 8.3, surface velocities in the WWRC under minimum pond elevations could reach 10.0 fps, which may have implications for non-motorized boats moving through the WWRC near the Project. To support the relicensing effort, Duke Energy carried out a Whitewater River Cove Existing Recreational Use Evaluation with the goal of characterizing the existing recreational use of Whitewater River cove to inform Duke Energy on the level of boating use disruption that could occur in the cove during the Bad Creek II Complex construction.[6] The final Existing Recreational Use Evaluation, which was developed in consultation with relicensing stakeholders, was filed with Initial Study Report in January 2024. Results of this study, which was carried out from Memorial Day through Labor Day in 2023, showed the majority of boats in Whitewater River cove were motorboats (83 percent), followed by personal watercraft (e.g., jet ski) (10 percent), kayaks (7 percent), and canoes (less than 1 percent); therefore, a minor percentage (<10%) of boaters using the WWRC do so in a non-motorized boat. It is likely from a recreational boater safety perspective, boats would be able to navigate this area of the WWRC by keeping to the east side of the WWRC along the shore opposite the proposed I/O structure since the new I/O structure would be situated approximately 200 ft back from the existing shoreline in a recessed alcove (shown on Figure 6-1). It is important to note that at low reservoir elevations, the northern portion of the WWRC would be dewatered and therefore be inaccessible (depicted on Figure 8-9) as the reservoir bottom elevation in this area is higher than 1,080 ft msl. As a result, boating in this area of WWRC would largely be precluded by low lake levels, regardless of Bad Creek II operations. Duke Energy plans to carry out additional analyses and develop proposed guidelines for boater safety

[6] Whitewater River cove will be closed to recreation during Bad Creek II construction (approximately 7 years) for public safety.

and recreational use under future operations in consultation with relicensing stakeholders; findings from that study will be included in the Updated Study Report.

10 References

HDR Engineering, Inc. (HDR). 2022. Bad Creek II Power Complex Feasibility Study Lower Reservoir CFD Flow Modeling Report. Prepared for Duke Energy. September 1, 2022.

Duke Energy Carolinas, LLC. 2024. Initial Study Report. Bad Creek Pumped Storage Station. Prepared by HDR. January 4, 2024. Available at FERC eLibrary: https://elibrary.ferc.gov/eLibrary/filelist?accession_num=20240104-5044

Attachment 1

Attachment 1 - Updated Pumping Estimated Velocities

					Velocities (fps)											
Operations	Water Surface Elevation (ft)	IO Structure	Flowrate (cfs)	Tunnel	Max velocity in 31-ft Tunnel*	Max at Tunnel Face**	Max - Tunnel Face				Max – 100 ft downstream				Depth Averaged 100 ft Downstream	Depth Averaged 200 ft Downstream
							X	Y	Z	Magnitude	X	Y	Z	Magnitude		
Pumping	1,110	1	16,240	1L	23.0	13.3	6.0	0.6	1.3	**6.2**	1.8	0.7	0.7	**2.1**	**2.0**	No Difference/Lower Velocity
				1R			5.5	0.6	1.3	**5.7**	1.9	0.2	0.4	**2.0**	**1.9**	
				2L		13.3	5.4	0.0	1.1	**5.5**	1.7	0.2	0.2	**1.7**	**1.7**	
				2R			5.8	0.9	1.0	**6.0**	1.7	0.4	0.3	**1.8**	**1.7**	
		2	19,560	1L	27.7	16.0	9.4	0.4	2.4	**9.7**	1.3	0.4	0.5	**1.4**	**1.5**	
				1R			9.6	0.0	1.7	**9.7**	1.7	0.2	0.8	**1.9**	**1.7**	
				2L		16.0	10.0	0.2	1.5	**10.1**	1.9	0.1	0.5	**2.0**	**1.8**	
				2R			9.4	0.4	1.9	**9.6**	1.7	0.3	0.4	**1.8**	**1.7**	
Pumping	1,096	1	16,240	1L	23.0	13.3	7.3	0.1	1.1	**7.4**	2.4	0.0	0.8	**2.5**	**2.4**	No Difference/Lower Velocity
				1R			7.0	0.1	2.5	**7.4**	2.4	0.1	0.3	**2.4**	**2.2**	
				2L		13.3	7.4	0.2	2.1	**7.7**	2.3	0.4	0.3	**2.3**	**2.2**	
				2R			6.3	0.5	3.6	**7.2**	2.3	0.3	0.6	**2.4**	**2.1**	
		2	19,560	1L	27.7	16.0	8.8	0.2	2.5	**9.2**	2.8	0.2	0.4	**2.8**	**2.6**	**3.0**
				1R			8.8	0.3	3.1	**9.3**	3.0	0.3	0.1	**3.0**	**2.7**	**3.1**
				2L		16.0	9.1	0.1	3.3	**9.7**	3.0	0.4	0.1	**3.0**	**2.7**	**3.3**
				2R			9.0	0.8	3.5	**9.7**	3.0	0.5	0.1	**3.1**	**1.9**	**3.4**
Pumping	1,080	1	16,240	1L	23.0	13.3	8.4	0.6	0.3	**8.4**	4.6	1.4	1.9	**5.2**	**4.9**	No Difference/Lower Velocity
				1R			8.1	0.0	1.1	**8.2**	4.7	0.8	0.3	**4.8**	**4.5**	
				2L		13.3	8.0	0.0	1.0	**8.1**	4.5	0.4	0.3	**4.5**	**4.3**	
				2R			7.9	0.0	0.8	**7.9**	4.6	0.8	0.7	**4.7**	**4.6**	
		2	19,560	1L	27.7	16.0	7.3	0.5	0.7	**7.4**	5.2	0.2	1.2	**5.3**	**4.4**	**5.8**
				1R			10.8	0.0	1.6	**10.9**	8.2	0.8	1.2	**8.3**	**7.3**	**8.0**
				2L		16.0	10.1	0.2	1.8	**10.3**	4.7	0.6	0.6	**4.8**	**4.3**	**9.8**
				2R			8.9	0.2	0.6	**8.9**	1.5	0.9	0.3	**1.8**	**1.8**	**9.7**

*Velocities will transition from calculated value based on horseshoe shaped chamber opening to calculated velocity in tunnels (circle shaped) as the geometry transitions, these values should be rough bookends for velocities in the intake structure/tunnel.
**Assumes equal flow distribution between each side of screen face, which is unlikely.

This page intentionally left blank.

Attachment 4

Water Exchange Rates and Lake Jocassee Reservoir Levels

WATER EXCHANGE RATES AND LAKE JOCASSEE RESERVOIR LEVELS

FINAL REPORT

WATER RESOURCES STUDY

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

March 26, 2024

This page intentionally left blank.

WATER EXCHANGE RATES AND LAKE JOCASSEE RESERVOIR LEVELS
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
TABLE OF CONTENTS

TABLE OF CONTENTS
CONTINUED

Section	Title	Page No.

Appendices

Section	**Title**	**Page No.**

LIST OF TABLES

Section	**Title**	**Page No.**

LIST OF FIGURES

TABLE OF CONTENTS
CONTINUED

Section	Title	Page No.

ACRONYMS AND ABBREVIATIONS

Bad Creek (or Project)	Bad Creek Pumped Storage Project
Bad Creek II	Bad Creek II Power Complex
Bad Creek Reservoir	upper reservoir
CFR	Code of Federal Regulations
cfs	cubic feet per second
CHEOPS	Computerized Hydro Electric Operations Planning Software
DCP	Drought Contingency Plan
Duke Energy or Licensee	Duke Energy Carolinas, LLC
EPD	Environmental Protection Division
ft	feet/foot
ft msl	feet/foot above mean sea level
FERC or Commission	Federal Energy Regulatory Commission
HDR	HDR Engineering, Inc.
HEC-DSS	Hydrologic Engineering Center Data Storage System
KT Project	Keowee-Toxaway Hydroelectric Project
LIP	Low Inflow Protocol
OSC	Operating Scenario Committee
PM	Performance Measures
RC	Resource Committee
RSP	Revised Study Plan
SCDNR	South Carolina Department of Natural Resources
SEPA	Southeastern Power Administration
sq mi	square miles
SR	Savannah River
TAF	thousand acre-feet
UIF	unimpaired incremental flow
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
1968 Operating Agreement	1968 Operating Agreement between USACE, SEPA, and Duke Energy
2014 Operating Agreement	2014 Operating Agreement between USACE, SEPA, and Duke Energy

1 Project Introduction and Background

Duke Energy Carolinas, LLC (Duke Energy or Licensee) is the owner and operator of the 1,400-megawatt Bad Creek Pumped Storage Project (Project) (FERC 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 expiration date of 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, 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 developed a Revised Study Plan (RSP) for the Project and proposed six studies for Project relicensing. The RSP was filed with the Commission and made available to stakeholders on December 5, 2022. FERC issued the Study Plan Determination on January 4, 2023, which approved the Water Resources Study in the RSP as proposed.

This study was conducted in consultation with the Water Resources Resource Committee (RC), Aquatic Resources RC, Operations RC, and other interested stakeholders. Copies of consultation records are included in Appendix A of the Updated Study Report. This report includes the findings for Task 4 (Water Exchange Rates and Lake Jocassee Reservoir Levels) of the Water Resources Study.

---

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

2 Study Goals and Objectives

Tasks carried out for the Bad Creek Water Resources Study have been consistent with the scope and level of effort described in the RSP filed with the Commission on December 5, 2022. This report is intended to provide sufficient information to support an analysis of the potential Project-related effects on water resources with clear nexus to the Project.

Operation of the proposed Bad Creek II Power Complex (Bad Creek II), which will add pumping and generating capacity to the Project, has the potential to affect the magnitude, rate, and frequency of water surface elevation changes[2] in downstream reservoirs. Therefore, the objective of this task is to update the existing Computerized Hydro Electric Operations Planning Software™ (CHEOPS) model developed during KT Project relicensing to evaluate reservoir elevation effects associated with water exchange rates, magnitude, and duration between Bad Creek Reservoir and Lake Jocassee. In addition, potential impacts to Lake Keowee levels and fluctuations resulting from operation of Bad Creek II are presented.

3 Study Area

The study area for the modeling effort includes the Bad Creek Reservoir, Lake Jocassee (i.e., the lower reservoir), Lake Keowee (Figure 3-1), and to a lesser extent, the three downstream reservoirs owned and operated by the U.S. Army Corps of Engineers (USACE).

[2] Water levels would be required to conform to the existing requirements of the KT Project License and associated agreements. Additionally, the originally licensed operating band of the upper Bad Creek reservoir (i.e., 160 feet) is not proposed to be modified.

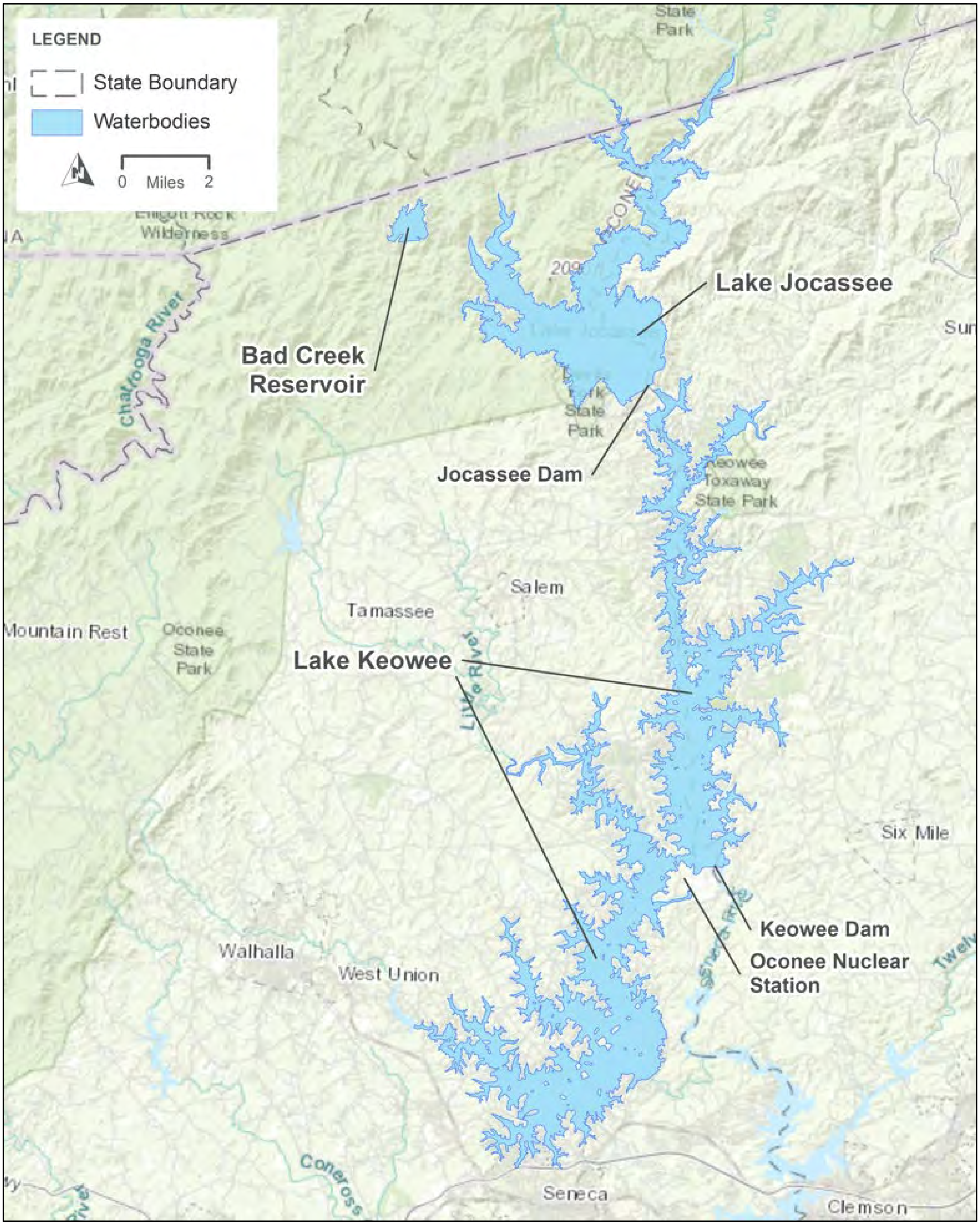


Figure 3-1. Study Area for CHEOPS Evaluation

4 Model Development

4.1 Model Overview

Duke Energy elected to use HDR's proprietary CHEOPS model to assess the effects of operations associated with the addition of Bad Creek II on the system's overall water exchange between the Bad Creek Reservoir and Lake Jocassee. CHEOPS is specifically designed to evaluate the effects of operational changes and physical modifications at multi-development hydroelectric projects. The model is a tool for evaluating a wide range of physical changes and operational constraints associated with relicensing and upgrading hydro facilities. One of the many strengths of the CHEOPS model is the degree of customization available to modelers; it can be tailored to meet the demands of the system being modeled. The CHEOPS program architecture provides a platform for investing project-specific features as defined by stakeholder interests.

CHEOPS utilizes daily flows, plant generating characteristics, and operating criteria of the system to simulate operations, allocate flow releases, and calculate energy production within the system. The model calculates headwater elevation, headlosses, net head, turbine discharge and spill, and power generation. CHEOPS is designed for long-term analysis of the effects of operational and physical changes made to the modeled hydroelectric system.

Modifications to the CHEOPS platform during KT relicensing to support the Savannah River (SR) CHEOPS Model included functionality enhancements enabling simulation of conditions (e.g., Duke Energy Low Inflow Protocol [LIP], and USACE Drought Contingency Plan [DCP]), which were developed during the KT Project relicensing process, as well as improved logic for upstream/downstream plant interactions, specifically with pumped storage plants in the system. The model was also enhanced to add wicket gate leakage for pumped storage plants when in partial pumping operations and the model administrative capabilities were modified to use OpenOffice instead of Microsoft Excel as the application which reads the model input files.

Additionally, a series of SR CHEOPS Model modifications were developed to support specific KT Relicensing Operating Scenario Committee (OSC) member group requests. The modifications included:

- The ability to specify reservoir fluctuation limits that are not a fixed elevation, but rather dependent upon the start-of-period elevation. This feature was added to support the request for fish spawning reservoir stabilization periods identified by the South Carolina Department of Natural Resources (SCDNR), and later was modified to be able to turn off this requirement when the LIP stage is other than "Normal."
- Enhanced support by upstream plants of downstream plant outflow requirements. The outflow enhancements take into account the sum of all required flows on the downstream plant, including required powerhouse outflows, wicket gate leakage, withdrawal requirements, and evaporation. This change prevents an upstream pumped storage or hybrid-pumped storage plant from pumping the downstream reservoir elevation too low when the downstream plant cannot meet its required flows releases.
- Pumped storage plant discharge operations may also be triggered/required without the requisite ability to pump back to support downstream plant outflow requirements.

A CHEOPS model is coded to run day-to-day operations based on a single set of operating conditions or rules. Actual hydroelectric operations generally follow the operating rules; however, human intervention periodically deviates from the general operating rules to accommodate day-to-day realities such as equipment failure and maintenance, changing hydrologic conditions, power demands, and other factors. In addition to differences between model operations versus actual operations that include human interventions, there are also inherent discrepancies due to input data inaccuracies (e.g., differences in calculated hydrology data, turbine or generator efficiencies, or reservoir storage curves). It is important to note CHEOPS model results cannot completely match historical or future operations due to these differences between actual operating conditions and modeled conditions.

4.2 Savannah River (SR) CHEOPS Model

The SR CHEOPS Model was originally developed during 2011-2013 to support relicensing of the KT Project based on input and physical characteristics included in the Savannah River ResSim model (HDR 2014b). It was custom-configured for the Upper Savannah River system based on the specific system constraints such as flow requirements, target reservoir elevations, powerhouse equipment constraints, and reservoir storage balancing between the Duke Energy hydroelectric reservoirs (Bad Creek Reservoir, Lake Jocassee, and Lake Keowee) and downstream USACE hydroelectric reservoirs (Lake Hartwell, Richard B. Russell Lake, and J. Strom Thurmond Lake). Model output was evaluated by the OSC whose members represented relicensing stakeholder interests.

In support of the ongoing Bad Creek relicensing, the SR CHEOPS Model has been updated to reflect both mechanical and operational changes that have occurred since initial model development (i.e., since KT relicensing) and changes anticipated to occur during the term of the new Bad Creek license. These changes include:

- An updated reservoir storage curve for the Upper Reservoir.
- Upgraded units at the Project.[3]
- Requirements of the current KT Project FERC license.
- Updated pumping and generation dispatch tables for both Bad Creek and Jocassee Pumped Storage Station. These tables were revised to reflect anticipated changes in operation at both facilities as additional renewable generation is incorporated into Duke Energy's generation portfolio.

4.3 Model Verification

Model verification is intended to validate the input data and ability of the programmed logic in simulating daily hydroelectric and reservoir operations. HDR performed model verification of the SR CHEOPS Model during KT relicensing by using comparisons of actual and model-simulated generation and total discharge.

Verification of the model was completed using two different scenarios or model runs. The first performed a verification of the model input data, logic, and conditions for calendar years 1998 through 2008. This scenario is referred to as the historical baseline (A1). In addition to the historical baseline scenario, a second verification scenario (v2007) was developed to simulate the

[3] On April 23, 2018, Duke Energy filed a Non-Capacity License Amendment Application to upgrade and refurbish the four Francis-type pump-turbines in the powerhouse, replace existing runners with Francis-type pump-turbine runners, and rehabilitate and/or upgrade the remaining components of the pump-turbine runners at the Bad Creek Project. Authorized Installed and Maximum Hydraulic capacities for the Project were increased to 1,400 megawatts (based upon the definition provided by 18 CFR §11.1[i]) and 19,760 cfs respectively.

detailed operations for calendar year 2007. Based on available historical generation records, modeled and historical generation were compared for the period 1998 through 2008 at all facilities except for Richard B. Russell. Generation at the Richard B. Russell development was only compared for the time period 2006 through 2008 because prior to 2006, Richard B. Russell pump units (four) were rarely operated. Generation data is commonly available for hydropower developments and is a metered value that has good accuracy compared to other forms of data that are not metered or based on estimated values with lower accuracy. The verification simulation was completed for hydrologic years with the best available historical reservoir operations over a wide range of hydrologic and reservoir operations conditions.

Generation is a measure of available flow and storage volume, which relates to inflows and reservoir elevations. When performing verification of water quantity models with power generation, it is common to find discrepancies between observed data and modeled output for generation and reservoir elevation when looking at a small sample of time periods (day, week, or month). This is due to the difference between the set of rules provided in the model vs. the day-to-day decisions common in large power developments that respond to power grid demands as well as storm forecasts and other non-measured impacts on the reservoir and equipment. Modeled results for each verification scenario were compared with historic generation, powerhouse flow, and reservoir levels. In addition to verifying the model under different hydrologic conditions, it was also important to select relatively recent years for model verification under conditions representative of current operating conditions.

As noted previously, the SR CHEOPS Model is coded to run day-to-day operations based on general operating conditions or rules. The model follows these rules strictly, 24 hours per day and 365 days per year, similar to an automated operation. Actual Project operations generally follow the operating rules, but deviations from general operating rules sometimes occur. Therefore, the verification goal is to obtain less than a five percent difference when comparing long-term modeled results to historical generation data over the hydrologic period. In cases where the modeled results exceeded a five percent difference, potential causes for the differences were examined to determine whether the difference was due to deviations in model setup, historical deviations in operations, or discrepancies in the reconstructed hydrology data.

4.3.1 Summary of Modeled Results versus Historical Operations

Verification of the SR CHEOPS Model was performed using historical operations data provided by Duke Energy and the USACE. The modeled flow releases from the hydroelectric facilities were compared to historical data to show whether the model provides a reasonable representation of hydroelectric operations throughout the year (e.g., timing, magnitude, and duration of operations).

The SR CHEOPS Model simulation of the historical baseline scenario (A1) estimated an average annual energy output two percent higher than historical generation for the same period, as shown in Table 4-1. There are significant annual swings in the percent difference between historical and modeled operations for the 1998 through 2008 period, with the largest variations at the Duke Energy facilities (as opposed to USACE facilities).

Table 4-1. Historical Base: Generation Comparison

Year	Bad Creek	Jocassee	Keowee	Hartwell	Richard B. Russell	J. Strom Thurmond	System Total
1998	4%	12%	5%	2%	--	-4%	4%
1999	7%	52%	-20%	0%	--	3%	14%
2000	0%	47%	15%	11%	--	11%	10%
2001	15%	16%	28%	11%	--	2%	14%
2002	5%	-10%	-9%	12%	--	24%	3%
2003	-9%	-9%	28%	24%	--	9%	-2%
2004	12%	-5%	17%	2%	--	4%	6%
2005	-3%	-10%	10%	3%	--	-8%	-4%
2006	5%	1%	-13%	-6%	-4%	-13%	0%
2007	-9%	6%	43%	21%	5%	12%	-1%
2008	-14%	-46%	38%	10%	7%	15%	-16%
Period Total (1998–2008)	**0%**	**1%**	**10%**	**7%**	**2%**	**3%**	**2%**

Note: Prior to 2006, the Richard B. Russell pump units (four) were rarely operated, therefore comparisons consider 2006-2008 only.

Duke Energy facilities are operated on demand with a priority on peaking operations to optimize the value of generation based on energy pricing, whereas USACE facilities are operated on a weekly baseload schedule. The result is that the operations of Duke Energy facilities (especially pumping operations) vary greatly depending on the value of generation. For the period assessed (1998-2008), the Duke Energy system was only required to release water to stay in balance with the system as outlined in the 1968 Operating Agreement[4] regarding stored water sharing (releases) from the then planned KT Project. The USACE system was driven by a combination of the power requirements to SEPA, the system storage balance, and the minimum discharge requirements from the J. Strom Thurmond Development (HDR 2014a).

As shown in Table 4-1, there are significant swings between modeled and historical generation. There are many factors inherent in the model data and setup that can contribute to output discrepancies (i.e., deviations) when compared to historical data. In many cases, several of these factors may be involved simultaneously, which makes it difficult to isolate individual sources of difference. Four examples of potential sources of deviations from historical data are:

- **Pumping Operations –** The model follows a set of defined rules for pumping, but it is seen in the historical records that pumping operations vary greatly from year-to-year, month-to-month, and even day-to-day. This is probably the single greatest contributor to deviations in the generation comparison and is also why the goal of this summary is to compare long-term trends rather than monthly or annual values.
- **Hydrology –** The model uses reconstructed unimpaired flow data as the input for daily inflow to the system. The unimpaired hydrology was synthesized based on streamflow gage data and plant records, both of which have a certain amount of inherent error especially when multiple locations and data sources are involved. The overall hydrologic dataset appears to be a good representation of daily inflows and is acceptable for use in future water management planning.
- **Minimum Streamflow Requirements –** The model is set up to account for minimum streamflow requirements automatically. As a result, the model is proactive in automatically addressing minimum streamflow requirements rather than reactive in providing excess flow to avoid potential violations, as may occur during actual operations.

[4] The 1968 Operating Agreement was an agreement between Duke Energy, the US USACE Savannah District, and the Southeastern Power Administration (SEPA). It was superseded by the 2014 Operating Agreement between the same parties.

- **Unit Outages and Performance –** The model has been set up with post upgrade/rehabilitation unit performance information and does not take into account detailed unit outage information. For example, Units 1 through 4 at Hartwell were rehabilitated over the 11-year period of 1997 through 2007 but unit outages associated with the rehabilitation were not taken into account in the model.

In interpreting the information provided in the model operations/verification report (HDR 2014b), it is important to consider purpose of the model: to reasonably characterize operations at the generation facility under evaluation. Comparing model results with historical data confirms use of the model as a tool for simulating "real" operations. It is not possible within reasonable time and budget constraints to account for every outside influence or condition to match historical operations and hydrology.

Small changes in input data or model logic can often result in large changes in output. This is due to a number of reasons including (but not limited to) runoff characteristics, reliance on coordinated operations, and numerous/variable flow requirements. Each of these elements individually contributes to the sensitivity of the system. Combined, the sensitivity effects are multiplied. The input data and logic in the historical base scenario is an attempt to consolidate the effects of these variables to achieve an approximation of "characteristic operations."

The sensitivity described above also means that those factors that cannot be accounted for in the model (short-term operations decisions based on pricing, demand, forecasts, etc.) as well as data that are impossible to replicate exactly (synthesized hydrology data, shutdowns due to irregular maintenance, etc.) can result in relatively large discrepancies between modeled output and historical data on a per-month/per-development basis. The factors and sensitivity warrant careful model review with awareness of the potential for outliers. The ultimate acceptance of the results should not hinge on the extremes but rather on the overall impression of consistency between modeled and historical operations.

Most importantly, model verification should be used solely to assess the relative impacts between scenarios. In other words, model verification is really the only time it is appropriate to compare model results with historical data. As previously stated, verification is intended to validate the model input data and model logic so the "Base Case" becomes the baseline for all subsequent analyses.

Verification results show the model compares favorably to historical data, reasonably characterizes study area operations, and is appropriate for use in evaluating the effects of alternative operating scenarios. As with any model, accuracy is highly dependent on input data; consequently, model results should be viewed in a relative, rather than absolute, context. The CHEOPS model is a tool that can be successfully used to evaluate the relative sensitivity and response of the Project to changing operational constraints.

For more information about the validation of the SR CHEOPS model, see "Operations Model Study Savannah River Basin Model Logic and Verification Report" (HDR 2014b).

4.4 Project Data

4.4.1 Bad Creek Project

The Project uses the Bad Creek Reservoir as its upper reservoir and Lake Jocassee as its lower reservoir. The approximately 300-acre upper reservoir, formed by the damming of Bad Creek and West Bad Creek, has a drainage area of approximately 1.5 square miles (sq mi). Due to the small drainage area of Bad Creek Reservoir, inflows are minimal. The Bad Creek Reservoir normal maximum reservoir elevation is 2,310 feet (ft) above mean sea level (msl)[5] with a minimum elevation of 2,150 ft msl.

The powerhouse contains four reversible motor-pump/turbine-generator units. There is no license-required operating guide curve; rather the reservoir is operated as needed for generation.

4.4.2 Jocassee Development

Lake Jocassee, which operates as the lower reservoir for the Project, was formed by impounding the Keowee River just downstream of the confluence of the Whitewater and Toxaway rivers. Lake Jocassee has a drainage area of 145 sq mi, a surface area of approximately 7,980 acres, and approximately 92 miles of shoreline at normal full pond (1,110 ft msl). Normal minimum pond elevation is 1,080 ft msl.

[5] All vertical elevations in this report are National Geodetic Vertical Datum 1929 unless noted differently.

The Jocassee Development is a pumped storage facility with four reversible motor-pump/turbine-generator units. The SR CHEOPS Model uses an end of day target elevation of 1,107 ft msl.

The Jocassee Development and the downstream Keowee Development comprise the KT Project.

4.4.3 Keowee Development

Lake Keowee is formed by two parallel watersheds connected by a 2,000-ft-long canal. The watershed draining directly into Lake Keowee is approximately 439 sq mi. The reservoir surface area is approximately 17,660 acres at the normal full pond elevation of 800 ft msl.

Keowee Hydroelectric Station contains two conventional turbine-generator units. For SR CHEOPS modeling purposes, a target curve of 798 ft msl from May 1 to October 15, which then lowers gradually to 797 ft msl on January 1 and refills gradually by May 1, has been simulated to calculate usable storage for coordination with the USACE. Based on a review of historical operations of Lake Keowee, code was added to the SR CHEOPS Model for Lake Keowee to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions (HDR 2014b).

Based on the additional SR CHEOPS Model control at Lake Keowee, the model will not schedule discretionary releases from Lake Keowee unless the reservoir is nearing its normal full pond elevation and available storage for capturing runoff is reduced. This additional logic for Lake Keowee was applied and evaluated through verification of the model. This additional logic is user input whereas the SR CHEOPS Model can be adjusted to evaluate operational alternatives.

4.4.4 Hartwell Development

The Keowee Development releases water into the 55,900-acre Hartwell Lake which is operated by the USACE. Hartwell Hydroelectric Station has five conventional turbine-generator units. The Hartwell Development includes 5 ft of flood control storage from an elevation of 660 to 665 ft msl, which contains approximately 293,000 acre-ft of storage. A flood surcharge zone exists from 665 to 679 ft msl. A seasonally varying guide curve provides additional flood control during the winter and early spring. The minimum pool elevation is 625 ft msl (HDR 2014b).

4.4.5 Richard B. Russell Development

The 26,650-acre Richard B. Russell Lake is impounded by the USACE's Richard B. Russell Dam 30 miles downstream of the Hartwell Dam. The powerhouse contains four conventional turbine-generator units and four motor-pump/turbine-generator units. Two small house turbine-generator units were not modeled as part of the previous SR CHEOPS Model effort.

The Richard B. Russell reservoir includes 5 ft of flood control storage from an elevation of 475 to 480 ft msl. The limited conservation storage range between reservoir elevation 470 and 475 ft msl and fluctuation caused by pumping/generating cycles necessitates a constant guide curve with no seasonal drawdown (HDR 2014b).

4.4.6 J. Strom Thurmond Development

The 71,100-acre J. Strom Thurmond Lake is impounded by the J. Strom Thurmond Dam. The dam is located 37 miles downstream of the Richard B. Russell Dam. The powerhouse contains seven conventional turbine-generator units.

The objective of flood control regulation at the J. Strom Thurmond project is to reduce flood damages to the lower Savannah River basin to the extent possible. Normal pool varies seasonally from 330 ft msl April 1 through October 15; and between October 15 and December 15, the pool is drawn down to a seasonal normal pool of 326 ft msl to allow for the statistically higher winter and spring inflows. Starting January 1, the pool is refilled to reach 330 ft msl on April 1 (HDR 2014b).

4.5 Hydrology

The hydrologic dataset, Savannah River Unimpaired Flow 1939-2008 Time Series Extension Report (ARCADIS 2010), applied in the SR CHEOPS Model was provided by ARCADIS and prepared for Duke Energy, the Savannah District of the USACE, and the Georgia Environmental Protection Division (EPD). The study performed by ARCADIS developed unimpaired incremental flow (UIF) time series data (UIF database dated September 16, 2010) for the five hydroelectric developments on the Savannah River from Lake Jocassee to J. Strom Thurmond Lake. Due to the small size of the Bad Creek watershed, HDR developed the UIF to Bad Creek as a portioned one percent of the developed Jocassee UIF. As outlined in the Savannah River

Unimpaired Flow 1939-2008 Time Series Extension Report released by ARCADIS on August 12, 2010, these data are suitable for the following purposes:

- Reservoir system operational modeling by Duke Energy and the USACE, with the USACE serving as a cooperating agency for the FERC relicensing of Duke Energy's KT Project
- Reservoir operational planning studies by the USACE
- Determination of desired flow regimes and consumptive water-use assessments for Georgia EPD

The excerpt below from Section 1 of the Savannah River Unimpaired Flow 1939-2008 Time Series Extension Report (ARCADIS 2010) defines the methods applied in the development of the UIF time series data. All time series data were supplied in the USACE'S Hydrologic Engineering Center Data Storage System (HEC-DSS) databases.

> *Incremental and cumulative UIFs are developed for the Seneca River at the Jocassee and Keowee sites from historical stream flows and reservoir releases at these locations by removing (1) effects of reservoir regulation (holdouts and releases from storage), (2) differential pre- and post-reservoir net evaporation (i.e., evaporation minus precipitation excess from the reservoir surface area), and (3) consumptive water uses within the respective local drainage areas. General assumptions and methods applicable to UIF development under this study are subsequently described as follows.*

- *The period of record (POR) for UIFs developed under this study uniformly extends from January 1939 through December 31, 2008. UIFs previously developed by Georgia EPD for 1939–2007 (Georgia EPD 2010) were recalculated.*
- *Daily incremental UIFs were developed at the following nodes within the Savannah River basin: Jocassee (Seneca River); Keowee (Seneca River); Hartwell, Richard B. Russell (U.S. Geological Survey [USGS] gage 02189000, Calhoun Falls); Bell (Broad River, USGS gage 02192000); Thurmond, Augusta (USGS gage 0219700); Burtons Ferry (USGS gage 02197500); Millhaven (Brier Creek, USGS gage 02198000); and Clyo (USGS gage 02198500).*

- *Georgia EPD has provided daily potential evapotranspiration (PET) time series data computed using the Hamon equation that extend from January 1, 1939 to December 31, 2008. These have been used in the computation of reservoir evaporation following procedures used in the development of the January 1, 1939 to December 31, 2007 UIF time series.*
- *Federal and non-federal reservoir holdouts, net evaporation, and daily inflows and outflows have been computed and applied as appropriate to UIF derivation. For reservoirs where time series data required for these calculations are not available, run-of-river operation has been assumed. Operational data were provided by Duke Energy, including Bad Creek Reservoir elevation time series data and elevation and outflow time series data for the Jocassee and Keowee projects, in addition to elevation-area-storage paired data for the Keowee and Jocassee projects.*
- *UIF data development has been primarily accomplished by filling and routing of missing 1939 to 2008 historical flow data and by adjustments for reservoir effects and water uses. Techniques may involve application of Riverside's TSTool software and USACE DSS utilities, interactively and by batch programming. All time series and paired data have been stored in HECDSS databases and map-referenced as approved by Georgia EPD. UIF development has largely relied upon time series previously developed by ARCADIS U.S., Inc. (ARCADIS) for Georgia EPD.*
- *Historical water use data, on a daily or monthly time step, have been provided by Georgia EPD in electronic form quality-controlled and suitable for UIF development. Water use data extends from 2005 to 2008.*
- *Routing techniques for observed flow filling and UIF derivation have been selected by ARCADIS for consistency with existing 1939 to 2007 Savannah UIF data previously developed for Georgia EPD.*

Additional information on the development of the UIF is available in the Savannah River Unimpaired Flow 1939-2011 Time Series Extension Report revised by ARCADIS in May 2013 (ARCADIS 2010, 2013).

During the initial stages of the model scenario development phase of the KT Project relicensing process, the OSC identified the desire to have a Savannah River Basin inflow dataset that verified well against the most severe historical drought period on record, the 2007-2008 drought. Through a review of inputs and assumptions used in the SR CHEOPS Model, the OSC concluded there was too much water accounted for in the back calculated incremental inflow time series. The OSC requested an investigation to determine the source of the apparent inconsistency in the inflow time series during 2007-2008 when comparing modeled results to historical data. ARCADIS assisted HDR with a review of the inflow time series development and documentation. The review compared the inflow time series to USACE calculated inflow series and recommended using a different combination of inflow data (from within the September 2010 HEC-DSS database) for all reservoirs with the most significant differences in the Richard B. Russell Lake. These datasets were pulled from the supplied September 2010 HEC-DSS files. The OSC approved revising the model inflow data series in the SR CHEOPS model.

The 1939 through 2008 hydrologic dataset adopted by the OSC in August 2012 was used for KT model relicensing scenario development from September 2010 through December 2012. In the fall of 2012, Duke Energy, following a recommendation from the OSC, funded an extension of the inflow dataset by three years. The inflow dataset was extended by ARCADIS using the same methodology developed to construct the original dataset expanding the period of record (POR) to 1939 through 2011. The final revised dataset was provided by ARCADIS on May 13, 2013, and extended the existing inflow hydrology files in the SR CHEOPS model as described in detail in the May 2013 Savannah River Unimpaired Flow Data Report (ARCADIS 2010, 2013).

4.6 Baseline Scenario

4.6.1 Logic

Figure 4-1 and Figure 4-2 provide an overview of the model logic in sequence.

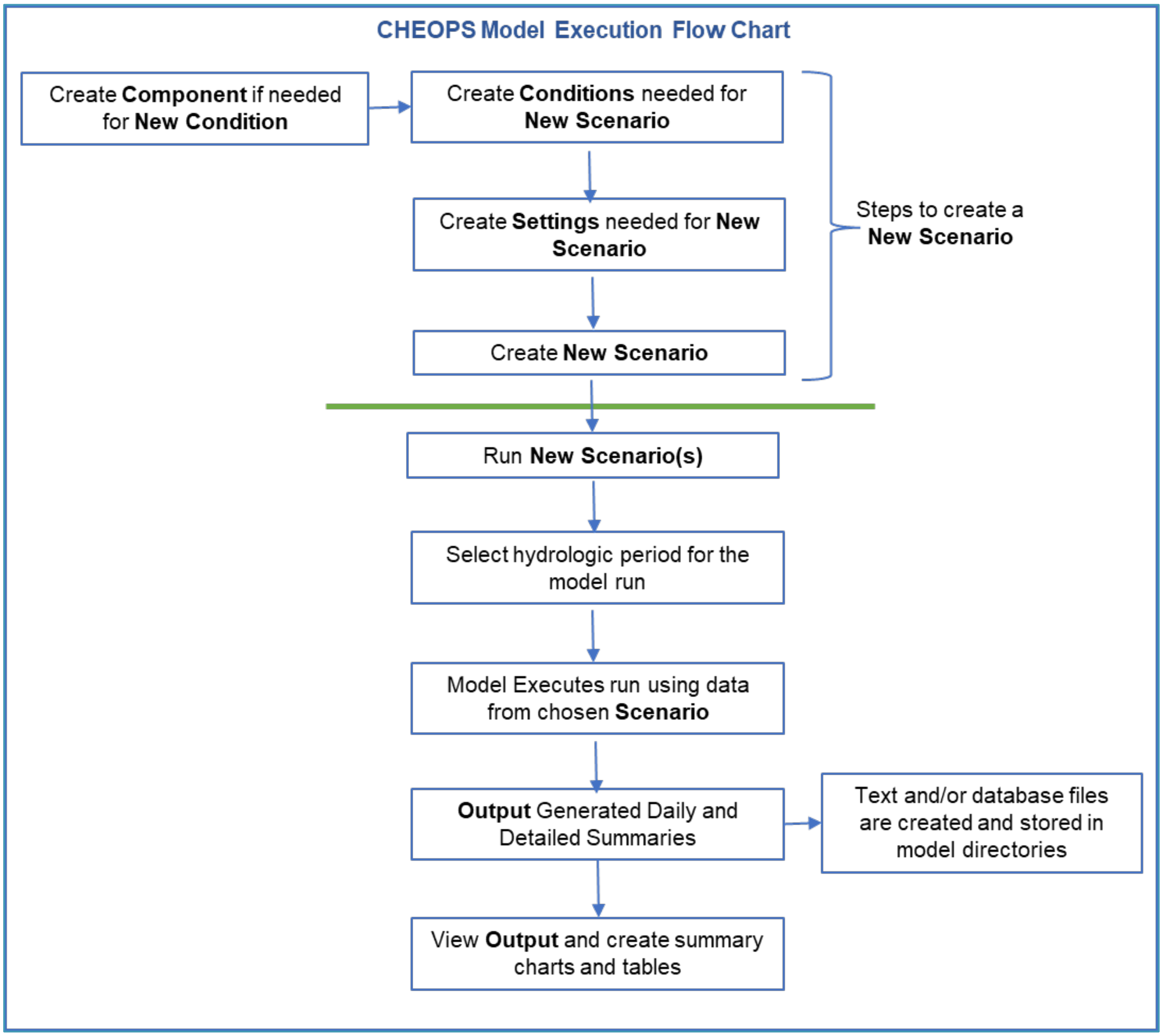


Figure 4-1. CHEOPS Model Execution Flow Chart

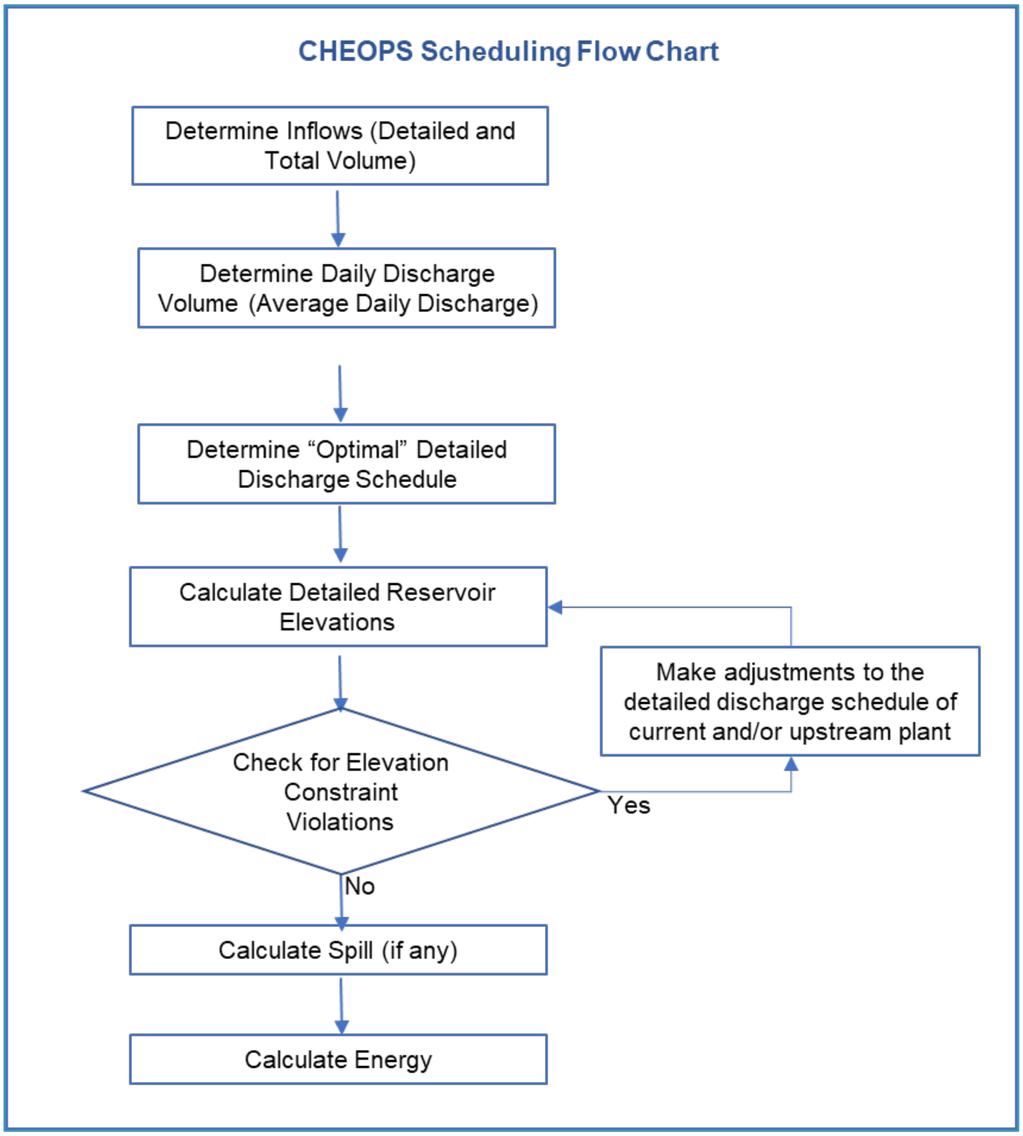


Figure 4-2. CHEOPS Scheduling Flow Chart

4.6.2 Input Data

The input data listed in the following subsections show the general operational constraints and physical parameters used in the SR CHEOPS Model to define the existing system configuration for the Baseline scenario setup. The following subsections are organized by the four components that define a CHEOPS scenario, as shown on Figure 4-3.

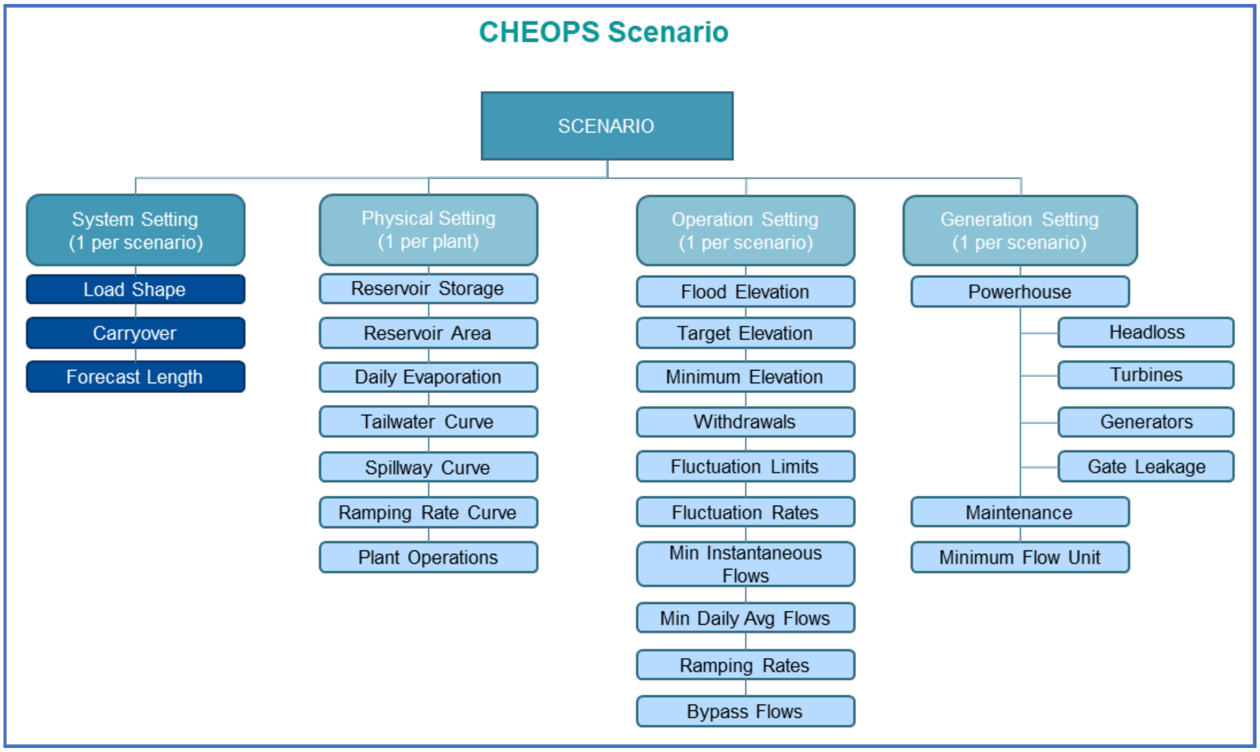


Figure 4-3. CHEOPS Scenario

4.6.3 System Data

4.6.3.1 Load Shapes and Energy Values

This section contains the load shape and energy value data common to the facilities on the Savannah River. The SR CHEOPS Model load shape defines the daily schedule, on an hourly basis, of relative power pricing and the hour durations of each price in the peak, off-peak, and shoulder periods, as presented in Table 4-2 and Table 4-3. The model uses the load shape data to schedule the release of water throughout the day, prioritizing generation during peak periods. Durations for the load shape reflect anticipated changes in operation as additional renewable generation is incorporated into Duke Energy's generation portfolio.

Table 4-2. Load Shape – Weekday Schedule

Weekday Schedule (hours/day)						
Month	**Morning Off Peak**	**Morning Secondary Peak**	**Morning Peak**	**Afternoon Secondary Peak**	**Afternoon Peak**	**Evening Secondary Peak**
January	1	5	2	10	3	3
February	1	5	2	10	4	2
March	1	5	2	11	2	3

Weekday Schedule (hours/day)						
Month	**Morning Off Peak**	**Morning Secondary Peak**	**Morning Peak**	**Afternoon Secondary Peak**	**Afternoon Peak**	**Evening Secondary Peak**
April	1	5	2	11	2	3
May	1	5	1	13	1	3
June	1	0	2	17	2	2
July	1	0	2	17	2	2
August	1	0	1	18	2	2
September	1	5	2	11	1	4
October	1	5	2	10	2	4
November	1	5	2	10	3	3
December	1	5	2	10	1	5

Table 4-3. Load Shape – Weekend Schedule

Weekend Schedule (hours/day)					
Month	**Morning Off Peak**	**Morning Peak**	**Afternoon Off Peak**	**Afternoon Peak**	**Evening Off Peak**
January	5	3	10	4	2
February	5	3	10	3	3
March	6	2	11	2	3
April	5	3	11	2	3
May	1	7	12	2	2
June	1	7	12	2	2
July	1	3	15	4	1
August	1	3	15	4	1
September	1	3	16	3	1
October	1	2	16	4	1
November	6	2	9	5	2
December	6	2	9	6	1

4.6.3.2 Carry-Over Elevations Condition

The Carry-Over Elevations Condition controls how to treat the beginning-of-year and end-of-year elevations. The model begins a run (scenario simulation) on January 1 of the start year with each reservoir at its target elevation. If the scenario is run for a multiple year period, then the model can either start subsequent years with the reservoirs at the target elevations or at the end of previous year elevations.

The Carry-Over Elevations is selected (i.e., the checkbox is checked) in this model. Therefore, the model will carry-over the end-of-year elevations to the next year, and reservoirs will start the next year at the ending elevations of the previous year.

4.6.3.3 Forecast Set-Up Condition

The Forecast Set-Up Condition requires two inputs: a number of forecast days, and an accuracy of the forecast. The number of days is how many days the model looks ahead in the inflow file to calculate how much water the system is going to receive. The model is set up to look 1 day ahead with 100 percent accuracy. Since the model has "perfect" forecasting as it looks at the actual inflow file, the accuracy setting allows the user to adjust the model's ability to forecast accurately. The accuracy setting adjusts inflow by a fixed multiple. The model looks ahead the given number of days, adds up the inflows, multiplies those inflows by the entered accuracy value, then schedules releases based on this forecasted inflow volume. If the accuracy setting is not 100 percent (1.0), then the forecasted volume is not accurate. By running the model with 90 percent (0.9) accuracy, and then running again at 110 percent (1.1) accuracy, the user can simulate operations where the operator has an ability to forecast inflows plus or minus 10 percent.

4.6.3.4 Operating Agreement (Storage Balance Operations)

This section provides details of the storage relationship between the Duke Energy and USACE facilities resulting from the development of the 2014 Operating Agreement which is implemented as part of the Baseline scenario for use during ongoing Bad Creek relicensing.

On October 1, 1968, Duke Energy's predecessor company, Duke Power Company, entered into 1968 Operating Agreement with the USACE Savannah District and SEPA regarding stored water sharing (releases) from the planned KT Project. The 1968 Operating Agreement was replaced by the 2014 Operating Agreement in conjunction with KT Relicensing.

The 2014 Operating Agreement defines balancing of the available storage in Duke Energy reservoirs (Bad Creek, Jocassee, and Keowee) with USACE available storage (Hartwell, Richard B. Russell, and J. Strom Thurmond) according to storage balance rules as outlined in the 2014 Operating Agreement. The SR CHEOPS Model incorporates the terms of the 2014 Operating Agreement through a series of programming rules where balance checks are performed on weekly basis. These rules are integral in simulating the storage relationships between the developments and significant time was spent refining these rules in the SR CHEOPS Model.

When a tandem or parallel reservoir system is defined within the SR CHEOPS Model, the model determines the priority and the amount of release to make from each reservoir to operate towards a user-defined storage balance. For every decision interval, an end-of-period storage is first estimated for each reservoir based on the sum of beginning-of-period storage and period average inflow volume, minus all potential outflow volumes. The estimated end-of-period storage for each reservoir is compared to a desired storage that is determined by using a system storage balance scheme. The priority for release is then given to the reservoir that is furthest above the desired storage. When a final release decision is made, the end-of-period storages are recomputed. Depending on other constraints or higher priority rules, system operation strives for a storage balance such that the reservoirs have either reached their guide curves or they are operating at the desired storage (percent of the active storage zone).

The storage balance operations of the system are simulated in CHEOPS using an OpenOffice-based input sheet referenced by the CHEOPS drought plan input. Each reservoir in the system from Lake Jocassee to J. Strom Thurmond Lake is simulated with a drought plan. The USACE developed and updated the DCP to help sustain the basin's water supply needs for domestic and industrial water users, navigation, and environmental protection. To decelerate the decline in reservoir elevations during the early stages of drought, the USACE reduces weekly average flow releases from the Hartwell and J. Strom Thurmond developments. Once the DCP has been activated, flows are reduced in a step-wise fashion starting with a reduction of downstream releases from J. Strom Thurmond Lake. Reservoir elevations at Lake Hartwell and J. Strom Thurmond Lake are kept in balance during both normal and drought conditions.

During 1988 drought conditions, the J. Strom Thurmond and Hartwell Lakes were almost 17 and 15 ft below the top of their conservation pools, respectively. (The conservation pool is the amount of usable storage in the reservoir.) Accordingly, during the 1988 drought period, the USACE was not able to fully meet authorized project purposes. This led the USACE to initially develop the 1989 DCP with three trigger levels (USACE 1989). In 2006, the DCP was revised to include a fourth trigger level. The 2006 DCP allows the USACE to maintain higher pools at the reservoirs without further impacts to any water intakes upstream or downstream of the dams. In

2012, the DCP flows required out of J. Strom Thurmond Lake were revised, along with the addition of an inflow trigger.

The reservoir storage at the Bad Creek Project and Richard B. Russell developments are not included in the DCP. However, for model stability purposes and implementation of the KT LIP, Bad Creek reservoir and Richard B. Russell Lake storage are included in the CHEOPS Model storage index calculations while using a rule-link but no reservoir storage adjustments are required. Each reservoir in the system is linked to its downstream reservoir (except as noted) with a system storage balance relationship. The storage balance definition defines the rate of drawdown at each reservoir in relation to the next downstream reservoir and is user definable. The application of the storage balance definition simulates the system in accordance with the 2014 Operating Agreement and the USACE DCP.

4.6.3.5 Low Inflow Protocol (LIP)

This section provides details of the SR CHEOPS Model functionality to simulate the LIP.

The LIP specifies how Duke Energy will operate the Bad Creek and KT Projects during droughts. The LIP includes five stages based on specific triggers (i.e., remaining usable storage and DP levels, stream flows, and the U.S. Drought Monitor[6]). The LIP also specifies maximum reservoir drawdowns and maximum downstream flow releases from Keowee Hydro Station based upon the specific LIP stage. It should also be noted the remaining usable storage for determination of LIP stage (only applicable at Duke Energy reservoirs) is based on normal full pond elevations.

The SR CHEOPS Model incorporates the terms of the LIP as outlined in the KT Project FERC license through a series of programming rules. The LIP functionality was added to the SR CHEOPS during KT Relicensing to enable LIP stage definitions and specify required actions for each LIP stage. Model logic measures, on the specified day, the Duke Energy usable storage based on full pond elevations and gage hydrology, then implements the LIP stage change after the appropriate delay. The LIP adds Bad Creek and Richard B. Russell reservoirs to the USACE

[6] The U.S. Drought Monitor is produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the National Oceanic and Atmospheric Administration, and the U.S. Department of Agriculture. It blends precipitation, streamflows, temperatures, evaporative demand, and other factors to interpret drought conditions.

DCP usable storage calculations, which required modifications to the USACE DCP input file. The modifications to the USACE DCP file to reflect the LIP include specifying whether to include the Bad Creek and Richard B. Russell reservoirs in the usable storage calculation, and also provided cells for inputting the elevation which is considered bottom of usable storage pool for all six reservoirs.

Additional SR CHEOPS model parameters associated with the LIP include:

- The minimum elevation for Lake Keowee is 790.0 ft msl. However, the elevation will remain above 791.5 ft msl until the Duke Energy system remaining usable storage is at or below 12 percent (see Table 4-4).
- The percentage of Duke Energy remaining usable storage at which the outflow from Lake Keowee is limited to evaporation, water use, and leakage is 12 percent.
- The LIP minimum reservoir elevations for each LIP stage as listed in Table 4-4.
- The Lake Keowee water release calculation uses 790.0 ft msl as the minimum Lake Keowee reservoir elevation for the calculation of Duke Energy remaining usable storage.
- The Jocassee minimum reservoir elevation for the calculation of Duke Energy remaining usable storage is 1,080.0 ft msl.
- Full pond at the Duke Energy reservoirs is defined as the maximum elevation in the remaining usable storage calculation.
- The volume of storage in the Bad Creek Upper Reservoir from elevation 2,310.0 ft msl to 2,150.0 ft msl is included in the calculation of Duke Energy storage balancing contribution with the USACE system.
- The volume of storage in the Richard B. Russell reservoir between elevations 475.0 ft msl and 470.0 ft msl is included in the USACE remaining usable storage balancing calculations.

The Baseline scenario references USGS gage averaging using a 4-month rolling average and LIP logic to reference “triggered” DCP level versus “in-effect” DCP level during LIP recovery. The referenced DCP level allows the LIP to change more quickly to a lower stage number during the recovery process, eliminating the 2-ft recovery delay in the USACE’s DCP.

Table 4-4. Lakes Jocassee and Keowee Low Inflow Protocol Stage Minimum Elevation

LIP Stage	Lake Jocassee Elevation (ft msl)	Lake Keowee Elevation (ft msl)
0	1,096.0	796.0
1	1,092.0	795.0
2	1,087.0	793.0
3	1,083.0	792.0
4	1,080.0	791.5*

*Note: In LIP Stage 4, the Keowee reservoir elevation will be maintained at or above 791.5 ft msl until the Duke Energy storage balance reaches 12 percent. The minimum elevation used to calculate the usable storage for storage balancing with the USACE is 790.0 ft msl.

Additionally, LIP/DCP functionality includes the following logic:

- Functionality to allow the user to limit spring lake stabilization to LIP Stage 0 (Normal).
- Functionality to allow the user to specify that the USACE and Duke Energy reservoir storage balancing logic use full pond elevation versus target elevation at Duke Energy reservoirs for calculations of usable storage.
- Functionality to fine-tune simulated Lake Keowee operations and limit discharge from Lake Keowee by allowing the user to define a percentage above the target curve (published in the 1968 Operating Agreement) for the model to attempt to maintain a Full Pool.
- Functionality to allow the user to define two Maximum Required Weekly Release volumes from Lake Keowee for LIP Stage 4. The first is based on a Duke Energy Percent Usable Storage Remaining trigger and the second is the default if less than the defined Duke Energy Percent Usable Storage Remaining.
- Functionality to allow the user to revise the LIP logic to reference “triggered” DCP level versus “In-Effect” DCP level during LIP recovery. This allows the LIP to more quickly change to a lower stage number during recovery process, eliminating the 2-foot recovery delay in DCP protocol.
- Ability to set lake level fluctuation base elevation to be set at the lowest instantaneous elevation from the day prior to the start of the lake stabilization period.

4.6.3.6 System Power

The USACE developments have a power generation requirement with SEPA to achieve a minimum generation value (HDR 2014b). The weekly generation requirement can be met by any combination of the three USACE plants, and the requirement value varies by month. The weekly targets are based on power contracts with SEPA, as listed in Table 4-5. These values are currently entered into the model in the Drought Plan input sheet.

Table 4-5. Weekly Target Generation from USACE Projects

Month	Weekly Target Generation (megawatt-hours)
January	27,233
February	26,714
March	20,669
April	18,504
May	21,948
June	25,935
July	31,195
August	32,035
September	30,685
October	27,304
November	26,284
December	27,104

4.6.4 Physical Data

4.6.4.1 Reservoir Storage Curves

The Reservoir Storage Curve is a tabulated link between the reservoir elevation and reservoir volume. The model uses this curve to calculate elevations based on inflows and model-determined releases. Figure 4-4 shows the Bad Creek reservoir storage curve based on LiDAR data collected in 2018.[7] The Lake Jocassee and Lake Keowee storage-volume relationships were based on bathymetric data collected in 2010 (Figure 4-5 and Figure 4-6) and the USACE storage-volume relationships for Hartwell, Richard B. Russell, and J. Strom Thurmond lakes (Figure 4-7 through Figure 4-9) were based on published storage-volume relationships revised based on applying regional sedimentation rates from the Savannah River basin. Sedimentation rates were converted to sediment volume using methods outlined in USACE Engineer Manual 1110-2-4000 and estimated compressed density of the sediment[8].

[7] Values for 2110 feet and lower are based on historic 1974 data.

[8] Storage volume curves for the USACE reservoirs are identical to those used during KT relicensing. No additional sedimentation was calculated.

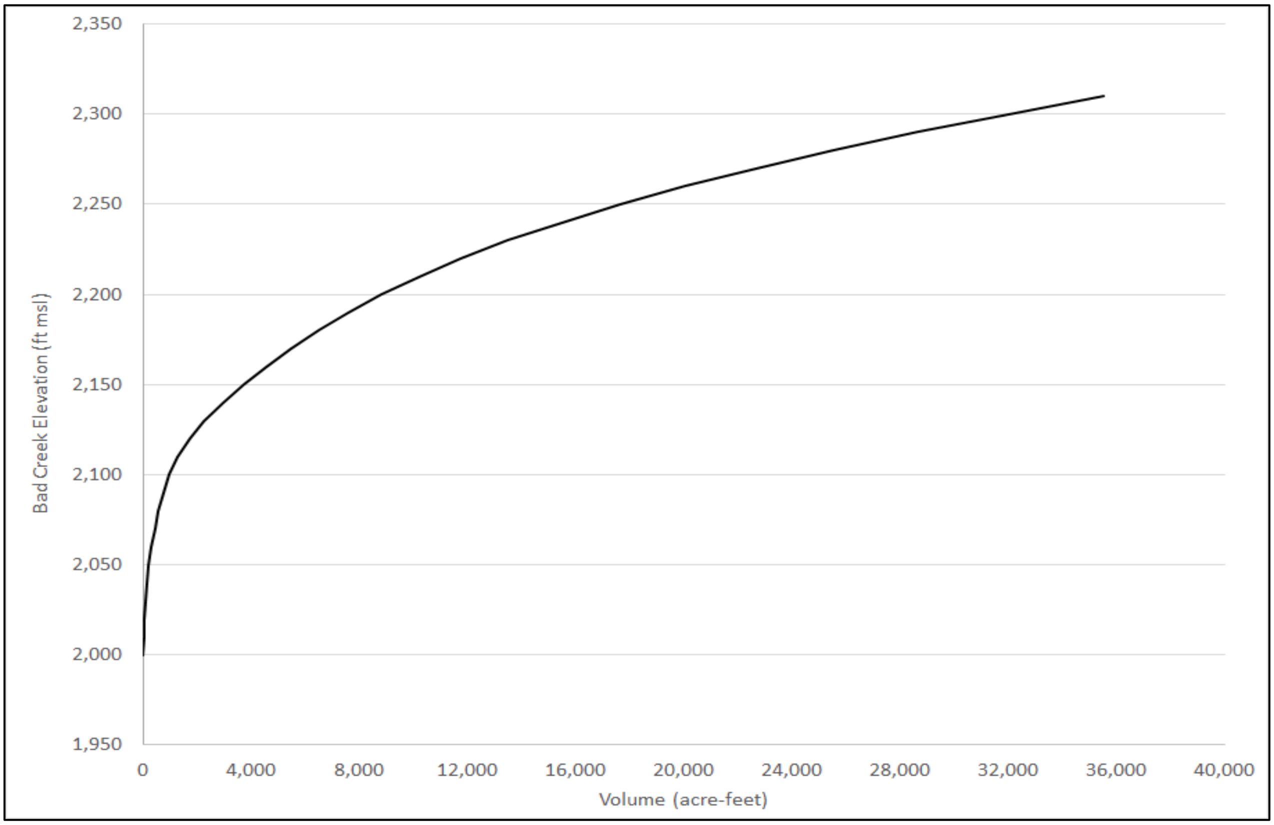


Figure 4-4. Bad Creek Reservoir Storage Volume Curve

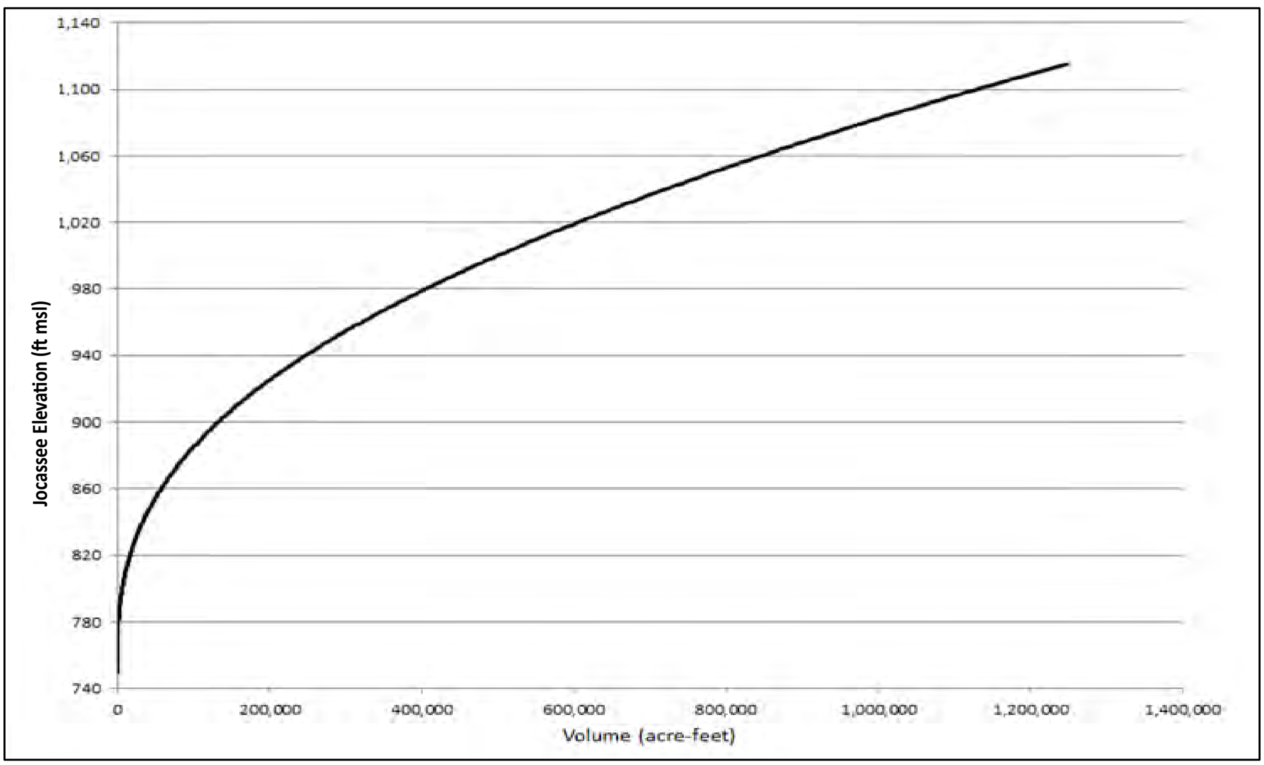


Figure 4-5. Jocassee Reservoir Storage Volume Curve

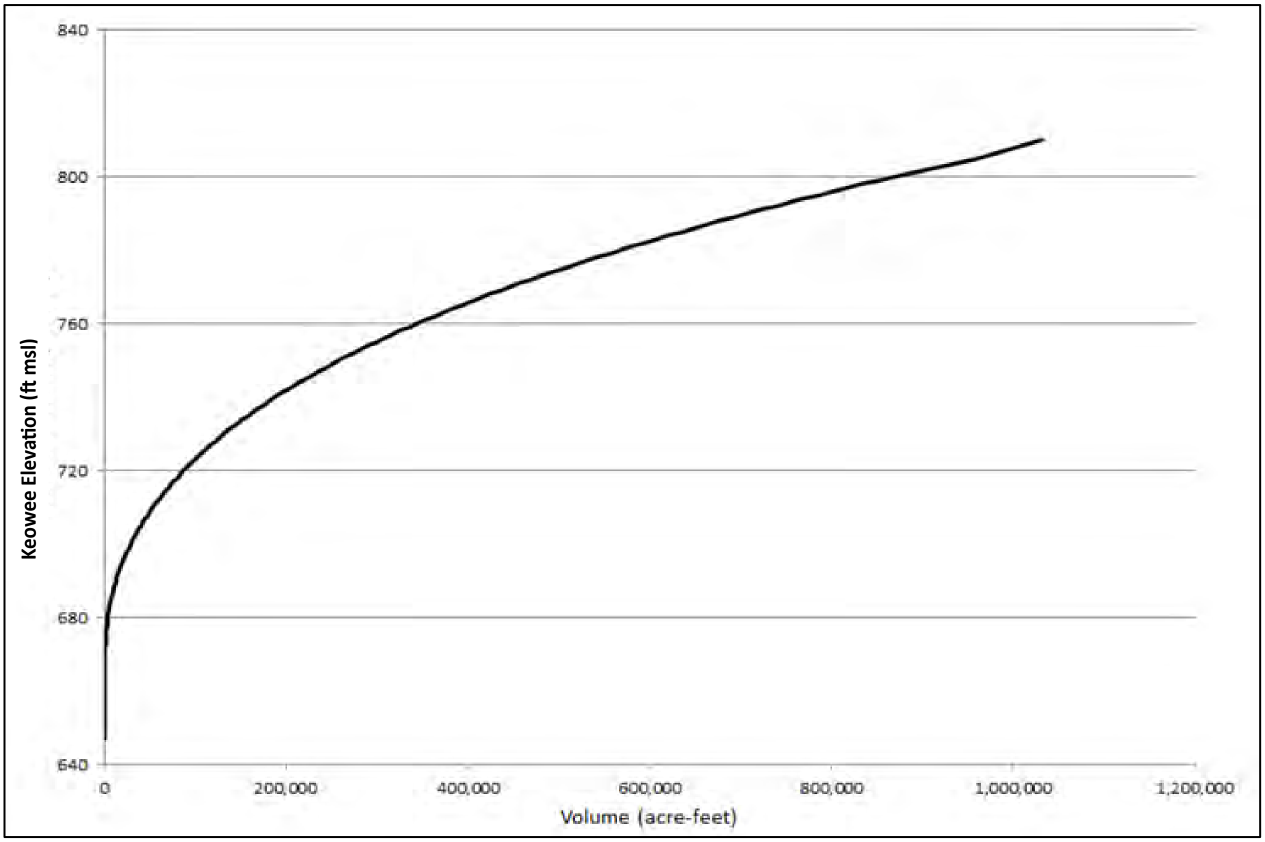


Figure 4-6. Keowee Reservoir Storage Volume Curve

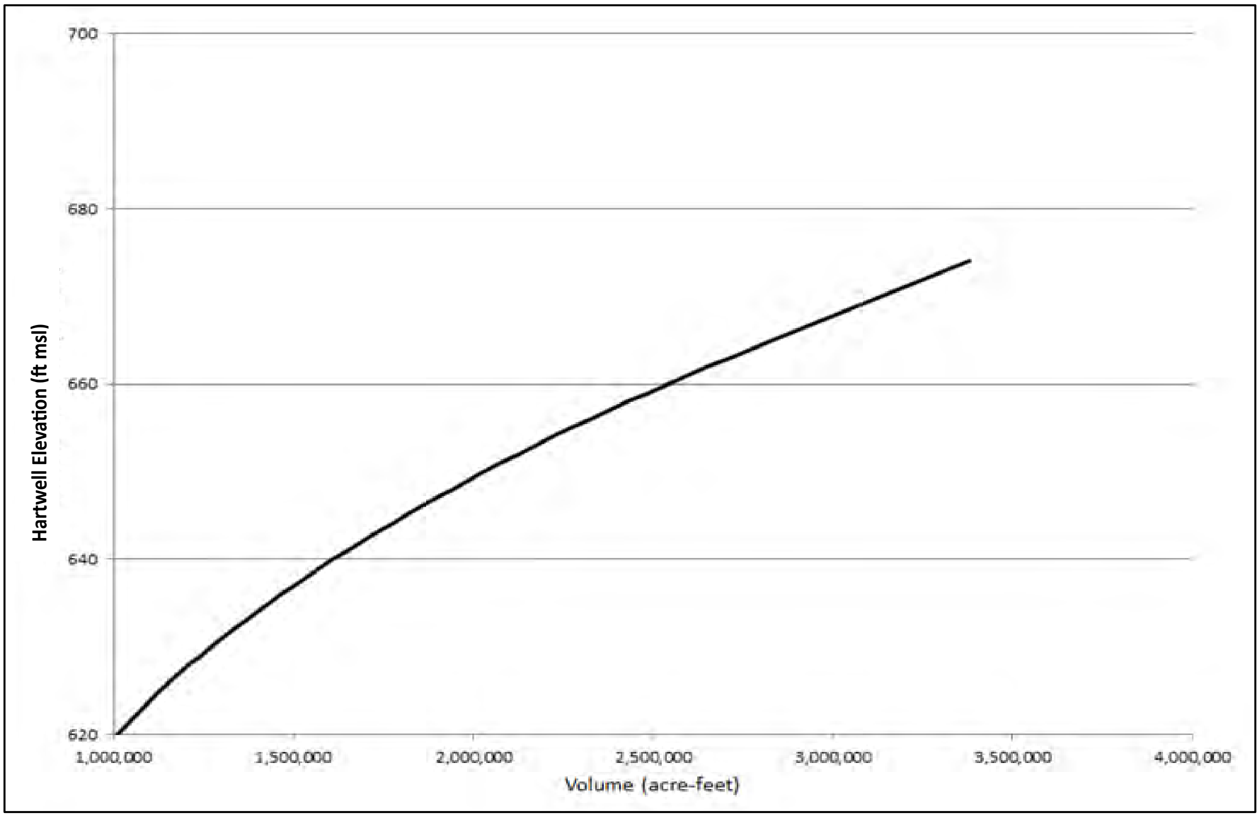


Figure 4-7. Hartwell Reservoir Storage Volume Curve

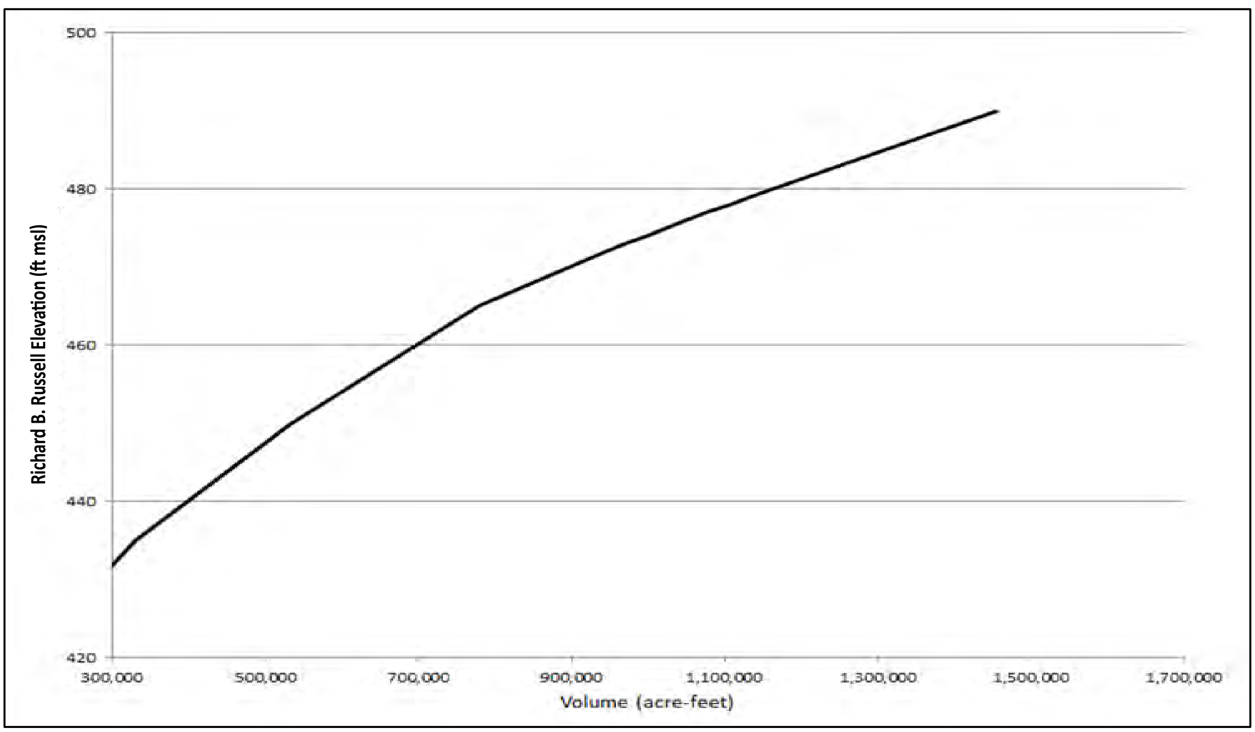


Figure 4-8. Richard B. Russell Storage Volume Curve

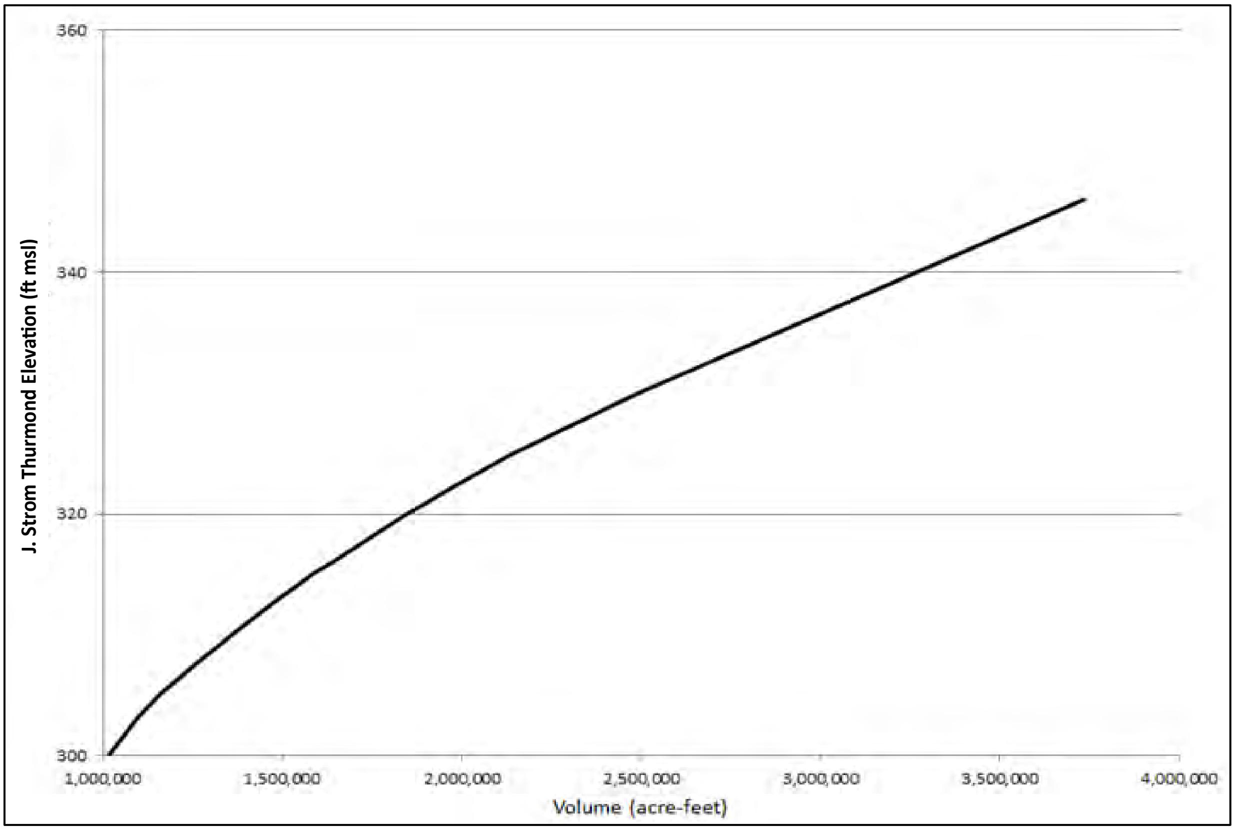


Figure 4-9. J. Strom Thurmond Reservoir Storage Volume Curve

4.6.4.2 Reservoir Area Curves

The Reservoir Area Curve is a tabulated link between the reservoir elevation and reservoir surface area. The model uses this curve to calculate the surface area and uses this data for computing evaporation losses. Figure 4-10 through Figure 4-15 show the reservoir area curves used in the model.

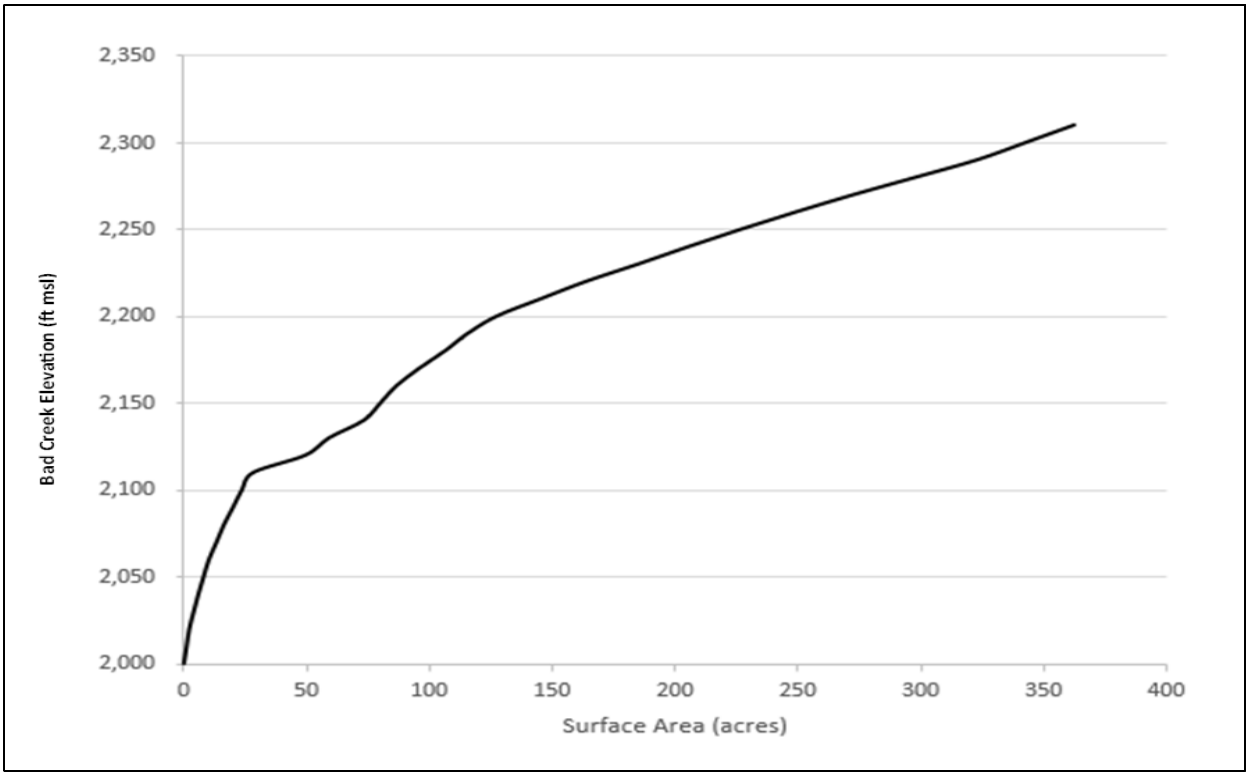


Figure 4-10. Bad Creek Reservoir Area Curve

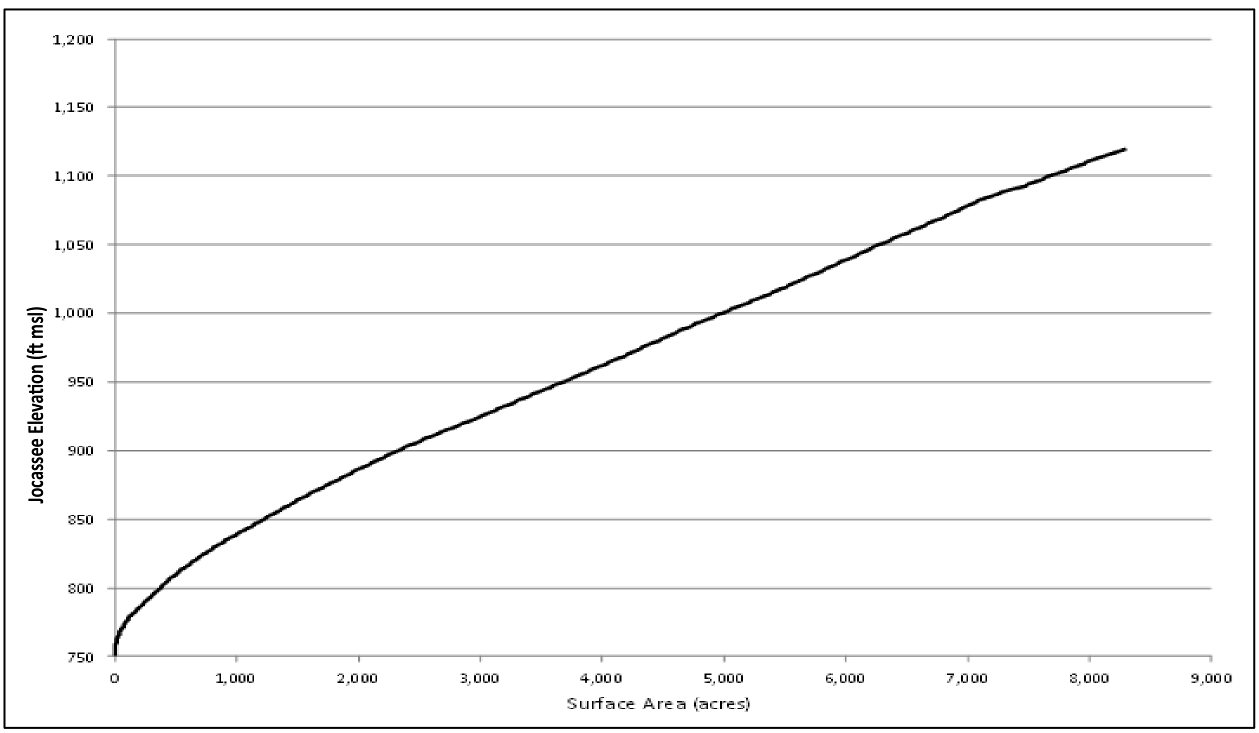


Figure 4-11. Jocassee Reservoir Area Curve

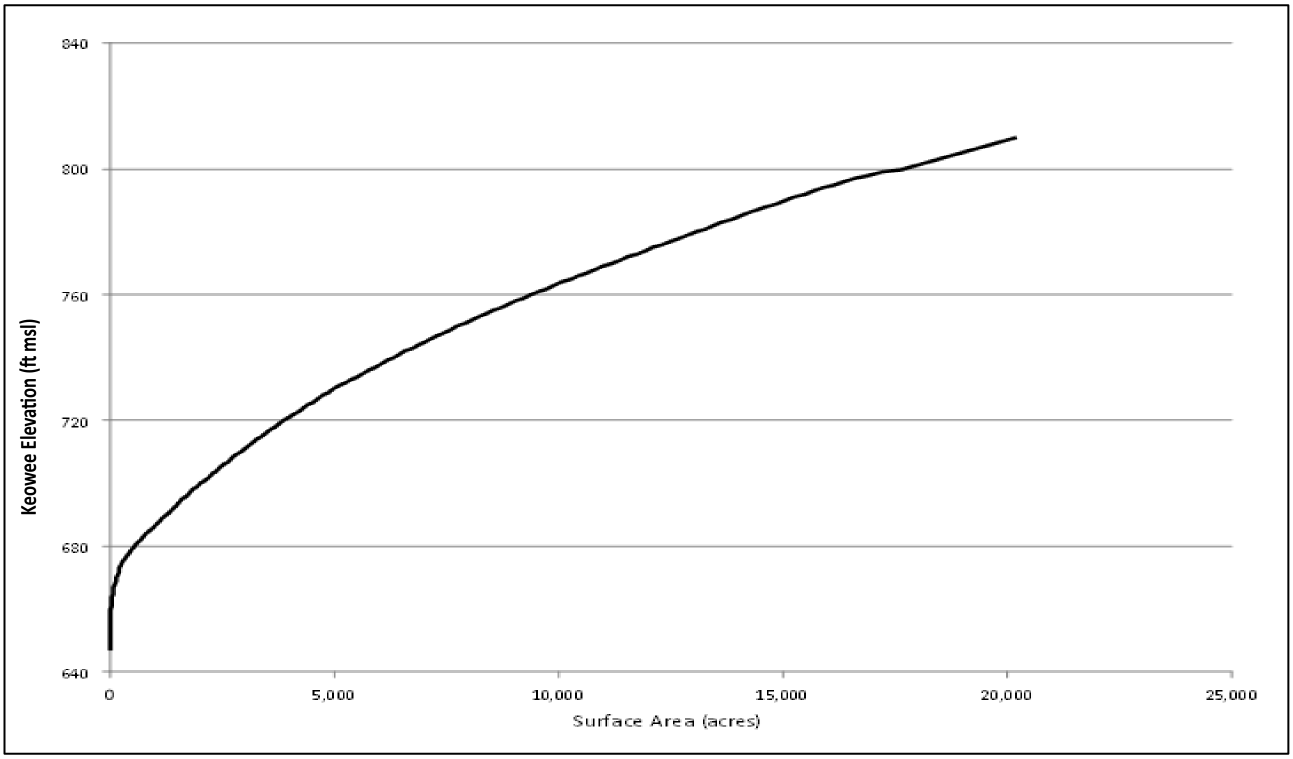


Figure 4-12. Keowee Reservoir Area Curve

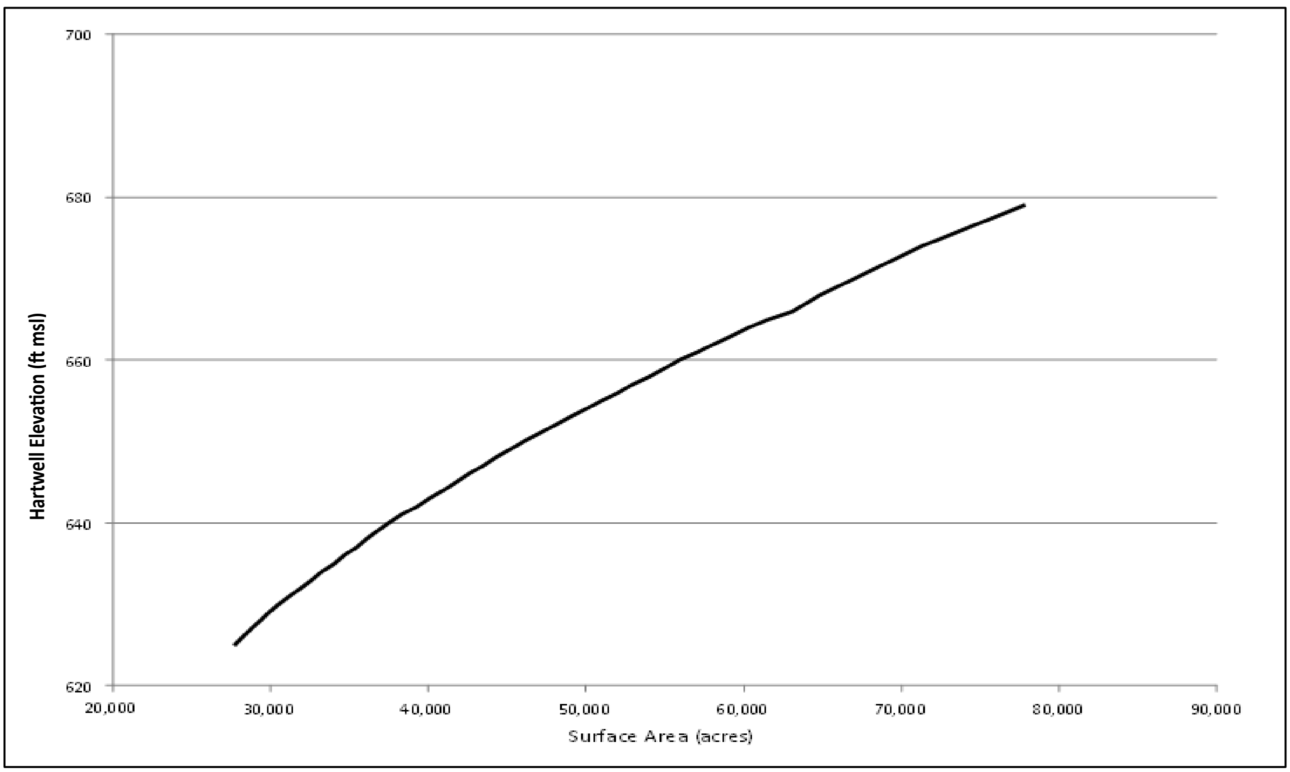


Figure 4-13. Hartwell Reservoir Area Curve

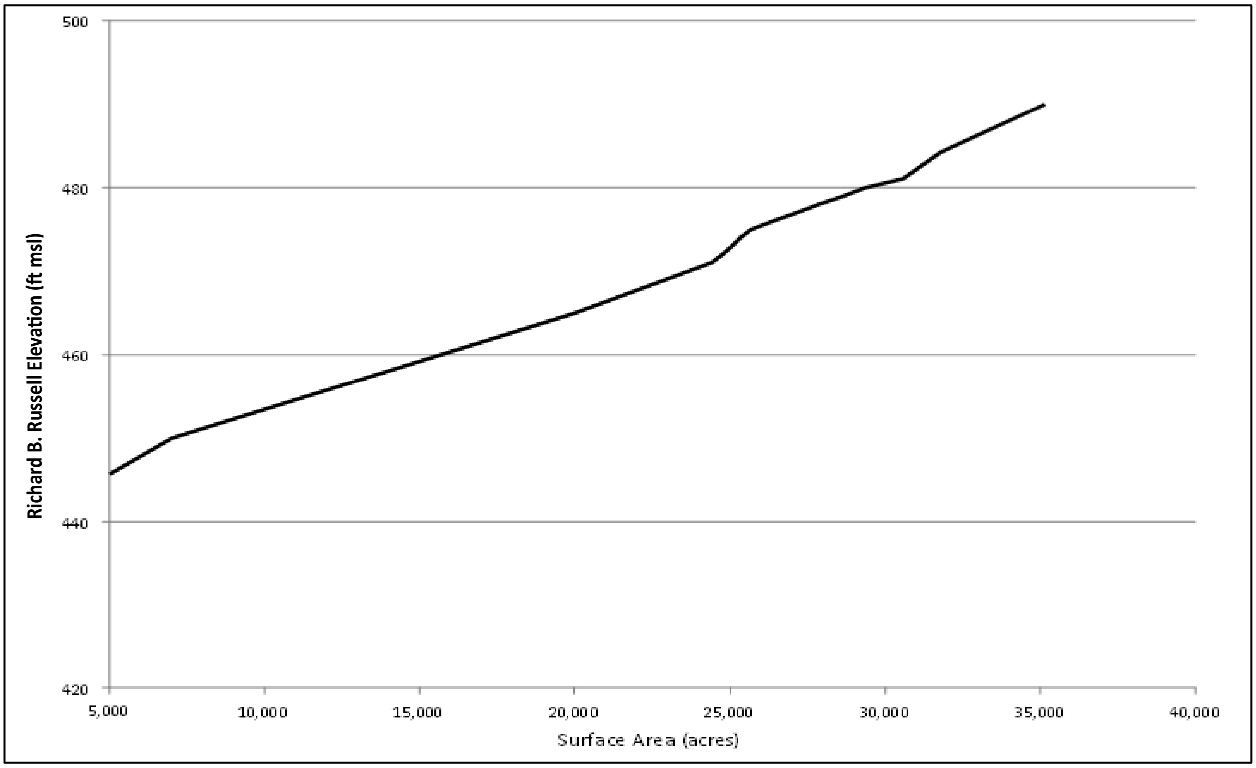


Figure 4-14. Richard B. Russell Reservoir Area Curve

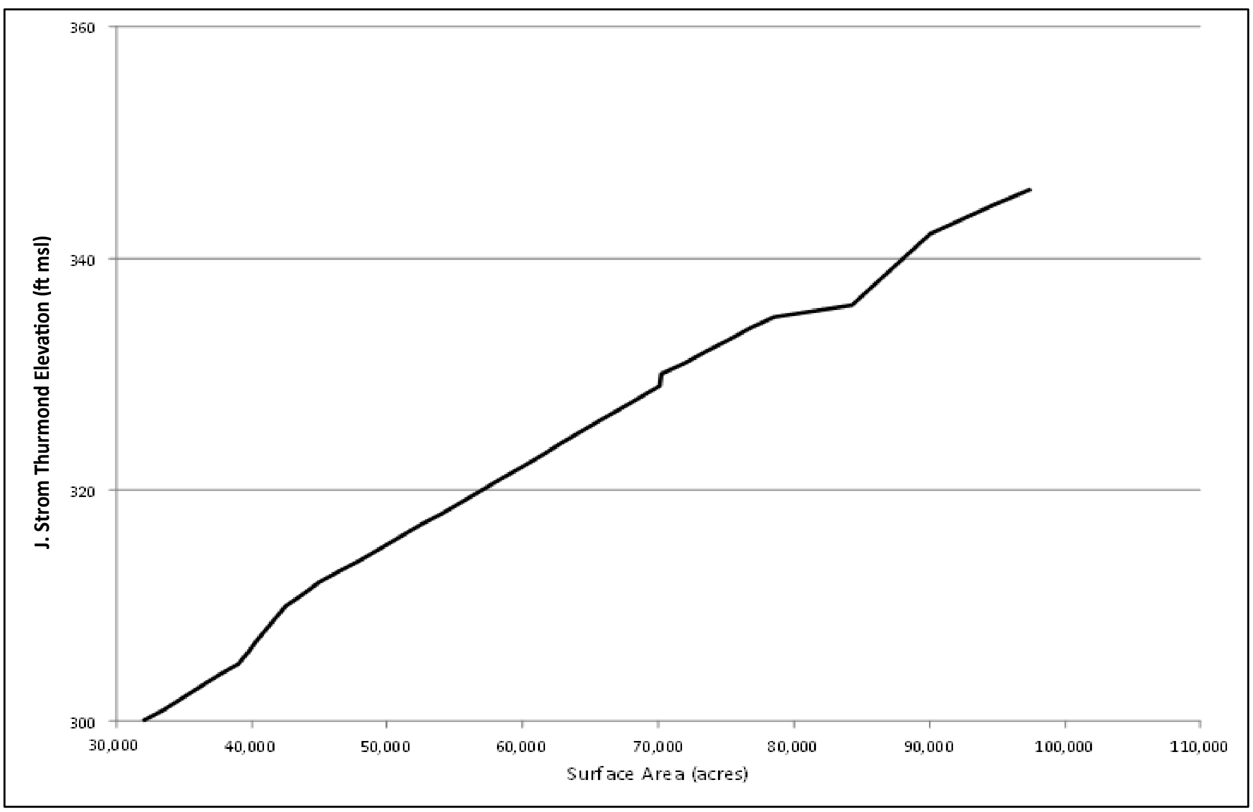


Figure 4-15. J. Strom Thurmond Reservoir Area Curve

4.6.4.3 Monthly Evaporation

Evaporation is based upon a monthly varying coefficient that defines the evaporative loss per reservoir. This evaporative loss is not strictly composed of losses due to evaporation, but rather a net change to inflows due to evaporation, direct precipitation to water surface, precipitation runoff, and changes to evapotranspiration losses. Negative values indicate a net inflow to the reservoir. Based on the median data, the precipitation inflow to the reservoir exceeds the evaporation from the reservoir. This coefficient (which is entered into the model in ft per day per acre) is multiplied by the surface area of the reservoir to compute total evaporative loss volume for the reservoir. Table 4-6 shows the SR CHEOPS Model evaporation loss coefficients for each reservoir by month. The evaporation loss coefficients reflect the monthly 2008 values published by ARCADIS in the Savannah River Basin May 13, 2013, time series release (ARCADIS 2010, 2013). The September 16, 2010 ARCADIS time series release contains the same 2008 evaporation values as provided in the May 2013 release.

Table 4-6. Evaporative Loss Coefficients

Month	Bad Creek Evaporation Loss (ft/day/acre)	Jocassee Evaporation Loss (ft/day/acre)	Keowee Evaporation Loss (ft/day/acre)	Hartwell Evaporation Loss (ft/day/acre)	Richard B. Russell Evaporation Loss (ft/day/acre)	J. Strom Thurmond Evaporation Loss (ft/day/acre)
Jan	-4.2E-03	-2.8E-03	-1.5E-03	-1.5E-03	-1.1E-03	-3.2E-03
Feb	-2.3E-03	-7.6E-04	1.0E-04	4.3E-05	-5.7E-04	-1.9E-03
Mar	-6.8E-03	-4.2E-03	6.9E-05	1.6E-05	-6.2E-05	-8.3E-05
Apr	2.5E-03	4.0E-03	4.6E-03	4.1E-03	4.1E-03	3.6E-03
May	6.1E-03	7.4E-03	6.6E-03	7.6E-03	9.6E-03	8.9E-03
Jun	1.1E-02	1.2E-02	1.3E-02	1.2E-02	1.3E-02	1.3E-02
Jul	6.3E-03	8.0E-03	9.1E-03	8.6E-03	6.5E-03	7.8E-03
Aug	-1.2E-03	1.2E-03	1.0E-03	1.9E-03	4.2E-03	3.9E-03
Sep	5.4E-03	6.4E-03	7.1E-03	7.9E-03	6.7E-03	6.4E-03
Oct	7.4E-04	1.8E-03	2.6E-03	2.1E-03	8.5E-04	7.4E-04
Nov	-1.6E-03	-6.5E-04	1.3E-04	1.3E-04	-1.1E-03	-6.4E-03
Dec	-8.8E-03	-6.6E-03	-5.8E-03	-4.9E-03	-3.0E-03	-3.4E-03

4.6.4.4 Tailwater Data

The Tailwater Curve relates the powerhouse tailwater elevation to the development's outflow. In cases where the powerhouse releases directly into a downstream reservoir, the downstream reservoir's elevation is used to compute tailwater elevation. The tailwater elevation is subtracted from the reservoir elevation to calculate the gross head used in determining turbine and pump-turbine hydraulic performance.

Bad Creek releases directly into Lake Jocassee, so the elevation of Jocassee is the controlling factor for Bad Creek's tailwater elevation. Likewise, the Jocassee powerhouse releases directly into Lake Keowee, so the elevation of Keowee is the controlling factor for Jocassee's tailwater elevation computation.

The Keowee powerhouse discharges into Hartwell Lake. However, due to backwater effects in the upstream lake channel, there is a difference between Hartwell Lake elevation (at Hartwell Dam) and the water surface elevation below the Keowee powerhouse when the turbines are in operation. Table 4-7 shows the Keowee Development's powerhouse tailwater curve in stage units of ft msl for various powerhouse outflows in cfs.

Table 4-7. Keowee Powerhouse Tailwater Rating Curve

Stage (ft msl)	Flow (cfs)	Stage (ft msl)	Flow (cfs)
657	0	680	39,867
660	5,042	684.8	59,879
665.1	11,345	689.9	85,879
670	16,545	695	113,612
674.9	26,000		

Similar to Bad Creek and Jocassee Hydro, the Hartwell powerhouse releases directly into Richard B. Russell Lake without backwater effects. Therefore, the Richard B. Russell Lake elevation is the control for Hartwell Hydro Station's tailwater elevation. The CHEOPS Model uses the greater of 475 ft msl or Richard B. Russell Lake water surface elevation. Reservoir elevation 475 ft msl is the minimum tailwater elevation provided by the USACE for modeling purposes.

Richard B. Russell powerhouse releases into J. Strom Thurmond Lake. The J. Strom Thurmond Lake elevation is the control for Richard B. Russell's tailwater elevation. The J. Strom Thurmond tailwater rating curve is shown in Table 4-8.

Table 4-8. J. Strom Thurmond Powerhouse Tailwater Rating Curve

Stage (ft msl)	Flow (cfs)	Stage (ft msl)	Flow (cfs)
187	0	220	280,000
190	15,000	230	440,000
200	65,000	240	640,000
210	155,000	250	870,000

4.6.4.5 Spillway Capacity

The Spillway Curve contains the data relating reservoir elevation and spillway discharge capacity. These data allow the model to determine the maximum amount of water that can be spilled at the current reservoir elevation and is the sum of all spillway conveyances with gates open to maximum setting. The CHEOPS Model allows for a simple spillway relationship of elevation and flow; therefore, all spillways, including gates, are modeled as a relationship of elevation and flow.

Spillway capacity data for the Bad Creek Project is shown in Table 4-9, derived from the Bad Creek Pumped Storage Project Supporting Technical Information Document (Duke Energy 2008). The Bad Creek emergency spillway is also known as the East Dike.

Table 4-9. Bad Creek Spillway Values

Elevation (ft msl)	Capacity (cfs)	Elevation (ft msl)	Capacity (cfs)
2,313.5	0	2,315	2,313
2,313.8	17	2,315.5	4,477
2,314.3	477	2,316	7,153
2,314.6	1,051		

Table 4-10 shows the maximum spillway capacity of the two-gated spillways as delineated in the Jocassee Development Supporting Technical Information Document (HDR 2010).

Table 4-10. Jocassee Total Gated Spillway Capacity Values

Elevation (ft msl)	Capacity (cfs)	Elevation (ft msl)	Capacity (cfs)
1,077	0	1102	34,531
1,082	2,762	1107	46,054
1,087	8,117	1112	58,671
1,092	15,374	1117	67,321
1,097	24,248	1122	74,138

Four-gated spillway capacity values for Keowee are shown in Table 4-11 as delineated in the Keowee Supporting Technical Information Document (HDR 2012a).

Table 4-11. Keowee Total Gated Spillway Capacity Values

Elevation (ft msl)	Capacity (cfs)	Elevation (ft msl)	Capacity (cfs)
765	0	790	63,268
770	5,505	795	82,550
775	15,851	800	102,810
780	29,399	805	123,645
785	45,393	810	144,639

The spillway capacities of the USACE projects are shown in Table 4-12 through Table 4-14. These values include original data provided by the USACE, as represented in the Savannah River ResSim Model.

Table 4-12. Hartwell Total Gated Spillway Capacity Values

Elevation (ft msl)	Capacity (cfs)	Elevation (ft msl)	Capacity (cfs)	Elevation (ft msl)	Capacity (cfs)
630	0	657	258,924	666	416,148
635	16,800	658	274,896	667	434,184
640	52,800	659	291,288	668	452,508
645	102,000	660	308,100	669	471,120
650	160,800	661	325,320	670	489,996
653	199,248	662	342,972	671	509,160
654	213,540	663	361,032	672	528,600
655	228,252	664	379,500	673	548,316
656	243,384	665	398,400	674	568,308

Table 4-13. Richard B. Russell Total Gated Spillway Capacity Curves

Elevation (ft msl)	Capacity (cfs)	Elevation (ft msl)	Capacity (cfs)	Elevation (ft msl)	Capacity (cfs)
436	0	473	0	482	630,000
440	0	474	0	483	650,000
450	0	475	0	484	670,000
455	0	476	0	485	690,000
460	0	477	0	486	710,000
465	0	478	0	487	725,000
470	0	479	0	488	740,000
471	0	480	593,000	489	755,000
472	0	481	620,000	490	771,000

*Spill elevation set to 475.3 ft msl and spillway capacity set to zero below 480 ft msl to support logic to prevent pumping above 475 ft msl.

Table 4-14. J. Strom Thurmond Total Gated Spillway Capacity Values

Elevation (ft msl)	Capacity (cfs)	Elevation (ft msl)	Capacity (cfs)
300	0	325	405,000
305	27,000	330	545,000
310	95,000	335	688,000
315	182,000	340	855,000
320	282,000	345	1,025,000

4.6.4.6 Plant Operation Type

The Plant Operation Type is how the CHEOPS model classifies and operates the plants. Four different components are used to describe the operation of the plants.

- **Min Powerhouse Flow –** All plants in this model have zero (0) value entered, as the turbine input curves accurately define the lowest operating flow of the units.

- **Plant Operation Type –** This condition specifies what type of scheduling logic is to be used for the plant. Options include Strictly Peaking, Non-generating, Run-of-River, and others. The plant operation types for the nodes in this model are shown below. Pumped storage plants follow pumping and discharge schedules. Strictly Peaking plants use logic to generate as much power as possible during the peak period, followed by secondary-peak and then off-peak periods. Hybrid-pumped storage plants have a pumping schedule, but schedule plant discharge using peaking plant logic.
    - Bad Creek – Pumped Storage
    - Jocassee – Hybrid-Pumped Storage
    - Keowee – Strictly Peaking
    - Hartwell – Strictly Peaking
    - Richard B. Russell – Hybrid-Pumped Storage
    - J. Strom Thurmond – Strictly Peaking
- **Delinked Owner –** This condition sets the level of water conveyance support a plant receives and provides to other plants operated by the same licensee/operator. All plants in the model have this value unchecked, meaning the plants provide supporting operation to other plants operated by the same owner.
- **Delinked System –** This condition sets the level of support a plant receives and provides to other plants operated by other licensees/operators in the modeled system. All plants in this model have this condition checked, meaning the default CHEOPS logic for support between plants is not in effect for plants operated by different operators. In this model, other methods and rules of setting the support between plants and owners are used.

4.6.5 Operational Data

4.6.5.1 Spill and Minimum Elevations

The spill or flood control elevation relates to a variety of physical situations (spillway crest, partial gate coverage, maximum normal pool, etc.), but it represents the elevation at which the model will begin to simulate spill to avoid increasing water elevation. Under a Strictly Peaking plant, when the model calculates an end-of-period elevation above the spill elevation, the model will calculate spill as well as the turbine/diversion discharge. The model's logic, under a Strictly

Peaking plant, also attempts to reduce or eliminate occurrences when the reservoir elevation exceeds the spill elevation.

The minimum elevation is the minimum allowable reservoir elevation. This elevation could be set by regulations or by a physical limit (lowest available outlet invert). Bypass flows, withdrawals, wicket gate leakage, and evaporation can draw the reservoir below this level. The model will operate to eliminate occurrences when the reservoir elevation dips below this elevation.

Table 4-15 lists the spill and minimum elevations for each development in the model.

Table 4-15. Reservoir Spill and Minimum Elevations

Development	Spill Elevation (ft msl)	Minimum Elevation (ft msl)
Bad Creek	2,310	2,150
Jocassee	1,110	1,080
Keowee	800	790
Hartwell	665	625
Richard B. Russell*	475.3	470
J. Strom Thurmond	335	312

* Richard B. Russell spill elevation set to 475.3 ft msl and spillway capacity set to zero below 480 ft msl to support logic to prevent pumping above 475 ft msl.

4.6.5.2 Target Elevations

The Target Elevation is the user-defined elevation that the model attempts to meet (targets) as the end-of-day reservoir elevation. The model straight-line interpolates between user input points to identify a target elevation for each day. The model will deviate from the target to accommodate forecasted inflows, to meet the plant's own outflow requirements or constraints, and to support downstream minimum flow requirements from the J. Strom Thurmond development.

Table 4-16 lists the guide curve elevations for the Duke Energy reservoirs (curves needed for modeling), and Table 4-17 lists the guide curves for the USACE reservoirs. Target requirements for the USACE developments were provided by the USACE with the Savannah River ResSim Model (HDR 2014b).

Table 4-16. Guide Curve Target Elevation of Duke Energy Reservoirs

Day of Year	Bad Creek Target Elevation (ft msl)	Jocassee Target Elevation (ft msl)	Keowee Target Elevation (ft msl)
Jan 1	2,280	1,107	797
May 1	2,280	1,107	798
Oct 15	2,280	1,107	798
Dec 31	2,280	1,107	797

Table 4-17. Guide Curve Target Elevations of USACE Reservoirs

Day of Year	Hartwell Target Elevation (ft msl)	Richard B. Russell Target Elevation (ft msl)	J. Strom Thurmond Target Elevation (ft msl)
Jan 1	656	475	326
Apr 1	660	475	330
Oct 15	660	475	330
Dec 15	656	475	326

4.6.5.3 Water Withdrawals

Historical water use (withdrawals and returns in cfs) were estimated as part of the Savannah River Basin September 16, 2010, UIF time series release (ARCADIS 2010, 2013). The median 2003-2008 monthly water use in cfs was modeled in the historical baseline scenario to represent historical municipal and industrial water use from each reservoir. Table 4-18 shows the historical baseline scenario modeled withdrawals and returns in cfs. The example calculation below describes the withdrawal calculation for a reservoir for a month:

$$WR_{R1,Month} = Median(WR_{Day,Year})$$

where:

$WR_{R1,Month}$ is the net withdrawal (in cfs) for the reservoir for the month

$WR_{Day,Year}$ is the withdrawal (in cfs) for the reservoir for each day of the month for each of the months of interest in the 2003 through 2008 period.

During KT relicensing, Duke Energy contracted with HDR to complete a Water Supply Study of the Savannah River Basin. This study is detailed in the *Final Keowee-Toxaway Water Supply Study Report* (HDR 2014c). The Water Supply Study provided the following data which have been adopted for the Project scenarios, including the scenarios outlined in this report:

- Water withdrawals and returns within the Savannah River Basin (Basin) that are greater than or equal to 100,000 gallons per day (HDR 2014b).
- Future projections for water withdrawals and returns within the Basin to the year 2066.

The withdrawals and returns simulated in the Water Supply Study are included in Appendix A of this report.

Table 4-18. 2003-2008 Median Monthly Water Use - Historical Baseline Scenario

Water Withdrawal (avg cfs/day)						
Day of Year	**Bad Creek**	**Jocassee**	**Keowee**	**Hartwell**	**Richard B. Russell**	**J. Strom Thurmond**
01-Jan	0.00	0.00	76.66	29.14	0.00	2.61
01-Feb	0.00	0.00	76.67	29.53	0.00	1.70
01-Mar	0.00	0.00	76.88	30.15	0.00	0.32
01-Apr	0.00	0.00	74.67	33.75	0.00	3.14
01-May	0.00	0.00	71.82	42.23	0.00	7.00
01-Jun	0.00	0.00	84.00	50.51	0.00	7.70
01-Jul	0.00	0.00	84.70	45.39	0.00	7.25
01-Aug	0.00	0.00	83.24	45.92	0.00	8.25
01-Sep	0.00	0.00	88.23	44.03	0.00	7.01
01-Oct	0.00	0.00	79.59	42.82	0.00	6.05
01-Nov	0.00	0.00	68.19	34.16	0.00	5.07
01-Dec	0.00	0.00	74.69	29.75	0.00	3.70
Water Return (avg cfs/day)						
Day of Year	**Bad Creek**	**Jocassee**	**Keowee**	**Hartwell**	**Richard B. Russell**	**J. Strom Thurmond**
01-Jan	0.00	0.00	0.00	0.00	4.75	0.00
01-Feb	0.00	0.00	0.00	0.00	5.50	0.00
01-Mar	0.00	0.00	0.00	0.00	6.37	0.00
01-Apr	0.00	0.00	0.00	0.00	3.92	0.00
01-May	0.00	0.00	0.00	0.00	1.80	0.00
01-Jun	0.00	0.00	0.00	0.00	1.26	0.00
01-Jul	0.00	0.00	0.00	0.00	1.65	0.00
01-Aug	0.00	0.00	0.00	0.00	1.10	0.00
01-Sep	0.00	0.00	0.00	0.00	0.96	0.00
01-Oct	0.00	0.00	0.00	0.00	1.88	0.00
01-Nov	0.00	0.00	0.00	0.00	2.92	0.00
01-Dec	0.00	0.00	0.00	0.00	4.60	0.00

4.6.5.4 Minimum Flows

The Hartwell, Richard B. Russell, and J. Strom Thurmond developments have fish spawning rules in the SR CHEOPS Model. The rule requires outflow to equal inflow if the reservoir is at or below target elevation during the month of April. Additionally, J. Strom Thurmond Lake has a required average daily discharge of at least 3,800 cfs year-round.

4.6.5.5 Maximum Flows

The model allows a Maximum Flow constraint to be applied either at a powerhouse or at a downstream node. This will limit operations to restrict flow to a maximum of the defined limit. The J. Strom Thurmond development has a maximum flow restriction at the downstream node in Augusta, Georgia, depending on the reservoir elevation of J. Strom Thurmond Lake. If the lake elevation is below 330 ft msl, the maximum allowable flow at Augusta is 20,000 cfs; if the reservoir elevation is greater than or equal to 330 ft msl, the maximum allowable flow is 30,000 cfs. These flow restrictions are based on goals for normal operation at the development. Under extreme flooding, these flows can be exceeded.

The Richard B. Russell development has a maximum flow constraint of 60,000 cfs, and the Hartwell development has a maximum flow constraint of 28,500 cfs.

4.6.5.6 Pump Operations

Bad Creek uses pumped storage logic and Jocassee and Richard B. Russell use hybrid-pumped storage logic. These settings require pump operations schedules. Bad Creek pump operations specify pumping and discharge schedules (specified in the tables by number of units available to operate), while Jocassee and Richard B. Russell specify pumping only. In Table 4-19 through Table 4-21, pump operations schedules are described by negative numbers. The magnitude of each negative number indicates the number of units available for pumping during a given hour. Table 4-19 includes positive numbers, which indicate discharge during a given hour. Durations for the Bad Creek and Jocassee schedules reflect anticipated changes in operation as additional renewable generation is incorporated into Duke Energy’s generation portfolio.

The model will deviate from the user-specified pumping or generating schedule when certain conditions are encountered, such as when the upper reservoir is approaching the spill elevation, the lower reservoir is approaching the minimum elevation, and when a powerhouse is undergoing maintenance. Additionally, the model will attempt to avoid operations that may empty the upper reservoir, cause spill at the downstream reservoir, or end the day significantly different from the target elevation. The model does this by evaluating the starting elevation, desired ending elevation, and user-specified pumping and generating unit-hours for the day. Using pumping and generating volume capacities at the start of the day, the model will adjust (reduce only), the number of unit-hours to balance the generation volume and pumping volume, taking into account the desired daily change in storage. For example, if a user inputs four unit hours of generation and four unit hours of pumping, the model will reduce the generation unit-hours to three so the total volume released from the upper reservoir can be made up with the four unit hours in the pump schedule.

For hybrid-pumped storage logic, the model will pump with the specified number of units during the hours specified unless the upper reservoir approaches spill elevation, the lower reservoir approaches minimum elevation, or units are in maintenance. The generation release scheduling of a hybrid-pumped storage plant occurs just as if the plant is a typical peaking plant, where outflow is determined by change in storage and inflow, which includes upstream plant discharge, upstream plant bypass flow return, upstream plant spill, incremental accretion, water withdrawal returns, and pumping operations. A powerhouse will not be scheduled to release for generation if an hour has been specified for pumping operations and pumping was actually scheduled.

Table 4-19. Bad Creek Pump Operations

Month	Day Set	Hour (number of units available per hour of the day)*																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	0	0	0	0	1	1	1	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	3	4	4	4	0	0
Feb	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	0	0	0	0	1	1	1	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	3	4	4	4	0	0
Mar	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	0	0	0	0	0	1	1	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	4	4	4	4	0	0
Apr	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	0	0	0	0	1	1	1	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	3	4	4	4	0	0
May	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	1	1	1	1	1	1	1	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	0	3	4	4	0	0
Jun	Weekday	0	2	4	0	0	0	0	-1	-2	-4	-4	-4	-4	-4	-4	-4	-2	-1	4	4	4	4	0	0
	Weekend	0	1	1	1	1	1	1	1	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	0	3	4	4	0	0
Jul	Weekday	0	2	4	0	0	0	0	-1	-2	-4	-4	-4	-4	-4	-4	-4	-2	-1	4	4	4	4	0	0
	Weekend	0	1	1	1	0	0	0	0	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	2	2	4	4	3	0
Aug	Weekday	0	2	4	0	0	0	0	-1	-2	-4	-4	-4	-4	-4	-4	-4	-2	-1	4	4	4	4	0	0
	Weekend	0	1	1	1	0	0	0	0	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	2	2	4	4	3	0
Sep	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	1	1	1	0	0	0	0	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	0	4	4	4	3	0
Oct	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	1	1	1	0	0	0	0	-2	-4	-4	-4	-4	-4	-4	-4	-2	0	0	4	4	4	3	0
Nov	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	0	0	0	0	0	1	1	-2	-4	-4	-4	-4	-4	-4	-4	-2	2	2	4	4	4	0	0
Dec	Weekday	0	0	0	0	0	0	2	4	-2	-4	-4	-4	-4	-4	-4	-4	-2	-2	4	4	4	4	0	0
	Weekend	0	0	0	0	0	0	1	1	-2	-4	-4	-4	-4	-4	-4	-4	-2	2	2	4	4	2	2	0

*Pumping unit operations are described with negative values.

Table 4-20. Jocassee Pump Operations

Month	Day Set	Hour (number of units available per hour of the day)*																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Feb	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Mar	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Apr	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
May	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Jun	Weekday	0	0	0	0	0	0	0	-1	-4	-4	-4	-4	-4	-4	-4	-4	-2	-1	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Jul	Weekday	0	0	0	0	0	0	0	-1	-4	-4	-4	-4	-4	-4	-4	-4	-2	-1	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Aug	Weekday	0	0	0	0	0	0	0	-1	-4	-4	-4	-4	-4	-4	-4	-4	-2	-1	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Sep	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Oct	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Nov	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0
Dec	Weekday	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	-2	0	0	0	0	0	0
	Weekend	0	0	0	0	0	0	0	0	-4	-4	-4	-4	-4	-4	-4	-4	-2	0	0	0	0	0	0	0

*Pumping unit operations are described with negative values.

Table 4-21. Richard B. Rusell Pump Operations

Month	Day Set	Hour (number of units available per hour of the day)*																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Annual	Weekdays	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Saturdays	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sundays	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Pumping unit operations are described with negative values.

4.6.6 Generation Data

Unit performance information was modeled based on the information available at the time of model development.

4.6.6.1 Headloss Coefficients

The CHEOPS model allows two common headloss coefficients for each plant and an individual coefficient for each unit. Headloss for each unit is calculated by multiplying the unit's common coefficient by the total flow for that common coefficient squared added to the individual coefficient multiplied by the individual unit flow squared. The formula is:

$$H_i = \left(\sum_{j=1}^{n} F_i \right)^2 h_C + F_i^2 h_i$$

Where:

H_i is the unit headloss in ft

h_c is the common coefficient for the i^{th} unit

h_i is the individual coefficient for the i^{th} unit

F_i is the flow for the i^{th} unit

j runs from 1 to n

n is the number of units that have the same common coefficient as the unit i

Table 4-22 presents the estimated headlosses for each plant as a function of flow (Q):

Table 4-22. Headloss Coefficients

Development	Common 1	Common 2	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8
Bad Creek	1.25E-07	-	-	-	-	-	-	-	-	-
Jocassee	1.41E-08	1.41E-08	6.99E-08[a]	6.99E-08[a]	6.99E-08[b]	6.99E-08[b]	-	-	-	-
Keowee	1.22E-08	-	2.33E-08[a]	2.33E-08[a]	-	-	-	-	-	-
Hartwell	-	-	3.55E-08	3.55E-08	3.55E-08	3.55E-08	-	-	-	-
Richard B. Russell	-	-	2.40E-08	2.40E-08	2.40E-08	2.40E-08	2.40E-08	2.40E-08	2.40E-08	2.40E-08
J. Strom Thurmond	-	-	1.56E-07	1.56E-07	1.56E-07	1.56E-07	1.56E-07	1.56E-07	1.56E-07	-

a) Unit headloss plus Common 1
b) Unit headloss plus Common 2

4.6.6.2 Turbine Efficiency Curves

Turbine performance is entered by plant and as flow versus efficiency at five separate net heads. The Bad Creek Powerhouse contains four reversible motor-pump/turbine-generator units with a design head of 1,115 ft msl. The modeled performance of the turbines in generation mode is presented in Table 4-23. The Jocassee powerhouse also contains four reversible motor-pump/turbine-generator units; modeled performance is presented in Table 4-24.

The Keowee powerhouse contains two similarly sized conventional turbine-generator units. The modeled performance of these turbines is presented in Table 4-25. The Hartwell powerhouse contains five conventional turbine-generator units, four of which were rehabilitated over the 11-year span of 1997 through 2007. The Richard B. Russell powerhouse contains four similarly sized conventional turbine-generator units and four reversible turbine-generator/motor-pump units. The J. Strom Thurmond powerhouse contains seven similarly sized conventional turbine-generator units. The modeled performance of the USACE turbines is presented in Table 4-26 through Table 4-29.

Table 4-23. Bad Creek Development Units 1 through 4 Turbine Efficiencies Over a Range of Net Heads

Units 1 through 4									
Net Head of 1,000 ft		Net Head of 1,050 ft		Net Head of 1,115 ft		Net Head of 1,181 ft		Net Head of 1,230 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
3,070	88.60%	3,105	89.65%	3,352	91.10%	3,458	92.10%	3,352	92.10%
3,176	89.00%	3,176	89.90%	3,529	91.65%	3,529	92.35%	3,529	92.70%
3,352	89.60%	3,352	90.55%	3,705	92.20%	3,705	92.85%	3,705	93.10%
3,529	90.25%	3,529	91.10%	3,882	92.50%	3,882	93.15%	3,882	93.30%
3,705	90.95%	3,705	91.60%	4,058	92.60%	4,058	93.15%	4,058	93.25%
3,882	91.45%	3,882	91.95%	4,164	92.50%	4,235	92.90%	4,235	93.05%
3,987	91.48%	4,058	92.10%	4,235	92.35%	4,411	92.55%	4,411	92.75%
4,058	91.40%	4,235	91.75%	4,411	92.00%	4,587	92.20%	4,587	92.45%
4,235	91.00%	4,411	91.25%	4,587	91.55%	4,764	91.80%	4,764	92.10%
4,376	90.50%	4,517	90.85%	4,729	91.15%	4,940	91.40%	4,940	91.75%

Table 4-24. Jocassee Development Units 1 through 4 Turbine Efficiencies Over a Range of Net Heads

Units 1 through 4									
Net Head of 278 ft		Net Head of 289 ft		Net Head of 301 ft		Net Head of 312 ft		Net Head of 323 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
7,140	91.17%	6,877	91.06%	6,612	90.93%	6,395	90.70%	6,213	90.18%
7,150	91.19%	6,900	91.13%	6,900	91.50%	6,700	91.47%	6,325	90.64%
7,400	91.50%	7,150	91.64%	7,200	92.25%	6,950	92.00%	6,450	91.15%
7,600	91.50%	7,400	92.00%	7,450	92.56%	7,250	92.65%	6,700	91.83%
7,800	91.40%	7,600	92.10%	7,700	92.45%	7,500	92.95%	6,950	92.43%
8,000	91.10%	7,850	91.80%	8,000	92.00%	7,800	92.70%	7,200	92.80%
8,250	90.56%	8,100	91.41%	8,250	91.60%	8,050	92.40%	7,450	93.16%
8,450	90.10%	8,350	91.00%	8,500	91.25%	8,350	92.00%	7,700	93.15%
8,650	89.45%	8,550	90.62%	8,800	90.80%	8,600	91.67%	7,950	92.82%
8,850	88.70%	8,800	90.00%	9,050	90.10%	8,638	91.60%	8,200	92.55%

Table 4-25. Keowee Development Units 1 and 2 Turbine Efficiencies Over a Range of Net Heads

Units 1 and 2									
Net Head of 90 ft		Net Head of 105 ft		Net Head of 117 ft		Net Head of 125 ft		Net Head of 140 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
5,400	54.00%	5,000	51.00%	4,900	48.00%	4,700	44.50%	4,300	43.00%
6,400	66.50%	5,500	62.00%	5,300	60.00%	5,100	55.50%	4,600	50.50%
6,900	72.00%	6,000	68.50%	5,700	66.50%	5,600	65.50%	4,900	56.00%
7,400	77.00%	6,500	74.00%	6,200	73.00%	6,100	73.00%	5,200	62.00%
7,900	81.00%	7,000	78.00%	6,700	77.50%	6,600	77.00%	5,600	68.50%
8,400	84.50%	7,500	81.00%	7,200	81.00%	7,100	81.00%	6,000	73.00%
8,900	88.50%	8,000	84.00%	7,700	84.00%	7,600	84.00%	6,400	76.50%
9,100	90.00%	8,500	88.00%	8,200	87.00%	8,100	87.00%	6,800	79.50%
9,300	91.50%	8,800	90.50%	8,700	90.50%	8,400	89.00%	7,200	82.00%
9,500	92.00%	9,000	92.00%	8,900	91.50%	8,600	90.50%	7,600	84.50%
9,700	91.00%	9,200	93.00%	9,000	92.00%	8,700	91.00%	7,800	86.00%
9,900	90.00%	9,400	93.50%	9,200	93.00%	8,800	91.50%	8,000	87.00%
10,100	88.00%	9,700	92.50%	9,500	93.50%	8,900	92.00%	8,200	88.00%
10,300	86.00%	10,000	91.00%	9,700	93.00%	9,100	93.00%	8,400	89.50%

Table 4-26. Hartwell Development Units 1 through 4 Turbine Efficiencies Over a Range of Net Heads

Units 1 through 4									
Net Head of 170 ft		Net Head of 175 ft		Net Head of 180 ft		Net Head of 185 ft		Net Head of 190 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
2,724	81.74%	2,678	80.77%	2,635	79.81%	2,596	78.82%	2,560	77.83%
2,985	83.90%	2,931	83.00%	2,881	82.09%	2,837	81.11%	2,796	80.14%
3,245	85.71%	3,185	84.83%	3,128	83.98%	3,078	83.04%	3,032	82.08%
3,504	87.28%	3,438	86.42%	3,375	85.59%	3,319	84.68%	3,269	83.71%
3,756	88.81%	3,684	87.95%	3,619	87.05%	3,560	86.10%	3,505	85.15%
4,071	90.45%	3,987	89.71%	3,911	88.92%	3,848	87.93%	3,794	86.84%
4,335	91.34%	4,233	90.87%	4,145	90.22%	4,073	89.33%	4,012	88.30%
4,601	92.09%	4,491	91.65%	4,387	91.22%	4,299	90.57%	4,230	89.62%
4,870	92.70%	4,748	92.37%	4,637	91.95%	4,540	91.38%	4,451	90.75%
5,148	93.08%	5,015	92.82%	4,887	92.60%	4,782	92.08%	4,688	91.45%
5,463	92.77%	5,289	93.08%	5,153	92.89%	5,036	92.47%	4,924	92.09%
5,823	91.76%	5,605	92.60%	5,430	92.93%	5,291	92.80%	5,168	92.51%
6,227	90.20%	5,969	91.41%	5,739	92.43%	5,569	92.68%	5,426	92.62%
6,878	86.58%	6,482	89.25%	6,204	90.66%	5,952	91.94%	5,774	92.28%

Table 4-27. Hartwell Development Unit 5 Turbine Efficiencies Over a Range of Net Heads

Unit 5									
Net Head of 170 ft		Net Head of 175 ft		Net Head of 180 ft		Net Head of 185 ft		Net Head of 190 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
2,663	79.74%	2,618	78.77%	2,576	77.81%	2,538	76.82%	2,502	75.83%
2,918	81.90%	2,865	81.00%	2,816	80.09%	2,773	79.11%	2,733	78.14%
3,172	83.71%	3,113	82.83%	3,058	81.98%	3,009	81.04%	2,964	80.08%
3,425	85.28%	3,361	84.42%	3,299	83.59%	3,244	82.68%	3,195	81.71%
3,671	86.81%	3,601	85.95%	3,538	85.05%	3,480	84.10%	3,426	83.15%
3,979	88.45%	3,897	87.71%	3,823	86.92%	3,761	85.93%	3,709	84.84%
4,237	89.34%	4,138	88.87%	4,052	88.22%	3,981	87.33%	3,922	86.30%
4,497	90.09%	4,390	89.65%	4,288	89.22%	4,202	88.57%	4,135	87.62%
4,760	90.70%	4,641	90.37%	4,533	89.95%	4,438	89.38%	4,351	88.75%
5,032	91.08%	4,902	90.82%	4,777	90.60%	4,674	90.08%	4,583	89.45%
5,340	90.77%	5,170	91.08%	5,037	90.89%	4,923	90.47%	4,813	90.09%
5,692	89.76%	5,479	90.60%	5,308	90.93%	5,172	90.80%	5,052	90.51%
6,087	88.20%	5,835	89.41%	5,610	90.43%	5,444	90.68%	5,304	90.62%
6,723	84.58%	6,336	87.25%	6,064	88.66%	5,818	89.94%	5,644	90.28%

Table 4-28. Richard B. Russell Development Units 1 through 4 Turbine Efficiencies Over a Range of Net Heads

Units 1 through 4									
Net Head of 139 ft		Net Head of 144 ft		Net Head of 151 ft		Net Head of 157 ft		Net Head of 162 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
5,100	79.80%	5,190	81.00%	5,300	82.75%	5,300	83.50%	5,300	83.80%
5,400	81.50%	5,400	82.30%	5,600	84.50%	5,445	84.30%	5,550	85.20%
5,625	82.80%	5,725	84.25%	5,850	85.75%	5,700	85.50%	5,800	86.60%
5,900	84.50%	6,000	85.90%	6,100	87.20%	6,000	87.00%	6,100	88.00%
6,125	85.60%	6,225	87.00%	6,350	88.50%	6,200	88.20%	6,250	88.80%
6,400	87.25%	6,450	88.25%	6,600	89.70%	6,480	89.50%	6,400	89.60%
6,590	88.25%	6,690	89.25%	6,850	90.90%	6,700	90.50%	6,590	90.45%
6,800	89.20%	6,900	90.00%	7,050	91.40%	6,990	91.50%	6,750	91.00%
7,000	90.10%	7,100	90.60%	7,250	91.40%	7,200	91.55%	6,900	91.40%
7,150	90.20%	7,250	90.70%	7,400	90.75%	7,350	91.40%	7,095	92.00%
7,325	89.60%	7,450	90.25%	7,575	90.00%	7,500	91.10%	7,255	91.95%
7,575	88.50%	7,680	88.75%	7,840	88.75%	7,690	90.45%	7,450	91.50%
7,800	87.50%	7,900	87.50%	8,040	87.60%	7,875	89.50%	7,500	91.35%

Table 4-29. J. Strom Thurmond Development Units 1 through 7 Turbine Efficiencies Over a Range of Net Heads

Units 1 through 7									
Net Head of 114 ft		Net Head of 123 ft		Net Head of 132 ft		Net Head of 141 ft		Net Head of 148.5 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
3,110	84.32%	3,140	83.54%	3,230	84.01%	3,450	85.79%	3,570	86.53%
3,210	84.93%	3,180	84.00%	3,310	84.68%	3,570	86.43%	3,680	87.19%
3,340	86.29%	3,310	85.07%	3,430	85.64%	3,600	87.27%	3,790	87.82%
3,490	87.05%	3,440	86.05%	3,550	86.53%	3,790	88.06%	3,900	88.41%
3,640	87.74%	3,570	86.96%	3,670	87.37%	3,900	88.81%	4,010	88.97%
3,790	88.37%	3,710	87.56%	3,790	88.15%	4,020	89.29%	4,120	89.51%
3,940	88.96%	3,840	88.36%	3,910	88.88%	4,130	89.97%	4,230	90.01%
4,090	89.50%	3,980	88.87%	4,040	89.35%	4,250	90.39%	4,340	90.49%
4,230	90.22%	4,110	89.57%	4,160	90.01%	4,370	90.80%	4,450	90.95%
4,370	90.90%	4,240	90.23%	4,280	90.63%	4,490	91.18%	4,560	91.38%
4,520	91.33%	4,380	90.65%	4,410	91.02%	4,610	91.55%	4,680	91.60%
4,670	91.66%	4,520	91.03%	4,550	91.18%	4,740	91.70%	4,810	91.62%
4,850	91.24%	4,670	91.21%	4,690	91.33%	4,830	91.73%	4,940	91.63%
5,310	89.48%	4,840	90.99%	4,840	91.29%	4,930	91.58%	5,030	91.58%
5,520	87.96%	5,150	90.19%	5,230	90.49%	5,230	91.15%	5,070	91.64%

4.6.6.3 Generator Efficiency Curve

The generator data, like the turbine data, is entered by plant and then associated with a unit. The generator performance data is a relationship of generator output versus generator efficiency. The generator condition includes a maximum generator output. This value is the maximum generator output the model will allow, assuming there is turbine capacity to meet this limit. The model will limit turbine output based on the generator maximum desired output. The generator efficiency curves for each of the units in the system are shown in Table 4-30 through Table 4-36.

Table 4-30. Bad Creek Development Units 1 through 4 Generator Efficiency Curve

Units 1 through 4			
Efficiency	Output (MW)	Efficiency	Output (MW)
97.06%	78.25	98.95%	360
97.80%	110	98.98%	400
98.37%	156.5	99.00%	420
98.76%	234.75	99.00%	440
98.91%	313	99.00%	460

Table 4-31. Jocassee Development Units 1 through 4 Generator Efficiency Curve

Units 1 through 4			
Efficiency	Output (MW)	Efficiency	Output (MW)
95.20%	45	98.25%	150
96.15%	60	98.40%	180
97.50%	90	98.45%	195.5
98.00%	120	98.50%	215

Table 4-32. Keowee Development Units 1 and 2 Generator Efficiency Curve

Units 1 and 2					
Efficiency	Output (MW)	Efficiency	Output (MW)	Efficiency	Output (MW)
89.00%	10	97.36%	42.5	98.31%	72.5
92.00%	15	97.60%	47.5	98.39%	77.5
94.00%	20	97.79%	52.5	98.44%	82.5
95.30%	25	97.95%	57.5	98.46%	87.5
96.20%	30	98.09%	62.5	98.48%	90.0
96.80%	35	98.20%	67.5	98.50%	100.6
97.20%	40				

Table 4-33. Hartwell Development Units 1 through 4 Generator Efficiency Curve

Units 1 through 4					
Efficiency	Output (MW)	Efficiency	Output (MW)	Efficiency	Output (MW)
89.00%	10	97.41%	39	98.24%	64
92.00%	15	97.64%	43	98.30%	68
94.00%	19	97.83%	47	98.35%	72
95.25%	23	98.00%	52	98.40%	76
96.10%	27	98.11%	56	98.45%	80
96.75%	31	98.18%	60	98.50%	85
97.11%	35				

Table 4-34. Hartwell Development Unit 5 Generator Efficiency Curve

Unit 5					
Efficiency	Output (MW)	Efficiency	Output (MW)	Efficiency	Output (MW)
90.04%	10	96.27%	35	97.53%	60
92.76%	15	96.57%	39	97.64%	64
93.99%	19	96.82%	43	97.75%	68
94.83%	23	97.03%	47	97.84%	72
95.44%	27	97.25%	52	97.93%	76
95.90%	31	97.40%	56	98.04%	82

Table 4-35. Richard B. Russell Development Units 1 through 4 Generator Efficiency Curve

Units 1 through 4					
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**	**Efficiency**	**Output (MW)**
89.00%	10	97.36%	42.5	98.31%	72.5
92.00%	15	97.60%	47.5	98.39%	77.5
94.00%	20	97.79%	52.5	98.44%	82.5
95.30%	25	97.95%	57.5	98.46%	87.5
96.20%	30	98.09%	62.5	98.48%	90
96.80%	35	98.20%	67.5	98.50%	100.625
97.20%	40				

Table 4-36. J. Strom Thurmond Development Units 1 through 7 Generator Efficiency Curve

Units 1 through 7					
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**	**Efficiency**	**Output (MW)**
94.61%	10	97.39%	30	98.33%	50
95.56%	15	97.74%	35	98.45%	55
96.32%	20	98.00%	40	98.56%	60
96.93%	25	98.19%	45		

4.6.6.4 Wicket Gate Leakage

The Wicket Gate Leakage flow is active only during times of non-generation. Thus, during periods of non-generation, this leakage flow is used to make up all or a portion of the minimum flow requirement. Wicket gate leakage is only modeled at the Jocassee and Keowee Stations, where it is 11 cfs per Jocassee unit and 25 cfs per Keowee unit for a total of 44 cfs and 50 cfs when no units are operating, respectively.

4.6.6.5 Powerhouse Weekend Operations

The Powerhouse Weekend Operations Condition permits the simulation of reduced powerhouse operations during Saturdays and/or Sundays. B ypass flow requirements are still met since bypass flows are not powerhouse dependent. Minimum instantaneous and minimum daily average flow requirements are met by bringing the powerhouse online for the required flow only. This condition removes the change-in-storage component from consideration in computing a desired daily discharge. To simulate actual usage, Saturday and Sunday powerhouse operations are minimized at the Keowee, Hartwell, and Richard B. Russell developments. During high inflow periods with little usable storage available, the model will bring the powerhouse online to generate with outflows, rather than permit spilling.

4.6.6.6 Maintenance

The Maintenance schedule provides the functionality to take a unit out of service for all or part of each year for a scenario run. There are currently no outages modeled.

4.6.6.7 Pump Efficiency

The Pump Efficiency Condition provides the functionality to enter pump efficiency information for pumped storage plants. This dataset is required for plants with plant operation type specified as pumped storage and hybrid-pumped storage. The pump efficiency information modeled for the Bad Creek, Jocassee, and Richard B. Russell developments is presented in Table 4-37 through Table 4-39.

Table 4-37. Bad Creek Pump Efficiency

Total Head (ft)	Efficiency	Power (MW)	Flow (cfs)
1,066	92.80%	405.0	4,164
1,145	93.45%	377.1	3,635
1,173	93.51%	367.3	3,458
1,201	93.43%	357.2	3,282
1,253	93.00%	338.1	2,964

Table 4-38. Jocassee Pump Efficiency

Total Head (ft)	Efficiency	Power (MW)	Flow (cfs)
286	92.45%	207.5	7,921
296	92.80%	205.3	7,601
307	93.10%	204.7	7,331
318	93.40%	201.8	7,001
328	93.50%	196.8	6,626

Table 4-39. Richard B. Russell Pump Efficiency

Total Head (ft)	Efficiency	Power (MW)	Flow (cfs)
140	91.20%	93.6	7,201
145	91.68%	93.7	6,996
150	92.10%	93.7	6,791
155	92.50%	93.4	6,581
160	92.80%	92.9	6,361

4.7 Bad Creek II Scenario

Bad Creek II scenario inputs are identical to the Baseline ("Base Case") scenario except for the following changes:

- Four additional units with the turbine efficiencies in Table 4-40, the generator efficiencies in Table 4-41, the pump efficiencies in Table 4-41, and the headlosses in Table 4-42, are available to meet energy requirements; and,

- The pump operations schedule was revised to reflect the availability of 8 units at Bad Creek due to the additional four units at Bad Creek II (Table 4-43).

Table 4-40. Bad Creek II Units 5 through 8 Turbine Efficiencies over a Range of Net Heads

Units 5 through 8									
Net Head of 1,000 ft		Net Head of 1,050 ft		Net Head of 1,150 ft		Net Head of 1,200 ft		Net Head of 1,230 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
1,100	65.10%	1,100	68.40%	1,100	71.70%	1,100	73.10%	1,100	74.50%
1,300	71.00%	1,400	77.00%	1,400	79.00%	1,400	80.90%	1,400	82.10%
1,650	79.00%	1,650	81.80%	1,650	83.60%	1,650	85.00%	1,650	86.00%
2,000	85.00%	2,000	86.50%	2,000	87.80%	2,250	91.00%	2,000	89.50%
2,600	91.55%	2,635	92.30%	2,650	92.90%	2,750	93.80%	2,250	91.50%
3,000	94.00%	3,000	94.20%	3,000	94.50%	3,000	94.60%	2,750	94.00%
3,200	94.90%	3,200	94.70%	3,200	95.00%	3,200	94.90%	3,200	95.30%
3,450	95.30%	3,600	95.30%	3,700	95.30%	3,850	95.30%	3,875	95.30%
4,110	94.75%	4,201	94.73%	4,300	94.75%	4,450	94.75%	4,525	94.75%
4,990	92.90%	4,990	93.20%	4,990	93.50%	4,960	93.70%	4,810	94.30%

Table 4-41. Bad Creek II Units 5 through 8 Generator Efficiency Curve

Units 5 through 8			
Efficiency	Output (MW)	Efficiency	Output (MW)
94.00%	78.3	98.10%	348.5
95.00%	110	98.25%	400
96.20%	161.5	98.28%	430
97.00%	200	98.31%	464
97.40%	233	98.33%	500
97.80%	290		

Table 4-42. Bad Creek II Pump Efficiency

Total Head (ft)	Efficiency	Power (MW)	Flow (cfs)
1,058	93.60%	468.1	4,890
1,136	94.15%	467.4	4,575
1,185	94.35%	469.5	4,415
1,229	94.55%	468.8	4,265
1,244	94.60%	468.4	4,208

Table 4-43. Headloss Coefficients

Development	Common 1	Common 2	Unit 5	Unit 6	Unit 7	Unit 8
Bad Creek II	1.61E-07	1.61E-07	4.09E-07[a]	4.09E-07[b]	4.09E-07[b]	4.09E-07[b]

a) Unit headloss plus Common 1
b) Unit headloss plus Common 2

Table 4-44. Bad Creek and Bad Creek II Pump Operations

Month	Day Set	Hour (number of units available per hour of the day)*																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	4	8	8	4	0	0
	Weekend	0	0	0	0	0	2	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	4	4	8	4	0	0
Feb	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	4	8	8	4	0	0
	Weekend	0	0	0	0	0	2	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	4	4	8	4	0	0
Mar	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	4	8	8	4	0	0
	Weekend	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	6	4	8	6	0	0
Apr	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	4	8	8	4	0	0
	Weekend	0	0	0	0	0	2	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	4	4	8	4	0	0
May	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	4	4	8	8	0	0
	Weekend	0	1	1	1	1	1	1	1	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	4	3	8	4	0	0
Jun	Weekday	0	2	4	0	0	0	0	-1	-2	-2	-8	-8	-8	-4	-2	-2	-2	-1	4	4	8	6	0	0
	Weekend	0	1	1	1	1	1	1	1	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	4	3	8	4	0	0
July	Weekday	0	2	4	0	0	0	0	-1	-2	-2	-8	-8	-8	-4	-2	-2	-2	-1	4	4	8	6	0	0
	Weekend	0	1	1	1	0	0	0	0	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	2	6	8	4	3	0
Aug	Weekday	0	2	4	0	0	0	0	-1	-2	-2	-8	-8	-8	-4	-2	-2	-2	-1	4	4	8	6	0	0
	Weekend	0	1	1	1	0	0	0	0	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	2	6	8	4	3	0
Sep	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	4	8	8	4	0	0
	Weekend	0	1	1	1	0	0	0	0	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	2	4	6	8	3	0
Oct	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	6	8	6	4	0	0
	Weekend	0	1	1	1	0	0	0	0	-2	-2	-8	-8	-8	-4	-2	-2	-2	0	2	4	6	8	3	0
Nov	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	6	8	6	4	0	0
	Weekend	0	0	0	0	0	0	1	1	-2	-2	-8	-8	-8	-4	-2	-2	-2	2	2	6	8	6	0	0
Dec	Weekday	0	0	0	0	0	0	2	2	-2	-2	-8	-8	-8	-4	-2	-2	-2	-2	8	8	4	4	0	0
	Weekend	0	0	0	0	0	0	1	1	-2	-2	-8	-8	-8	-4	-2	-2	-2	2	2	6	8	4	2	0

*Pumping unit operations are described with negative values.

4.8 Climate Sensitivities

Two water quantity sensitivity assessments were completed for the Baseline and Bad Creek II scenarios. These sensitivity assessments were simulated to evaluate possible impacts of future temperature increases and basin inflow reduction and were developed from climate change sensitivity scenarios identified during KT relicensing (HDR 2012b).

Climate change sensitivities CC-01 and CC-02 (as explained below) represent future possible climate change conditions. These two sensitivities are a simplification of possible future decreases in available water in the basin but were agreed upon by the OSC as a method to provide stakeholders with additional information to evaluate proposed operation scenarios during KT relicensing. The POR (January 1939 through December 31, 2011) plus the two climate change sensitivities represent the three hydrologic conditions discussed in this report.

4.8.1 Low Impact of Climate Change Sensitivity (CC-01 or ccLow)

The ccLow scenarios were simulated with a 3.0°Farenheit (°F) temperature increase, which was modeled as a 10 percent increase in natural surface evaporation and was developed based on the recommended CC-01 climate change scenario. The net impact was to simulate a reduction in available water in the basin due to increased surface evaporation applied uniformly over the entire 12 months of each year simulated. The application of the surface evaporation increase to the modeled net monthly evaporation coefficient included consideration of a positive or negative coefficient due to some months historically having more precipitation than evaporation. In the case of a negative monthly net evaporation coefficient, the adjustment was applied as to always result in less water being available in that reservoir.

4.8.2 High Impact of Climate Change Sensitivity (CC-02 or ccHigh)

The ccHigh scenarios were simulated with the addition of a 6.0°F temperature rise and a 10 percent decrease in incremental inflows to each reservoir. The 6.0°F increase in temperature was modeled as a 20 percent increase in natural surface evaporation (see explanation of application of increased evaporation in Section 4.8.1). The high impact climate change sensitivity was developed based on the recommended CC-02 climate change scenario (HDR 2014b)

4.9 Performance Measures

Performance Measures (PM) provide a means for relicensing stakeholders to readily distinguish between the outcomes of different scenarios. The PMs were initially developed by the OSC during KT relicensing. The PMs were generally retained for use during Bad Creek relicensing with minor modifications.

5 Modeled Results

5.1 Scenario Results

Elevation duration plots showing the detailed elevations for each scenario, for each reservoir, and for each of the three hydrologic conditions (Normal, ccLow, and ccHigh) are provided in Figure 5-1 through Figure 5-3. Discharge duration plots from Lake Keowee (discharge from the KT Project) are provided for each scenario and hydrologic condition in Figure 5-4. Performance Measure Sheets for each of the hydrologic conditions are provided in Appendix B. All simulated results presented in this report are based on the 15-minute model output, unless stated otherwise.

5.1.1 Baseline (Current License)

The Baseline scenario simulates reservoir operations by Duke Energy based on KT license requirements, including the LIP and 2014 Operating Agreement, and current Bad Creek License requirements. As demonstrated by the model results in Table 5-1 and the reservoir elevation duration curves in Figure 5-1through Figure 5-3, minimum and maximum reservoir elevations for Bad Creek Reservoir, Lake Jocassee, and Lake Keowee meet the FERC license normal minimum and maximum reservoir elevations for both the Project as well as the KT Project under the three hydrology conditions (i.e., Normal, ccLow and ccHigh). Simulated reservoir levels for the Bad Creek Reservoir, Lake Jocassee, and Lake Keowee were generally comparable under Normal and ccLow hydrology, but additional Bad Creek Reservoir storage was accessed for a short duration with the ccHigh hydrology. Simulated reservoir elevations under all three hydrology conditions maintain reservoir elevations at Lake Keowee higher than the minimum operating levels for the existing municipal water intakes and Oconee Nuclear Station. Bad Creek and the KT Project were simulated to be in some stage of the LIP approximately 67 to 70 percent of the POR depending on the hydrology. Reservoir elevation duration curves are shown in Figure 5-1 through Figure 5-3.

Table 5-1. Minimum and Maximum Simulated Reservoir Elevations and Reservoir Operating Band for the Baseline Scenario (ft msl)

Hydrology	Bad Creek			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	2,246.1	2,259.5	2,280.0	33.9
ccLow	2,246.1	2,259.5	2,280.0	33.9
ccHigh	2,160.0	2,259.5	2,280.0	120.0
	Jocassee			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	1,084.1	1,107.0	1,110.0	25.9
ccLow	1,083.8	1,107.0	1,110.0	26.2
ccHigh	1,083.0	1,106.9	1,109.5	26.5
	Keowee			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	791.6	799.2	800.0	8.4
ccLow	791.6	799.2	800.0	8.4
ccHigh	792.0	799.1	800.0	8.0

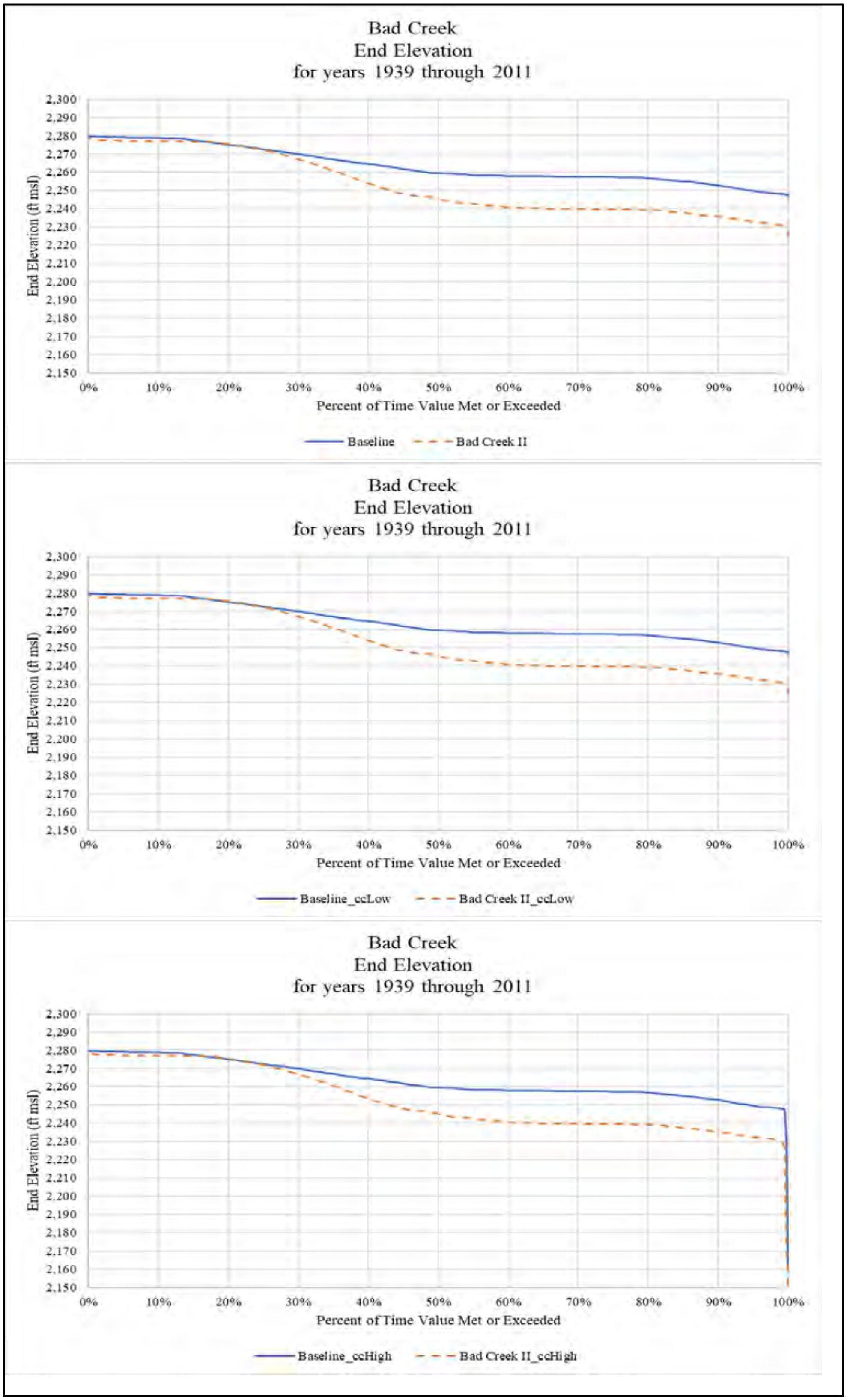


Figure 5-1. Bad Creek Simulated Reservoir Elevation Duration Curves for 1939 – 2011

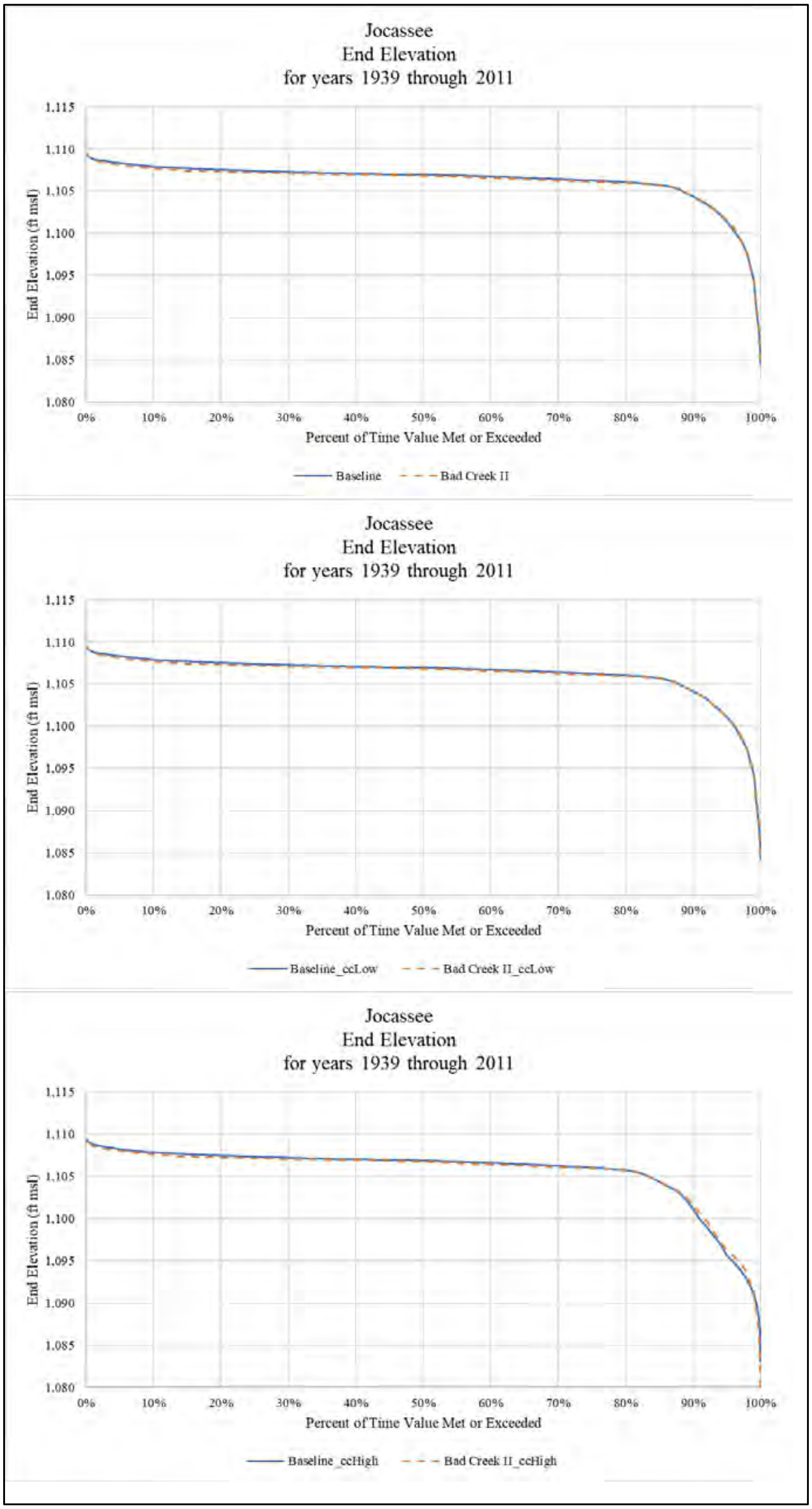


Figure 5-2. Jocassee Simulated Reservoir Elevation Duration Curves for 1939 – 2011

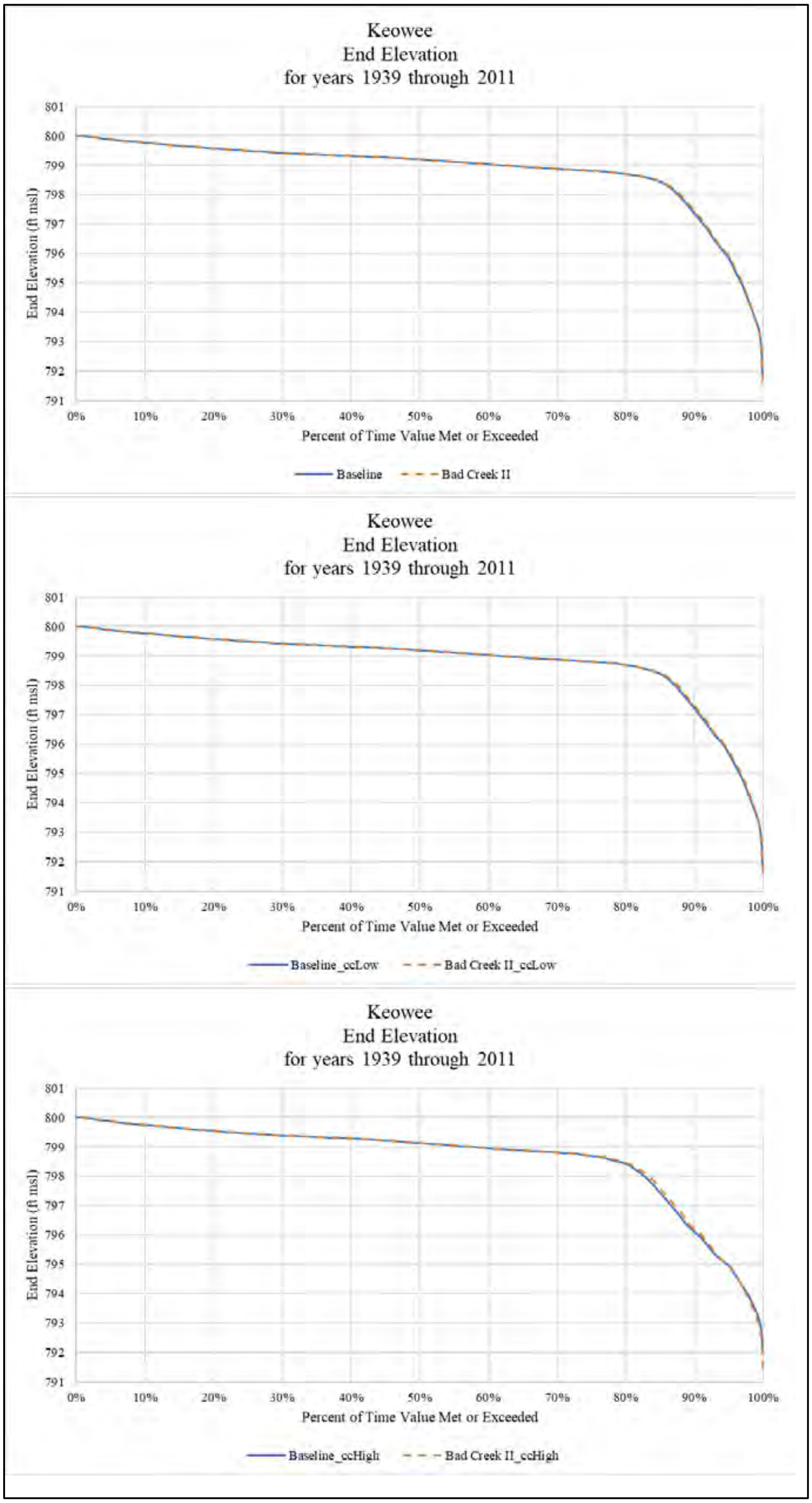


Figure 5-3. Keowee Simulated Reservoir Elevation Duration Curves for 1939 – 2011

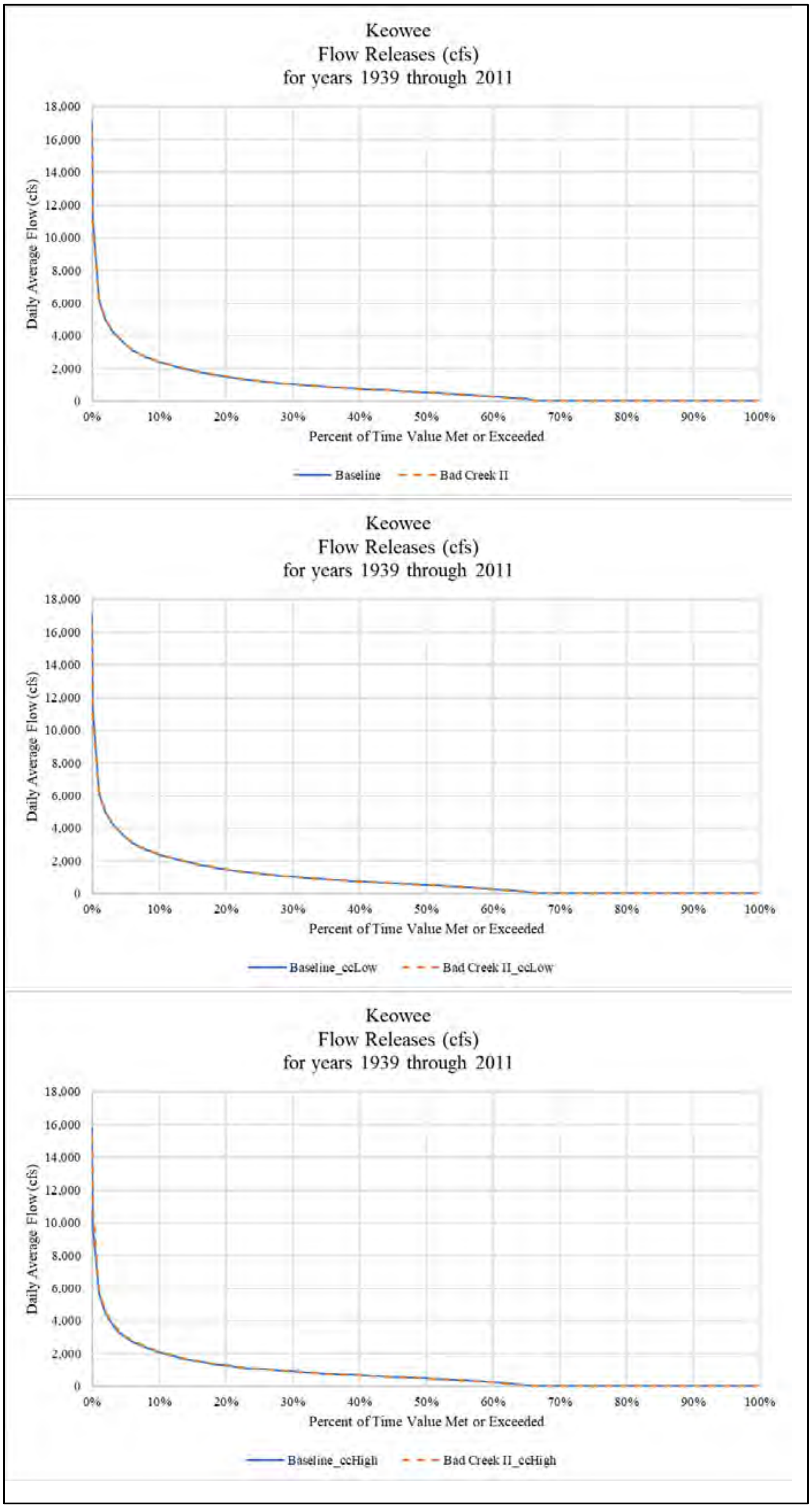


Figure 5-4. Keowee Daily Average Flow Releases for 1939 – 2011

5.1.2 Bad Creek II

The Bad Creek II scenario is identical to the Baseline scenario except for the differences described in Section 4.7. As with the Baseline Scenario, the model results in Table 5-2 and Figure 5-1 through Figure 5-3 demonstrate minimum and maximum reservoir elevations for Bad Creek Reservoir, Lake Jocassee, and Lake Keowee meet the FERC license normal minimum and maximum reservoir elevations for both the Project as well as the KT Project under the three hydrology conditions (i.e., Normal, ccLow and ccHigh).

As with the Baseline scenario, simulated reservoir levels for the Bad Creek Reservoir, Lake Jocassee, and Lake Keowee were generally comparable under Normal and ccLow hydrology, but additional Bad Creek Reservoir storage was accessed with the ccHigh hydrology. Simulated reservoir elevations under all three hydrology conditions maintain reservoir elevations at Lake Keowee higher than the minimum operating levels for the existing municipal water intakes and Oconee Nuclear Station. The Project and the KT Project were simulated to be in some stage of the LIP 81 to 87 percent of the POR, depending on hydrology.

Table 5-2. Minimum and Maximum Simulated Reservoir Elevations for the Bad Creek II Scenario (ft msl)

Hydrology	Bad Creek			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	2,224.7	2,245.6	2,280.0	55.3
ccLow	2,224.7	2,245.6	2,280.0	55.3
ccHigh	2,151.6	2,245.3	2,280.0	128.4
	Jocassee			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	1,084.5	1,106.8	1,110.0	25.5
ccLow	1,084.2	1,106.8	1,110.0	25.8
ccHigh	1,080.0	1,106.7	1,109.9	29.9
	Keowee			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	791.6	799.2	800.0	8.4
ccLow	791.7	799.2	800.0	8.3
ccHigh	791.4	799.1	800.0	8.6

6 Effects of Bad Creek II

Model results for the Baseline and Bad Creek II scenarios were compared to identify potential differences in the effects of Bad Creek II as contrasted with existing license conditions. This comparison is focused primarily on reservoir elevation effects.

As demonstrated by the modeling results, the effects of Bad Creek II are constrained by Duke Energy's continued compliance with the existing KT Project FERC license including the KT LIP and the 2014 Operating Agreement. These requirements would not be modified with the relicensing of the Project or the construction and operation of Bad Creek II, so little to no effects to the downstream USACE hydroelectric projects were identified in the model results.

The relative size differences between the Bad Creek Reservoir, Lake Jocassee, and Lake Keowee directly affect how generation and pumping volumes affect reservoir levels within the three reservoirs. As a general guide and ignoring all other inflows, withdrawals, downstream flow releases, and evaporation, a change of 1.0 ft of reservoir storage at the Bad Creek Reservoir results in 0.05 ft (0.6 inches) of change in Lake Jocassee's water level. If the same volume of water was then moved upstream or downstream at Jocassee, Lake Keowee's level would change by 0.02 ft (0.25 inches).

The following sections summarize key comparisons of modeling results for the Baseline and Bad Creek II scenarios. See Appendix B for the Performance Measures sheets for additional information regarding the modeled outcomes for the Project and KT Project.

6.1 Project and KT Project Reservoir Levels

Model results in Table 6-1 through Table 6-3 demonstrate an additional 8.4 ft to 21.4 ft, depending on hydrology, of storage at the Bad Creek Reservoir would be accessed under the Bad Creek II scenario as compared to the Baseline scenario. Depending on hydrology, effects on minimum reservoir levels at Lake Jocassee and Lake Keowee are less pronounced. As demonstrated by the reservoir elevation curves for Lake Jocassee and Lake Keowee (see Figure 5-2 and Figure 5-3), reservoir elevations under both scenarios are comparable. This is further demonstrated by the Performance Measures sheets in Appendix B. There are very few differences in reservoir level-related measures when comparing the Baseline and Bad Creek II scenarios under all three hydrology conditions.

Both the Project and the KT Project normal minimum and normal maximum reservoir level limits in the existing Project license and the KT Project license would remain unchanged. As discussed above, reservoir elevations at Lake Keowee under the three hydrology conditions remain above the minimum reservoir operating levels for municipal water intakes and Oconee Nuclear Station, so no new effects to existing water intakes are anticipated.

Table 6-1. Normal Hydrology Minimum Simulated Reservoir Elevations Compared to the Baseline Scenario (ft msl)

Scenario	Bad Creek	Jocassee	Keowee
Baseline (Existing License)	2,246.1	1,084.1	791.6
Bad Creek II	2,224.7	1,084.5	791.6
Difference from Baseline	**-21.4**	**0.4**	**0.0**

Table 6-2. ccLow Sensitivity Minimum Simulated Reservoir Elevations Compared to the Baseline Scenario (ft msl)

Scenario	Bad Creek	Jocassee	Keowee
Baseline (Existing License)	2,246.1	1,083.8	791.6
Bad Creek II	2,224.7	1,084.2	791.7
Difference from Baseline	**-21.4**	**0.4**	**0.1**

Table 6-3. ccHigh Sensitivity Minimum Simulated Reservoir Elevations Compared to the Baseline Scenario (ft msl)

Scenario	Bad Creek	Jocassee	Keowee
Baseline (Existing License)	2,160.0	1,083.0	792.0
Bad Creek II	2,151.6	1,080.0	791.4
Difference from Baseline	**-8.4**	**-3.0**	**-0.6**

6.1.1 Lake Level Fluctuations and Shoreline Erosion

6.1.1.1 Fluctuation Rates

Model results in Table 6-4 demonstrate the maximum reservoir fluctuation over a 24-hour window during the POR for both the Baseline and Bad Creek II scenarios. Figure 6-1 through Figure 6-3 show the variation in reservoir fluctuation over the POR for Bad Creek, Jocassee, and Keowee. Typically, about 60 percent of the time, the Bad Creek II scenario results in an approximately 15-foot increase in 24-hour fluctuation at Bad Creek as compared with the

Baseline scenario. In contrast, at Jocassee, about 97 percent of the time, the Bad Creek II scenario results in an approximately 0.4- to 0.2-ft decrease in 24-hour fluctuation as compared to the Baseline scenario. The decreased range in 24-hour fluctuations in Lake Jocassee is due to increased generation and pumping volumes associated with Bad Creek II. Both Bad Creek and Bad Creek II operations are synched with Jocassee Pumped Storage Station operations in the model such that both Bad Creek and Bad Creek II typically generate and pump when Jocassee generates and pumps. However, a larger volume of water moves between Bad Creek Reservoir and Lake Jocassee in the Bad Creek II scenario, offsetting more of the lake level fluctuation effects at Lake Jocassee caused by Jocassee Pumped Storage Station operations. The model indicates little to no difference in 24-hour fluctuations at Lake Keowee between the Bad Creek II scenario and the Baseline scenario.

The reduction in Jocassee reservoir elevation fluctuations for the Bad Creek II scenario is demonstrated by the Performance Measures related to spawning success. Under all three hydrology conditions, reservoir elevations are within a tighter fluctuation band compared to the Baseline scenario. At Lake Keowee, there are no significant differences in the spawning fluctuation bands. See Appendix B for the Performance Measures sheets.

Table 6-4. Normal Hydrology Maximum Simulated Reservoir Fluctuation Over 24-hours Compared to the Baseline Scenario (ft)

Scenario	Bad Creek	Jocassee	Keowee
Baseline (Existing License)	33.1	4.3	2.3
Bad Creek II	52.6	4.5	2.3
Difference from Baseline	**19.2**	**0.2**	**0.0**

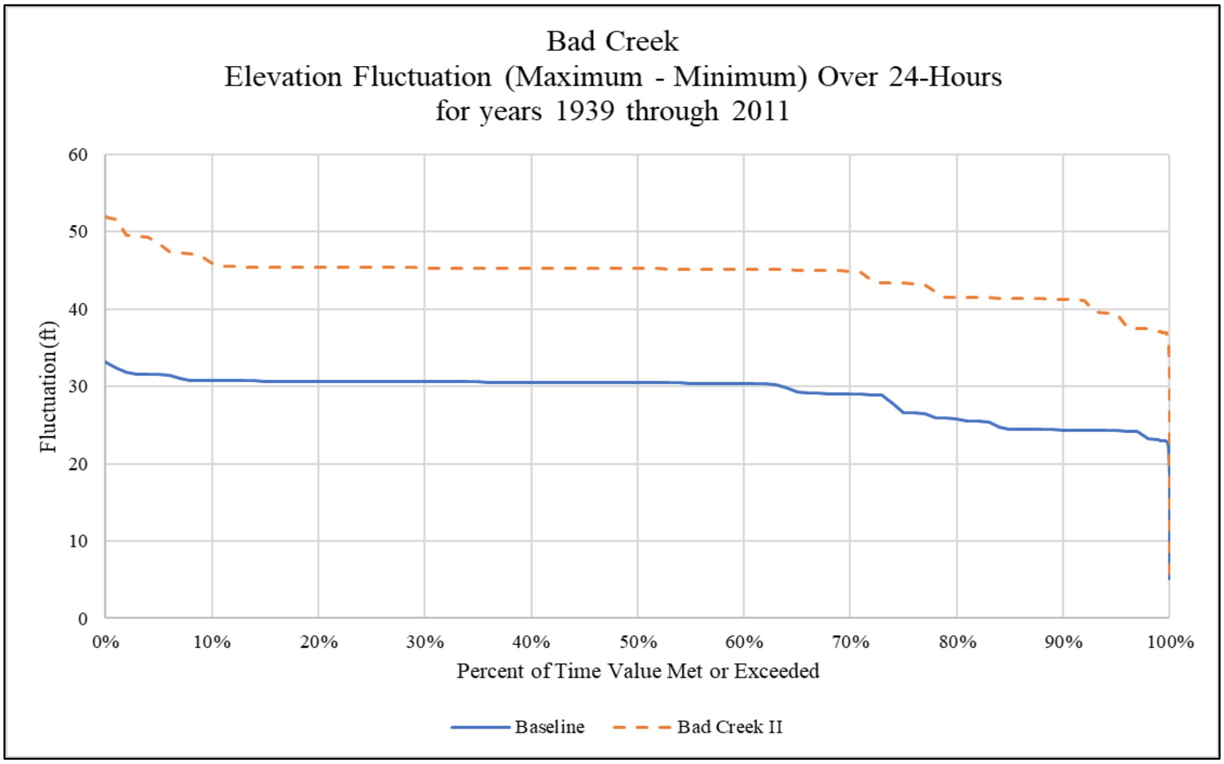


Figure 6-1. Normal Hydrology Bad Creek 24-hour Reservoir Fluctuation for 1939 – 2011

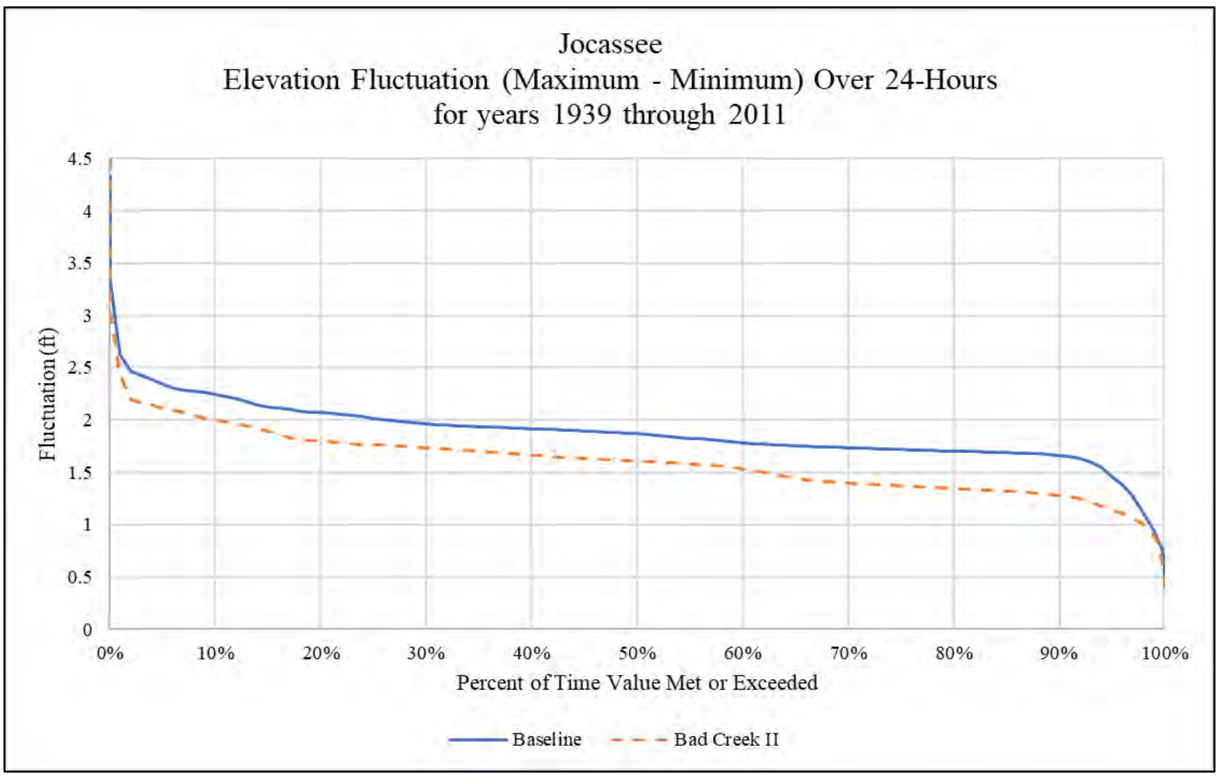


Figure 6-2. Normal Hydrology Jocassee 24-hour Reservoir Fluctuation for 1939 – 2011

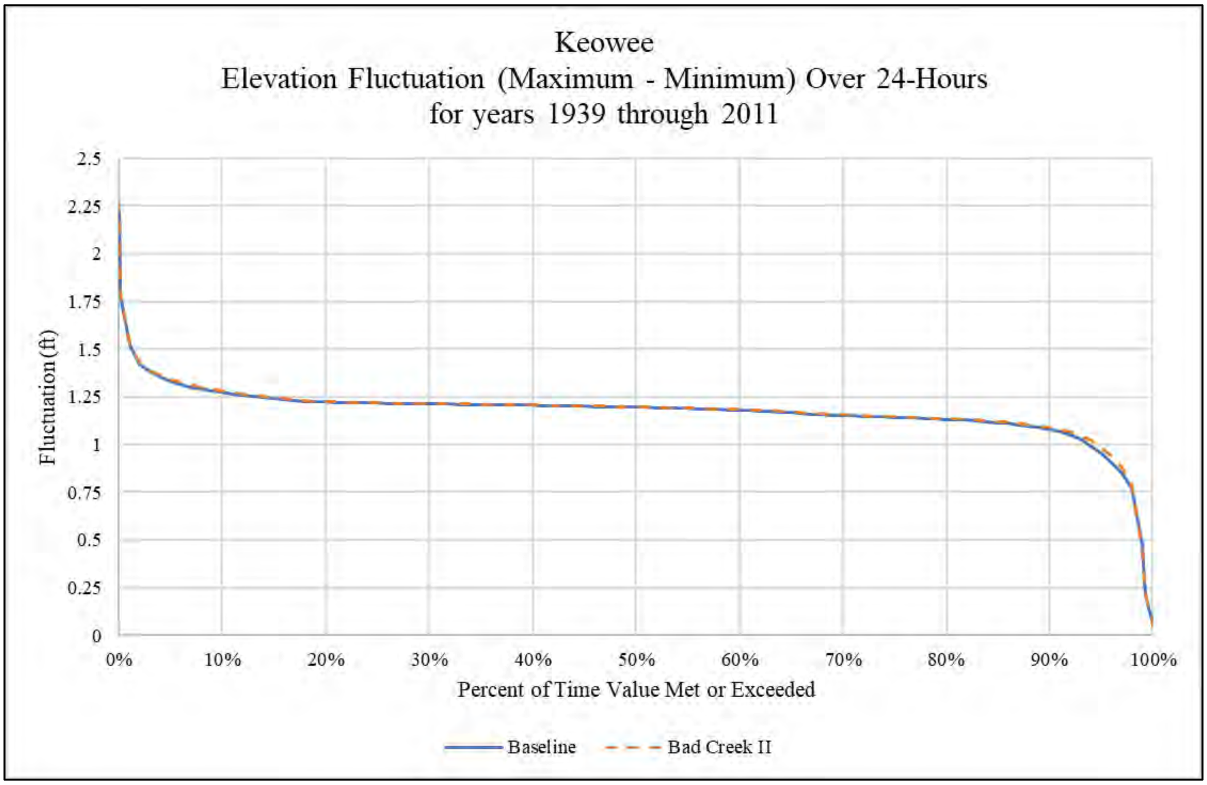


Figure 6-3. Normal Hydrology Keowee 24-hour Reservoir Fluctuation for 1939 – 2011

6.1.1.2 Whitewater River Cove Shoreline Erosion

As part of the Bad Creek II Feasibility Study authorized by Duke Energy, HDR developed a three-dimensional Computational Fluid Dynamic model for lower reservoir modeling to complement the Upper and Lower Reservoir Operational Impact Studies. This effort was carried out in support of evaluating a second inlet/outlet structure and the potential associated erosion impacts to the Whitewater River cove of Lake Jocassee. The final report "Lower Reservoir CFD Flow Modeling Report" was filed with the Bad Creek RSP as Appendix I in December 2022 (HDR 2022).

The results of the modeling indicate additional generation flows resulting from Bad Creek II would not increase erosion potential along the east bank (i.e., opposite bank) of the Whitewater River cove in Lake Jocassee across from the inlet/outlet structure assuming the geology is consistent along the eastern bank (i.e., bedrock). The modeled velocities were approximately equivalent to the physical model study velocities, which are representative of existing conditions. Flows from the existing configuration and operations have not resulted in erosion along the east bank and velocities are within the general range compared to the proposed configuration; detailed results are included in HDR (2022).

6.1.1.3 Lake Jocassee Shoreline Erosion

To assess general characteristics of shoreline erosion along Lake Jocassee (and Lake Keowee), Duke Energy conducted a Shoreline Erosion Study (Baird 2013) during KT Project relicensing. The purpose of the erosion study was to determine the main drivers of shoreline erosion and to quantify erosion along the shorelines. The Baird (2013) study results showed sources of erosion include physical weathering (e.g., freeze-thaw), wave action from wind and recreational boating, concentrated runoff, non-project development along the shoreline (i.e., land development), and operation of the reservoir (cyclic raising and lowering lake levels). Results indicated the majority of shoreline erosion was caused by wave action associated with wind and boat wakes, and while water level fluctuations due to operations affected the elevations at which wave-induced erosion occurs, water level fluctuations themselves do not appear to contribute appreciably to the overall rate of shoreline erosion. Results indicated approximately 25 to 45 percent of the erosion noted was attributed to boat wakes in Lake Jocassee and the remainder was attributable to wind waves (Baird 2013). In general, wind and wave-caused erosion is expected to continue in areas with erodible soils where bedrock has not been exposed but may occur at higher or lower rates if pool elevations are modified (Baird 2013). Because the operating band for Lake Jocassee and Lake Keowee will not change with Bad Creek II operations, and CHEOPS modeling demonstrates the Lake Jocassee elevations will be generally consistent between the Baseline and Bad Creek II scenarios, the addition of Bad Creek II is not anticipated to affect erosion rates along the shorelines of Lake Jocassee.

Additionally, shoreline studies at Lake Jocassee including scarp height (thickness of soil visible above the water line), recession of banks, and percentage of shoreline protection around the reservoir, have been carried out (Orbis 2012). Overall, the study results showed approximately 75 percent of the Lake Jocassee shoreline is either (a) bedrock or (b) shows no signs of erosion (past or present) (Orbis 2012).

Duke Energy is responsible for managing activities within the reservoir boundaries of Lakes Jocassee and Keowee in a manner promoting safe public use and maintaining environmental safeguards. Duke Energy maintains a Shoreline Management Plan for Lakes Jocassee and

Keowee classifying the respective shorelines and denotes where environmentally important habitat exists, where existing facilities and uses occur, and where future/existing shoreline activities may be considered.

6.1.2 Aquatic Resources

Potential effects to aquatic resources in Lake Jocassee related to changes in water level fluctuation and exchange of water between the upper and lower reservoirs are considered in the Aquatic Resources Study Report (Task 2 – Effects of Bad Creek II Complex and Expanded Weir on Aquatic Habitat).

6.1.3 LIP Stages

The percent of days in some stage of the LIP increased under all three hydrology conditions (Normal, ccLow and ccHigh) when comparing Bad Creek II with the Baseline scenario. The various LIP stages are triggered by the ratio of storage in the Duke Energy reservoirs compared to the storage in the USACE reservoirs. The addition of Bad Creek II results in increased (simulated) flow releases from Keowee, which in turn creates reservoir storage imbalances between the Duke Energy and USACE reservoirs. This effect is slightly more pronounced under the ccHigh hydrologic conditions. While these incremental changes in reservoir storage balance are small between the Duke Energy and USACE reservoirs (i.e., typically less than 1.5 percent), they are oftentimes enough to trigger the next LIP stage. As a result, the Bad Creek II scenario results in a shift of days from “normal” (i.e., non-drought stage) to LIP Stage 0 (the first drought stage), as shown on Figure 6-4. Likewise, there are a few occurrences where there is a similar shift in days from one LIP Stage to the next[9]. In reality, these shifts may not occur, or the frequency of occurrence may be less, due to real-time operations which would likely limit excess flow releases from Keowee during drought conditions. As a result, the number of days in any LIP stage may be less than what is depicted on Figure 6-4.

[9] See Performance Measures 64 through 69 in Appendix B which demonstrate the shifting of days between the earliest LIP stages.

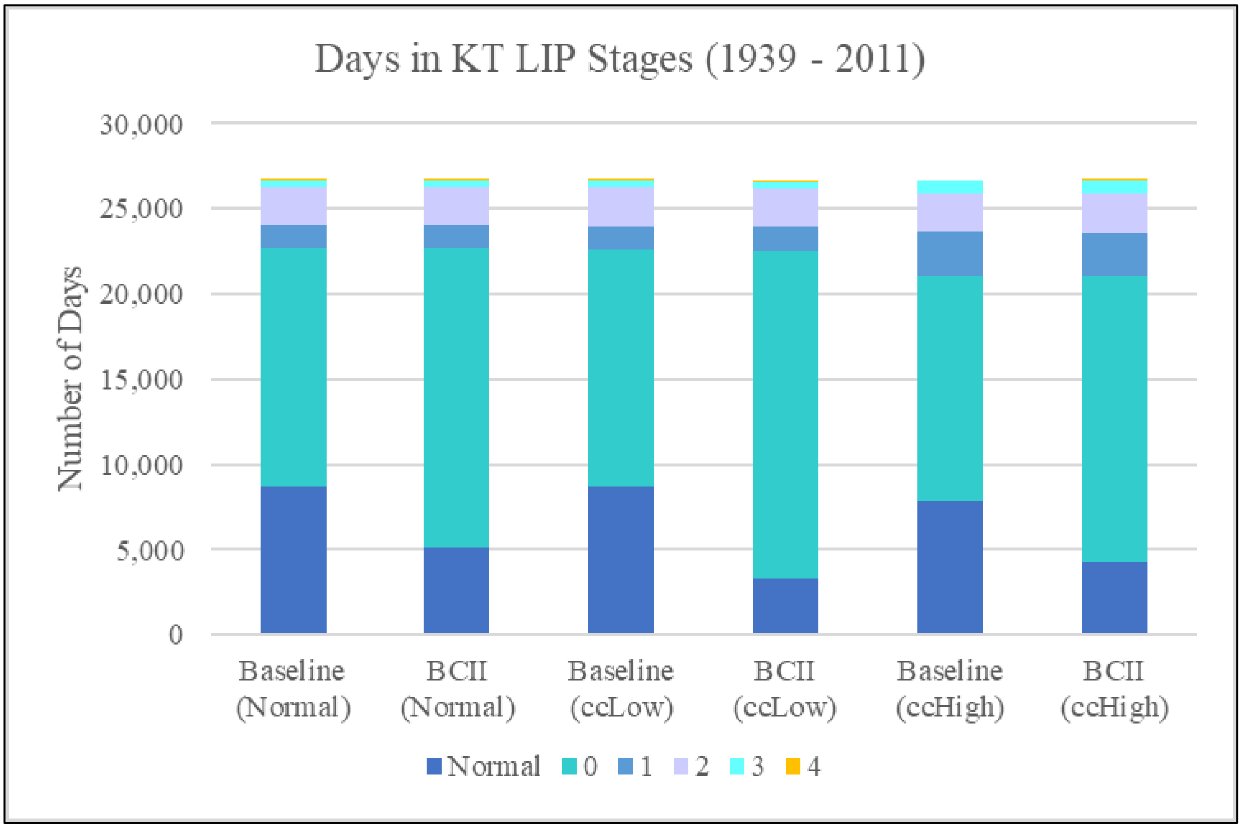


Figure 6-4. Days in KT LIP Stages for 1939 - 2011

6.2 Effects on USACE Reservoirs

The Water Resources Study Plan identified the geographic extent of the CHEOPS task as Lake Jocassee and Lake Keowee. However, FERC identified the geographic scope of the cumulative effects analysis for water resources as the Savannah River to its mouth. To support this evaluation, CHEOPS results for the three downstream USACE reservoirs were reviewed to identify differences in the timing and magnitude of flow releases from Keowee into Lake Hartwell, the most upstream USACE reservoir.

As discussed above, both the Baseline and Bad Creek II scenarios include continued compliance with the existing KT FERC license including implementation of the KT LIP and the 2014 Operating Agreement. These requirements limit the potential effects of Project operations and Bad Creek II proposed operations on the USACE reservoirs. As shown in Table 6-5, average annual downstream flow releases from the Keowee Development under both scenarios are identical under Normal and ccLow hydrology; using the ccHigh hydrology, differences are less than one percent. Consequently, the average annual releases from the J. Strom Thurmond

Development are identical for both scenarios using Normal and ccLow hydrology and differ by only 0.1 percent under ccHigh hydrology.

Table 6-5. Average Annual Flow Releases from the Keowee and J. Strom Thurmond Developments for the Baseline and Bad Creek II Scenarios 1939 – 2011 (cfs)

Hydrology	Keowee Average Annual Release (cfs)			J. Strom Thurmond Average Annual Release (cfs)		
	Baseline	Bad Creek II	Change (%)	Baseline	Bad Creek II	Change (%)
Normal	944	944	0	7,719	7,719	0
ccLow	939	939	0	7,680	7,680	0
ccHigh	829	837	0.9	6,825	6,833	0.1

The timing of downstream releases is also tightly aligned as demonstrated by an evaluation of the total cumulative volume of water released downstream of the Keowee Development and J. Strom Thurmond for the POR (Figure 6-5). Given these findings, few if any effects on the USACE reservoirs are anticipated.

Figure 6-5. Keowee and J. Strom Thurmond Cumulative Release for 1939 – 2011 under Normal, ccLow, and ccHigh hydrology (total volume, thousand acre-ft [TAF])

7 Conclusions

Reviewing the results of the Baseline and Bad Creek II scenarios leads to the following observations:

- Additional reservoir storage at the Bad Creek Reservoir would be accessed with Bad Creek II operations as compared to operations under the Baseline scenario.
- Lake Jocassee reservoir level fluctuations over a 24-hour period would generally be smaller than would occur under the Baseline scenario. The 24-hour fluctuations would be

two feet or less approximately 90% of the time under the Bad Creek II scenario, but only 75% of the time under the Baseline Scenario.

- The effects of the proposed Bad Creek II on lake level fluctuations at Lake Keowee and would be comparable to the effects of Bad Creek. There is no significant long-term difference between reservoir elevations including reservoir level range or reservoir level fluctuation frequencies.
- Proposed Bad Creek II operations have no modeled effect on municipal water intakes on Lake Keowee or Oconee Nuclear Station.
- KT LIP Stage 0 would be triggered more frequently with Bad Creek II, but the differences in KT LIP stage frequencies generally diminish in the more advanced stages of the KT LIP.
- Proposed Bad Creek II operations have little to no modeled effects on the downstream USACE reservoirs or flow releases into the Savannah River.

8 Need for Protection, Mitigation, and Enhancement Measures to Protect Water Quality

Based on the results of CHEOPS modeling, and in consideration of results of other data collection efforts in support of KT relicensing (Duke Energy 2014), there is no need for additional PM&E measures to address reservoir elevation changes or downstream flow releases to the USACE reservoirs.

9 Variances from FERC-approved Study Plan

There were no variances from the FERC-approved RSP for this task of the Water Resources Study except for the addition of additional evaluation of the potential lake levels at the USACE reservoirs and flow releases downstream of the Project.

10 References

ARCADIS. 2010. Savannah River unimpaired flow 1939-2009 time series extension. Prepared for Duke Energy, the Savannah District of the U.S. Army Corps of Engineers, and the Georgia Environmental Protection Division. August 2010.

______. 2013. Savannah River Unimpaired Flow Data Report Revision 2 (May 2013): 2009 – 2011 Unimpaired Flow Extension. Prepared for Duke Energy. May 10, 2013.

Baird, W.F. & Associates Ltd. under Contract to Orbis, Inc. (Baird). 2013. Lake Keowee & Lake Jocassee Shoreline Erosion Study Final Report. FERC Project No. 2503. Prepared for Duke Energy Carolinas, LLC. January 14, 2013.

Dobson, M., and C. Frid. 2009. Ecology of Aquatic Systems, Second Edition. Oxford University Press, New York, NY.

Duke Energy Carolinas, LLC (Duke Energy). 2008. Bad Creek Pumped Storage Project (FERC No. 2740): Supporting Technical Information. February 2008.

______. 2014. Keowee-Toxaway Hydroelectric Project FERC Relicensing Final License Application (FERC Project No. 2503). August 2014.

HDR Engineering, Inc. (HDR). 2010. Keowee-Toxaway Project: Jocassee Pumped Storage Project (FERC No. 2503): Supporting Technical Information Document. October 2010.

______. 2012a. Keowee-Toxaway Project: Keowee Development (FERC No. 2503): Supporting Technical Information Document. Prepared for Duke Energy. January 2012.

______. 2012b. Keowee-Toxaway Climate Change Scenario Development Summary. Prepared for Duke Energy Carolinas, LLC September 19, 2012.

______. 2014a. Comprehensive environmental, engineering, and economic analysis impact report for revising the 1968 operating agreement for the Keowee-Toxaway Project. Prepared for Duke Energy Carolinas, LLC. April 4, 2014.

______. 2014b. Savannah River Basin Model Logic and Verification Report. Prepared for Duke Energy Carolinas, LLC. May 1, 2014.

______. 2014c. Water Supply Study Report. Keowee-Toxaway Hydroelectric Relicensing Project. Prepared for Duke Energy Carolinas, LLC. June 6, 2014.

______. 2022. Lower Reservoir CFD Flow Modeling Report. Bad Creek II Power Complex Feasibility Study. Prepared for Duke Energy. September 1, 2022.

Orbis. 2012. Riparian Vegetation Habitat Study on Lake Keowee, SC. Keowee-Toxaway Relicensing project – FERC No. 2503. Prepared for Duke Energy, Carolinas, LLC.

U.S. Army Corps of Engineers. 1989. Savannah River Basin Drought Contingency Plan. Savannah District USACE. March 1989.

———. 2010. Water Management Page for the Savannah River Projects. [Online] URL: http://water.sas.usace.army.mil/home/indexDU.htm (Accessed August 11, 2010).

———. 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.

Appendix A

Withdrawal and Return Estimates

This page intentionally left blank.

Bad Creek Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1940	2011	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1941	2012	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
1942	2013	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
1943	2014	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1944	2015	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
1945	2016	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
1946	2017	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
1947	2018	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
1948	2019	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
1949	2020	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
1950	2021	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
1951	2022	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
1952	2023	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
1953	2024	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
1954	2025	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
1955	2026	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
1956	2027	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
1957	2028	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
1958	2029	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
1959	2030	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
1960	2031	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1961	2032	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
1962	2033	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
1963	2034	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
1964	2035	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
1965	2036	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
1966	2037	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1967	2038	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1968	2039	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
1969	2040	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
1970	2041	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
1971	2042	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
1972	2043	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
1973	2044	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
1974	2045	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
1975	2046	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
1976	2047	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
1977	2048	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
1978	2049	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
1979	2050	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
1980	2051	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
1981	2052	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
1982	2053	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
1983	2054	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
1984	2055	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
1985	2056	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
1986	2057	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
1987	2058	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
1988	2059	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
1989	2060	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
1990	2061	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
1991	2062	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
1992	2063	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
1993	2064	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
1994	2065	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
1995	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1996	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1997	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1998	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1999	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2000	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2001	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2002	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2003	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2004	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2005	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2006	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2007	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2008	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2009	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2010	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2011	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Bad Creek Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1940	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1941	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1942	2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1943	2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1944	2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1945	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1946	2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1947	2018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1948	2019	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1949	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1950	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1951	2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	2023	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	2024	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	2026	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1956	2027	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	2028	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	2029	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	2031	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	2032	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	2033	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	2034	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	2035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	2036	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	2037	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	2038	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	2039	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	2040	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	2041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	2042	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	2043	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	2044	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	2045	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	2046	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	2047	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	2048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	2049	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	2050	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	2051	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	2052	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	2053	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	2054	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	2055	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	2056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	2057	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	2058	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	2059	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	2060	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	2061	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	2062	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	2063	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	2064	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	2065	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Jocassee Withdrawals (cfs)

Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22
1940	2011	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28
1941	2012	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34
1942	2013	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40
1943	2014	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46
1944	2015	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52
1945	2016	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58
1946	2017	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58
1947	2018	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59
1948	2019	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59
1949	2020	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
1950	2021	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
1951	2022	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
1952	2023	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61
1953	2024	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61
1954	2025	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62
1955	2026	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62
1956	2027	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63
1957	2028	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64
1958	2029	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65
1959	2030	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65
1960	2031	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66
1961	2032	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67
1962	2033	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68
1963	2034	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69
1964	2035	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69
1965	2036	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70
1966	2037	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71
1967	2038	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
1968	2039	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
1969	2040	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73
1970	2041	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74
1971	2042	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75
1972	2043	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75
1973	2044	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76
1974	2045	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77
1975	2046	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
1976	2047	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79
1977	2048	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79
1978	2049	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80
1979	2050	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81
1980	2051	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82
1981	2052	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82
1982	2053	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83
1983	2054	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84
1984	2055	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85
1985	2056	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86
1986	2057	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87
1987	2058	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88
1988	2059	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89
1989	2060	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90
1990	2061	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91
1991	2062	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92
1992	2063	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93
1993	2064	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94
1994	2065	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95
1995	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
1996	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
1997	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
1998	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
1999	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2000	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2001	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2002	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2003	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2004	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2005	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2006	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2007	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2008	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2009	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2010	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2011	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96

Jocassee Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1940	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1941	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1942	2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1943	2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1944	2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1945	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1946	2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1947	2018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1948	2019	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1949	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1950	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1951	2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	2023	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	2024	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	2026	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1956	2027	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	2028	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	2029	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	2031	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	2032	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	2033	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	2034	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	2035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	2036	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	2037	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	2038	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	2039	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	2040	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	2041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	2042	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	2043	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	2044	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	2045	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	2046	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	2047	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	2048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	2049	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	2050	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	2051	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	2052	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	2053	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	2054	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	2055	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	2056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	2057	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	2058	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	2059	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	2060	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	2061	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	2062	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	2063	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	2064	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	2065	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Keowee Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	94.67	93.15	91.34	98.09	101.61	117.99	116.09	113.32	109.48	98.73	89.68	94.04
1940	2011	97.13	95.57	93.73	100.72	104.41	121.23	119.24	116.39	112.45	101.41	92.13	96.55
1941	2012	99.60	97.99	96.12	103.35	107.21	124.47	122.39	119.45	115.41	104.10	94.59	99.07
1942	2013	102.06	100.41	98.50	105.99	110.01	127.72	125.53	122.52	118.37	106.79	97.05	101.58
1943	2014	104.53	102.83	100.89	108.62	112.81	130.96	128.68	125.59	121.34	109.48	99.51	104.09
1944	2015	106.99	105.25	103.28	111.26	115.61	134.20	131.83	128.66	124.30	112.17	101.96	106.61
1945	2016	109.46	107.67	105.66	113.89	118.42	137.44	134.98	131.72	127.26	114.86	104.42	109.12
1946	2017	111.32	109.48	107.46	116.02	120.85	140.21	137.63	134.30	129.73	117.13	106.53	111.13
1947	2018	113.17	111.28	109.26	118.15	123.28	142.97	140.28	136.87	132.19	119.40	108.63	113.13
1948	2019	115.03	113.08	111.06	120.28	125.71	145.74	142.93	139.44	134.66	121.67	110.74	115.14
1949	2020	116.89	114.89	112.85	122.42	128.14	148.50	145.58	142.02	137.13	123.94	112.85	117.14
1950	2021	118.74	116.69	114.65	124.55	130.57	151.27	148.23	144.59	139.59	126.21	114.95	119.15
1951	2022	120.60	118.50	116.45	126.68	133.00	154.03	150.88	147.16	142.06	128.48	117.06	121.15
1952	2023	122.46	120.30	118.25	128.81	135.43	156.80	153.53	149.74	144.52	130.75	119.17	123.16
1953	2024	124.32	122.11	120.05	130.94	137.86	159.56	156.18	152.31	146.99	133.02	121.27	125.17
1954	2025	126.17	123.91	121.85	133.07	140.29	162.33	158.82	154.88	149.46	135.29	123.38	127.17
1955	2026	128.03	125.72	123.64	135.20	142.72	165.09	161.47	157.46	151.92	137.56	125.49	129.18
1956	2027	131.45	129.08	126.95	138.77	146.44	169.42	165.72	161.60	155.92	141.16	128.76	132.59
1957	2028	134.88	132.45	130.25	142.34	150.16	173.75	169.97	165.75	159.92	144.77	132.04	136.01
1958	2029	138.30	135.82	133.55	145.91	153.89	178.07	174.22	169.89	163.93	148.38	135.31	139.43
1959	2030	141.73	139.19	136.86	149.48	157.61	182.40	178.47	174.04	167.93	151.98	138.59	142.85
1960	2031	145.16	142.55	140.16	153.05	161.33	186.73	182.72	178.19	171.93	155.59	141.86	146.26
1961	2032	148.58	145.92	143.46	156.63	165.05	191.06	186.97	182.33	175.93	159.20	145.14	149.68
1962	2033	152.01	149.29	146.77	160.20	168.78	195.38	191.22	186.48	179.93	162.80	148.41	153.10
1963	2034	155.43	152.66	150.07	163.77	172.50	199.71	195.47	190.62	183.93	166.41	151.68	156.52
1964	2035	158.86	156.02	153.37	167.34	176.22	204.04	199.72	194.77	187.94	170.02	154.96	159.93
1965	2036	162.28	159.39	156.68	170.91	179.94	208.36	203.97	198.92	191.94	173.62	158.23	163.35
1966	2037	164.12	161.18	158.47	173.05	182.40	211.17	206.63	201.49	194.41	175.90	160.35	165.37
1967	2038	165.96	162.97	160.26	175.19	184.85	213.97	209.28	204.07	196.89	178.19	162.47	167.38
1968	2039	167.81	164.76	162.05	177.33	187.30	216.77	211.94	206.64	199.36	180.47	164.58	169.39
1969	2040	169.65	166.55	163.84	179.47	189.75	219.57	214.59	209.22	201.84	182.75	166.70	171.41
1970	2041	171.49	168.34	165.63	181.61	192.20	222.37	217.25	211.79	204.31	185.03	168.82	173.42
1971	2042	173.33	170.13	167.42	183.76	194.65	225.17	219.90	214.37	206.79	187.31	170.94	175.43
1972	2043	175.17	171.92	169.21	185.90	197.10	227.97	222.56	216.94	209.26	189.59	173.05	177.45
1973	2044	177.01	173.71	171.00	188.04	199.55	230.77	225.21	219.52	211.74	191.87	175.17	179.46
1974	2045	178.85	175.50	172.79	190.18	202.00	233.57	227.87	222.10	214.21	194.15	177.29	181.47
1975	2046	180.69	177.29	174.58	192.32	204.45	236.37	230.52	224.67	216.69	196.43	179.40	183.49
1976	2047	182.49	179.03	176.33	194.41	206.85	239.11	233.11	227.19	219.10	198.66	181.47	185.45
1977	2048	184.29	180.78	178.08	196.50	209.24	241.84	235.70	229.70	221.52	200.88	183.54	187.42
1978	2049	186.09	182.53	179.83	198.59	211.63	244.57	238.30	232.21	223.93	203.11	185.60	189.38
1979	2050	187.88	184.28	181.58	200.68	214.02	247.30	240.89	234.73	226.35	205.34	187.67	191.35
1980	2051	189.68	186.02	183.32	202.77	216.41	250.03	243.48	237.24	228.77	207.56	189.73	193.31
1981	2052	191.48	187.77	185.07	204.86	218.80	252.77	246.07	239.76	231.18	209.79	191.80	195.28
1982	2053	193.28	189.52	186.82	206.95	221.20	255.50	248.66	242.27	233.60	212.01	193.87	197.24
1983	2054	195.08	191.27	188.57	209.04	223.59	258.23	251.25	244.78	236.01	214.24	195.93	199.21
1984	2055	196.88	193.02	190.32	211.13	225.98	260.96	253.84	247.30	238.43	216.47	198.00	201.17
1985	2056	198.67	194.76	192.07	213.22	228.37	263.70	256.43	249.81	240.84	218.69	200.06	203.14
1986	2057	200.72	196.75	194.05	215.59	231.09	266.80	259.38	252.67	243.59	221.22	202.41	205.37
1987	2058	202.76	198.74	196.04	217.97	233.81	269.91	262.33	255.53	246.34	223.76	204.77	207.61
1988	2059	204.81	200.73	198.03	220.35	236.53	273.02	265.28	258.39	249.09	226.29	207.12	209.84
1989	2060	206.86	202.72	200.02	222.73	239.25	276.13	268.22	261.25	251.84	228.82	209.47	212.08
1990	2061	208.90	204.70	202.01	225.11	241.97	279.24	271.17	264.11	254.58	231.35	211.82	214.31
1991	2062	210.95	206.69	204.00	227.48	244.70	282.35	274.12	266.97	257.33	233.89	214.17	216.55
1992	2063	212.99	208.68	205.99	229.86	247.42	285.46	277.07	269.83	260.08	236.42	216.52	218.79
1993	2064	215.04	210.67	207.98	232.24	250.14	288.56	280.01	272.69	262.83	238.95	218.87	221.02
1994	2065	217.08	212.66	209.97	234.62	252.86	291.67	282.96	275.55	265.58	241.49	221.22	223.26
1995	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
1996	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
1997	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
1998	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
1999	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2000	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2001	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2002	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2003	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2004	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2005	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2006	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2007	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2008	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2009	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2010	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2011	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49

Keowee Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	2.71	2.21	1.82	2.28	2.24	2.70	2.44	2.51	2.61	2.22	2.03	2.43
1940	2011	2.82	2.30	1.89	2.37	2.33	2.81	2.54	2.61	2.71	2.31	2.11	2.52
1941	2012	2.93	2.38	1.96	2.46	2.42	2.91	2.63	2.71	2.81	2.40	2.19	2.62
1942	2013	3.03	2.47	2.03	2.54	2.50	3.02	2.73	2.81	2.91	2.48	2.26	2.71
1943	2014	3.14	2.55	2.09	2.63	2.59	3.12	2.82	2.91	3.02	2.57	2.34	2.81
1944	2015	3.24	2.64	2.16	2.72	2.67	3.23	2.92	3.01	3.12	2.66	2.42	2.90
1945	2016	3.35	2.73	2.23	2.80	2.76	3.33	3.01	3.11	3.22	2.74	2.50	3.00
1946	2017	3.45	2.81	2.29	2.89	2.84	3.43	3.10	3.20	3.32	2.82	2.57	3.09
1947	2018	3.55	2.89	2.36	2.97	2.92	3.53	3.19	3.30	3.42	2.91	2.64	3.18
1948	2019	3.65	2.97	2.42	3.05	3.00	3.63	3.28	3.39	3.52	2.99	2.72	3.27
1949	2020	3.75	3.05	2.49	3.14	3.09	3.73	3.37	3.49	3.62	3.07	2.79	3.36
1950	2021	3.85	3.13	2.55	3.22	3.17	3.83	3.46	3.58	3.71	3.15	2.87	3.45
1951	2022	3.95	3.21	2.62	3.30	3.25	3.93	3.55	3.67	3.81	3.24	2.94	3.54
1952	2023	4.05	3.30	2.68	3.38	3.33	4.03	3.64	3.77	3.91	3.32	3.01	3.63
1953	2024	4.16	3.38	2.75	3.47	3.41	4.13	3.73	3.86	4.01	3.40	3.09	3.72
1954	2025	4.26	3.46	2.81	3.55	3.49	4.23	3.82	3.96	4.11	3.48	3.16	3.82
1955	2026	4.36	3.54	2.87	3.63	3.58	4.33	3.91	4.05	4.20	3.57	3.23	3.91
1956	2027	4.46	3.62	2.94	3.72	3.66	4.43	4.00	4.15	4.30	3.65	3.31	4.00
1957	2028	4.56	3.70	3.00	3.80	3.74	4.53	4.09	4.24	4.40	3.73	3.38	4.09
1958	2029	4.66	3.78	3.07	3.88	3.82	4.63	4.18	4.34	4.50	3.81	3.46	4.18
1959	2030	4.76	3.86	3.13	3.96	3.90	4.73	4.27	4.43	4.60	3.90	3.53	4.27
1960	2031	4.86	3.95	3.20	4.05	3.99	4.83	4.36	4.53	4.70	3.98	3.60	4.36
1961	2032	4.96	4.03	3.26	4.13	4.07	4.93	4.45	4.62	4.79	4.06	3.68	4.45
1962	2033	5.06	4.11	3.33	4.21	4.15	5.03	4.54	4.71	4.89	4.14	3.75	4.54
1963	2034	5.16	4.19	3.39	4.30	4.23	5.13	4.63	4.81	4.99	4.23	3.83	4.63
1964	2035	5.26	4.27	3.46	4.38	4.31	5.23	4.72	4.90	5.09	4.31	3.90	4.72
1965	2036	5.36	4.35	3.52	4.46	4.39	5.33	4.81	5.00	5.19	4.39	3.97	4.81
1966	2037	5.46	4.43	3.58	4.55	4.48	5.43	4.90	5.09	5.28	4.47	4.05	4.90
1967	2038	5.56	4.52	3.65	4.63	4.56	5.53	4.99	5.19	5.38	4.56	4.12	4.99
1968	2039	5.67	4.60	3.71	4.71	4.64	5.63	5.08	5.28	5.48	4.64	4.20	5.09
1969	2040	5.77	4.68	3.78	4.79	4.72	5.73	5.17	5.38	5.58	4.72	4.27	5.18
1970	2041	5.87	4.76	3.84	4.88	4.80	5.83	5.26	5.47	5.68	4.80	4.34	5.27
1971	2042	5.97	4.84	3.91	4.96	4.88	5.93	5.35	5.56	5.78	4.88	4.42	5.36
1972	2043	6.07	4.92	3.97	5.04	4.97	6.03	5.44	5.66	5.88	4.97	4.49	5.45
1973	2044	6.17	5.01	4.03	5.13	5.05	6.13	5.53	5.75	5.97	5.05	4.56	5.54
1974	2045	6.27	5.09	4.10	5.21	5.13	6.23	5.62	5.85	6.07	5.13	4.64	5.63
1975	2046	6.38	5.17	4.16	5.29	5.21	6.33	5.71	5.94	6.17	5.21	4.71	5.72
1976	2047	6.48	5.25	4.23	5.37	5.29	6.43	5.80	6.04	6.27	5.30	4.78	5.81
1977	2048	6.58	5.33	4.29	5.46	5.37	6.53	5.89	6.13	6.36	5.38	4.86	5.90
1978	2049	6.68	5.41	4.35	5.54	5.45	6.63	5.98	6.22	6.46	5.46	4.93	5.99
1979	2050	6.77	5.49	4.42	5.62	5.53	6.72	6.07	6.31	6.56	5.54	5.00	6.08
1980	2051	6.87	5.57	4.48	5.70	5.61	6.82	6.15	6.41	6.65	5.62	5.07	6.17
1981	2052	6.97	5.65	4.54	5.78	5.69	6.92	6.24	6.50	6.75	5.70	5.15	6.26
1982	2053	7.07	5.73	4.61	5.86	5.77	7.02	6.33	6.59	6.85	5.78	5.22	6.35
1983	2054	7.17	5.81	4.67	5.94	5.85	7.12	6.42	6.69	6.94	5.86	5.29	6.44
1984	2055	7.27	5.89	4.73	6.03	5.93	7.22	6.51	6.78	7.04	5.94	5.36	6.53
1985	2056	7.37	5.97	4.79	6.11	6.01	7.32	6.60	6.87	7.14	6.02	5.44	6.62
1986	2057	7.49	6.06	4.87	6.20	6.10	7.43	6.70	6.98	7.25	6.12	5.52	6.72
1987	2058	7.60	6.15	4.94	6.29	6.19	7.54	6.80	7.08	7.36	6.21	5.60	6.82
1988	2059	7.71	6.24	5.01	6.38	6.28	7.65	6.90	7.19	7.47	6.30	5.68	6.92
1989	2060	7.82	6.33	5.08	6.48	6.38	7.76	7.00	7.29	7.57	6.39	5.76	7.03
1990	2061	7.94	6.43	5.15	6.57	6.47	7.87	7.10	7.40	7.68	6.48	5.85	7.13
1991	2062	8.05	6.52	5.22	6.66	6.56	7.98	7.20	7.50	7.79	6.57	5.93	7.23
1992	2063	8.16	6.61	5.29	6.75	6.65	8.09	7.29	7.61	7.90	6.66	6.01	7.33
1993	2064	8.27	6.70	5.37	6.85	6.74	8.20	7.39	7.71	8.01	6.76	6.09	7.43
1994	2065	8.39	6.79	5.44	6.94	6.83	8.32	7.49	7.81	8.12	6.85	6.17	7.53
1995	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
1996	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
1997	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
1998	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
1999	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2000	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2001	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2002	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2003	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2004	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2005	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2006	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2007	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2008	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2009	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2010	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2011	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63

Hartwell Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	52.40	55.65	55.48	58.80	63.36	67.38	67.47	67.72	65.47	61.21	60.35	55.05
1940	2011	55.18	58.90	58.74	62.35	67.24	71.59	71.71	71.96	69.51	64.87	64.15	58.24
1941	2012	57.96	62.15	62.01	65.90	71.13	75.81	75.95	76.19	73.56	68.53	67.94	61.42
1942	2013	60.74	65.40	65.27	69.45	75.01	80.03	80.18	80.42	77.61	72.19	71.73	64.60
1943	2014	63.51	68.65	68.54	73.00	78.89	84.24	84.42	84.66	81.66	75.84	75.52	67.79
1944	2015	66.29	71.90	71.80	76.55	82.77	88.46	88.66	88.89	85.71	79.50	79.31	70.97
1945	2016	69.07	75.15	75.07	80.10	86.66	92.68	92.90	93.12	89.76	83.16	83.10	74.15
1946	2017	70.05	76.28	76.20	81.33	88.00	94.13	94.36	94.58	91.15	84.43	84.41	75.27
1947	2018	71.03	77.41	77.33	82.57	89.34	95.59	95.81	96.03	92.54	85.70	85.71	76.39
1948	2019	72.01	78.54	78.46	83.80	90.68	97.05	97.27	97.49	93.93	86.96	87.02	77.51
1949	2020	72.98	79.68	79.59	85.03	92.03	98.51	98.73	98.94	95.32	88.23	88.33	78.62
1950	2021	73.96	80.81	80.72	86.26	93.37	99.97	100.19	100.40	96.71	89.50	89.63	79.74
1951	2022	74.94	81.94	81.85	87.49	94.71	101.43	101.65	101.85	98.10	90.77	90.94	80.86
1952	2023	75.92	83.07	82.99	88.72	96.05	102.88	103.11	103.31	99.50	92.04	92.25	81.98
1953	2024	76.90	84.20	84.12	89.96	97.40	104.34	104.57	104.76	100.89	93.31	93.55	83.10
1954	2025	77.88	85.34	85.25	91.19	98.74	105.80	106.03	106.22	102.28	94.58	94.86	84.21
1955	2026	78.86	86.47	86.38	92.42	100.08	107.26	107.49	107.67	103.67	95.84	96.17	85.33
1956	2027	80.98	88.67	88.58	94.68	102.41	109.65	109.89	110.08	106.03	98.13	98.45	87.52
1957	2028	83.10	90.87	90.79	96.93	104.73	112.05	112.29	112.48	108.40	100.42	100.74	89.70
1958	2029	85.22	93.08	92.99	99.19	107.06	114.44	114.69	114.89	110.76	102.71	103.03	91.88
1959	2030	87.35	95.28	95.19	101.45	109.39	116.84	117.09	117.29	113.12	105.00	105.32	94.07
1960	2031	89.47	97.48	97.40	103.71	111.72	119.24	119.49	119.69	115.49	107.28	107.61	96.25
1961	2032	91.59	99.68	99.60	105.96	114.04	121.63	121.89	122.10	117.85	109.57	109.90	98.44
1962	2033	93.71	101.88	101.80	108.22	116.37	124.03	124.29	124.50	120.22	111.86	112.18	100.62
1963	2034	95.84	104.09	104.01	110.48	118.70	126.42	126.69	126.91	122.58	114.15	114.47	102.80
1964	2035	97.96	106.29	106.21	112.73	121.02	128.82	129.10	129.31	124.94	116.43	116.76	104.99
1965	2036	100.08	108.49	108.41	114.99	123.35	131.21	131.50	131.71	127.31	118.72	119.05	107.17
1966	2037	100.86	109.35	109.28	115.92	124.36	132.30	132.60	132.81	128.36	119.68	120.01	108.02
1967	2038	101.64	110.22	110.14	116.85	125.38	133.40	133.69	133.91	129.41	120.65	120.97	108.86
1968	2039	102.42	111.08	111.00	117.78	126.39	134.49	134.79	135.01	130.46	121.61	121.94	109.71
1969	2040	103.20	111.95	111.86	118.71	127.40	135.58	135.89	136.11	131.52	122.57	122.90	110.56
1970	2041	103.98	112.81	112.73	119.64	128.42	136.68	136.99	137.21	132.57	123.54	123.86	111.40
1971	2042	104.76	113.68	113.59	120.57	129.43	137.77	138.09	138.31	133.62	124.50	124.83	112.25
1972	2043	105.54	114.54	114.45	121.50	130.44	138.86	139.19	139.41	134.68	125.46	125.79	113.10
1973	2044	106.32	115.41	115.31	122.43	131.46	139.96	140.29	140.51	135.73	126.43	126.75	113.94
1974	2045	107.10	116.27	116.18	123.36	132.47	141.05	141.39	141.61	136.78	127.39	127.71	114.79
1975	2046	107.88	117.14	117.04	124.28	133.48	142.15	142.48	142.71	137.83	128.36	128.68	115.64
1976	2047	108.69	118.02	117.92	125.23	134.51	143.26	143.60	143.83	138.90	129.34	129.65	116.50
1977	2048	109.50	118.90	118.80	126.18	135.55	144.37	144.72	144.95	139.98	130.32	130.62	117.37
1978	2049	110.30	119.79	119.69	127.13	136.58	145.48	145.84	146.07	141.05	131.30	131.60	118.24
1979	2050	111.11	120.67	120.57	128.07	137.61	146.59	146.95	147.19	142.12	132.29	132.57	119.10
1980	2051	111.92	121.56	121.45	129.02	138.64	147.70	148.07	148.31	143.19	133.27	133.54	119.97
1981	2052	112.73	122.44	122.33	129.97	139.67	148.82	149.19	149.42	144.26	134.25	134.51	120.83
1982	2053	113.53	123.33	123.21	130.92	140.71	149.93	150.30	150.54	145.33	135.23	135.49	121.70
1983	2054	114.34	124.21	124.09	131.86	141.74	151.04	151.42	151.66	146.40	136.22	136.46	122.57
1984	2055	115.15	125.09	124.98	132.81	142.77	152.15	152.54	152.78	147.47	137.20	137.43	123.43
1985	2056	115.95	125.98	125.86	133.76	143.80	153.26	153.65	153.90	148.54	138.18	138.41	124.30
1986	2057	116.84	126.95	126.83	134.80	144.94	154.49	154.88	155.13	149.72	139.26	139.47	125.25
1987	2058	117.73	127.93	127.80	135.84	146.07	155.71	156.11	156.36	150.90	140.34	140.54	126.20
1988	2059	118.62	128.90	128.77	136.88	147.20	156.93	157.33	157.59	152.07	141.42	141.61	127.16
1989	2060	119.51	129.87	129.74	137.92	148.34	158.15	158.56	158.82	153.25	142.50	142.68	128.11
1990	2061	120.40	130.84	130.71	138.96	149.47	159.37	159.79	160.05	154.43	143.59	143.75	129.06
1991	2062	121.29	131.82	131.68	140.01	150.61	160.59	161.02	161.28	155.60	144.67	144.81	130.01
1992	2063	122.18	132.79	132.65	141.05	151.74	161.81	162.24	162.50	156.78	145.75	145.88	130.97
1993	2064	123.07	133.76	133.62	142.09	152.87	163.04	163.47	163.73	157.96	146.83	146.95	131.92
1994	2065	123.96	134.74	134.59	143.13	154.01	164.26	164.70	164.96	159.13	147.91	148.02	132.87
1995	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
1996	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
1997	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
1998	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
1999	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2000	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2001	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2002	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2003	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2004	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2005	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2006	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2007	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2008	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2009	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2010	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2011	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82

Hartwell Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	23.61	23.87	23.07	22.94	23.81	22.56	21.85	22.66	23.65	23.28	24.21	25.57
1940	2011	23.84	24.11	23.31	23.16	24.01	22.75	22.04	22.85	23.87	23.48	24.41	25.79
1941	2012	24.07	24.35	23.54	23.38	24.20	22.94	22.23	23.05	24.09	23.68	24.61	26.01
1942	2013	24.30	24.59	23.78	23.60	24.39	23.12	22.42	23.24	24.30	23.88	24.82	26.23
1943	2014	24.53	24.83	24.02	23.82	24.59	23.31	22.61	23.44	24.52	24.08	25.02	26.45
1944	2015	24.76	25.07	24.26	24.04	24.78	23.50	22.80	23.64	24.73	24.28	25.22	26.66
1945	2016	25.00	25.31	24.49	24.26	24.98	23.69	22.98	23.83	24.95	24.49	25.42	26.88
1946	2017	25.18	25.50	24.68	24.43	25.14	23.84	23.15	24.00	25.13	24.65	25.59	27.06
1947	2018	25.36	25.69	24.87	24.61	25.30	24.00	23.31	24.17	25.31	24.82	25.76	27.25
1948	2019	25.55	25.88	25.06	24.78	25.46	24.16	23.47	24.33	25.49	24.99	25.93	27.43
1949	2020	25.73	26.07	25.25	24.96	25.63	24.32	23.64	24.50	25.67	25.16	26.10	27.61
1950	2021	25.91	26.26	25.44	25.14	25.79	24.48	23.80	24.67	25.85	25.33	26.27	27.79
1951	2022	26.10	26.44	25.63	25.31	25.95	24.63	23.96	24.83	26.04	25.50	26.44	27.97
1952	2023	26.28	26.63	25.82	25.49	26.11	24.79	24.13	25.00	26.22	25.67	26.61	28.15
1953	2024	26.46	26.82	26.01	25.66	26.28	24.95	24.29	25.17	26.40	25.84	26.78	28.33
1954	2025	26.65	27.01	26.20	25.84	26.44	25.11	24.45	25.34	26.58	26.01	26.95	28.52
1955	2026	26.83	27.20	26.39	26.02	26.60	25.26	24.62	25.50	26.76	26.17	27.12	28.70
1956	2027	27.01	27.38	26.57	26.19	26.76	25.43	24.78	25.67	26.94	26.34	27.29	28.87
1957	2028	27.19	27.57	26.76	26.37	26.93	25.59	24.94	25.84	27.13	26.51	27.46	29.05
1958	2029	27.37	27.76	26.95	26.55	27.09	25.75	25.10	26.01	27.31	26.68	27.63	29.22
1959	2030	27.55	27.95	27.14	26.73	27.26	25.92	25.27	26.17	27.49	26.85	27.80	29.40
1960	2031	27.73	28.13	27.32	26.91	27.42	26.08	25.43	26.34	27.67	27.02	27.97	29.58
1961	2032	27.91	28.32	27.51	27.08	27.58	26.24	25.59	26.51	27.85	27.19	28.14	29.75
1962	2033	28.09	28.51	27.70	27.26	27.75	26.41	25.75	26.68	28.03	27.36	28.31	29.93
1963	2034	28.27	28.70	27.89	27.44	27.91	26.57	25.91	26.84	28.22	27.53	28.48	30.10
1964	2035	28.44	28.88	28.08	27.62	28.07	26.73	26.08	27.01	28.40	27.70	28.65	30.28
1965	2036	28.62	29.07	28.26	27.79	28.24	26.89	26.24	27.18	28.58	27.87	28.82	30.46
1966	2037	28.76	29.21	28.40	27.93	28.36	27.04	26.36	27.31	28.72	28.00	28.95	30.58
1967	2038	28.89	29.36	28.55	28.07	28.49	27.18	26.48	27.44	28.85	28.13	29.08	30.70
1968	2039	29.02	29.50	28.69	28.22	28.62	27.32	26.61	27.57	28.99	28.26	29.21	30.83
1969	2040	29.15	29.64	28.83	28.36	28.75	27.46	26.73	27.70	29.13	28.39	29.34	30.95
1970	2041	29.28	29.79	28.97	28.50	28.88	27.61	26.85	27.83	29.27	28.52	29.47	31.07
1971	2042	29.41	29.93	29.11	28.64	29.01	27.75	26.97	27.96	29.41	28.65	29.60	31.20
1972	2043	29.54	30.07	29.26	28.78	29.14	27.89	27.09	28.09	29.54	28.78	29.73	31.32
1973	2044	29.67	30.21	29.40	28.92	29.26	28.03	27.22	28.21	29.68	28.92	29.86	31.45
1974	2045	29.80	30.36	29.54	29.06	29.39	28.18	27.34	28.34	29.82	29.05	29.99	31.57
1975	2046	29.93	30.50	29.68	29.20	29.52	28.32	27.46	28.47	29.96	29.18	30.12	31.69
1976	2047	30.19	30.77	29.95	29.45	29.76	28.56	27.69	28.72	30.22	29.42	30.36	31.94
1977	2048	30.45	31.04	30.22	29.71	30.00	28.79	27.93	28.96	30.48	29.66	30.61	32.19
1978	2049	30.71	31.31	30.49	29.97	30.23	29.03	28.16	29.20	30.74	29.91	30.85	32.44
1979	2050	30.96	31.58	30.76	30.23	30.47	29.27	28.39	29.44	31.00	30.15	31.10	32.69
1980	2051	31.22	31.85	31.03	30.48	30.71	29.50	28.63	29.68	31.26	30.40	31.34	32.94
1981	2052	31.48	32.12	31.29	30.74	30.94	29.74	28.86	29.92	31.52	30.64	31.59	33.20
1982	2053	31.74	32.38	31.56	31.00	31.18	29.98	29.09	30.17	31.78	30.88	31.83	33.45
1983	2054	32.00	32.65	31.83	31.25	31.42	30.21	29.33	30.41	32.04	31.13	32.08	33.70
1984	2055	32.25	32.92	32.10	31.51	31.65	30.45	29.56	30.65	32.30	31.37	32.32	33.95
1985	2056	32.51	33.19	32.37	31.77	31.89	30.69	29.79	30.89	32.56	31.62	32.57	34.20
1986	2057	32.82	33.52	32.69	32.07	32.17	30.97	30.07	31.18	32.87	31.90	32.86	34.50
1987	2058	33.13	33.84	33.01	32.38	32.46	31.26	30.35	31.47	33.18	32.19	33.15	34.79
1988	2059	33.44	34.16	33.34	32.69	32.74	31.55	30.63	31.76	33.49	32.48	33.45	35.09
1989	2060	33.75	34.48	33.66	33.00	33.03	31.83	30.91	32.05	33.80	32.77	33.74	35.39
1990	2061	34.06	34.81	33.98	33.30	33.31	32.12	31.19	32.34	34.11	33.06	34.03	35.69
1991	2062	34.36	35.13	34.30	33.61	33.60	32.40	31.47	32.63	34.41	33.35	34.33	35.99
1992	2063	34.67	35.45	34.62	33.92	33.88	32.69	31.75	32.92	34.72	33.64	34.62	36.29
1993	2064	34.98	35.77	34.94	34.23	34.17	32.97	32.03	33.20	35.03	33.93	34.91	36.59
1994	2065	35.29	36.09	35.27	34.54	34.45	33.26	32.31	33.49	35.34	34.22	35.20	36.89
1995	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
1996	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
1997	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
1998	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
1999	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2000	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2001	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2002	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2003	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2004	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2005	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2006	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2007	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2008	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2009	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2010	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2011	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18

Richard B. Russell Withdrawals (cfs)

Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	8.59	8.43	9.03	9.72	10.38	11.73	11.57	12.23	11.56	10.32	9.48	8.81
1940	2011	8.67	8.51	9.11	9.80	10.46	11.82	11.65	12.31	11.64	10.40	9.56	8.89
1941	2012	8.75	8.59	9.19	9.88	10.54	11.90	11.74	12.39	11.72	10.48	9.63	8.97
1942	2013	8.83	8.67	9.27	9.96	10.62	11.98	11.82	12.48	11.80	10.56	9.71	9.05
1943	2014	8.91	8.75	9.35	10.04	10.70	12.06	11.90	12.56	11.88	10.64	9.79	9.12
1944	2015	8.99	8.82	9.43	10.12	10.78	12.14	11.98	12.64	11.96	10.72	9.87	9.20
1945	2016	9.07	8.90	9.51	10.20	10.86	12.23	12.06	12.72	12.04	10.80	9.95	9.28
1946	2017	10.62	10.46	11.06	11.75	12.42	13.79	13.62	14.29	13.60	12.36	11.50	10.83
1947	2018	12.17	12.01	12.61	13.31	13.98	15.35	15.18	15.85	15.17	13.92	13.06	12.38
1948	2019	13.73	13.56	14.17	14.87	15.54	16.92	16.75	17.42	16.73	15.47	14.61	13.93
1949	2020	15.28	15.12	15.72	16.42	17.10	18.48	18.31	18.98	18.29	17.03	16.17	15.49
1950	2021	16.84	16.67	17.28	17.98	18.66	20.04	19.87	20.55	19.85	18.59	17.72	17.04
1951	2022	18.39	18.22	18.83	19.54	20.22	21.61	21.43	22.11	21.41	20.15	19.27	18.59
1952	2023	19.94	19.78	20.39	21.09	21.78	23.17	22.99	23.68	22.97	21.71	20.83	20.14
1953	2024	21.50	21.33	21.94	22.65	23.34	24.73	24.55	25.24	24.54	23.27	22.38	21.69
1954	2025	23.05	22.89	23.50	24.21	24.90	26.30	26.12	26.81	26.10	24.83	23.94	23.24
1955	2026	24.61	24.44	25.05	25.76	26.45	27.86	27.68	28.37	27.66	26.38	25.49	24.79
1956	2027	24.65	24.48	25.10	25.81	26.50	27.91	27.72	28.42	27.71	26.43	25.53	24.83
1957	2028	24.69	24.52	25.14	25.85	26.55	27.96	27.77	28.47	27.75	26.47	25.58	24.87
1958	2029	24.73	24.57	25.18	25.89	26.59	28.01	27.82	28.52	27.80	26.52	25.62	24.91
1959	2030	24.78	24.61	25.23	25.94	26.64	28.06	27.87	28.57	27.85	26.56	25.66	24.95
1960	2031	24.82	24.65	25.27	25.98	26.68	28.11	27.91	28.62	27.90	26.61	25.70	24.99
1961	2032	24.86	24.69	25.31	26.03	26.73	28.15	27.96	28.67	27.94	26.65	25.74	25.03
1962	2033	24.90	24.73	25.36	26.07	26.78	28.20	28.01	28.72	27.99	26.70	25.78	25.07
1963	2034	24.94	24.78	25.40	26.11	26.82	28.25	28.06	28.77	28.04	26.74	25.83	25.11
1964	2035	24.99	24.82	25.44	26.16	26.87	28.30	28.10	28.82	28.08	26.79	25.87	25.15
1965	2036	25.03	24.86	25.49	26.20	26.91	28.35	28.15	28.87	28.13	26.83	25.91	25.19
1966	2037	25.07	24.90	25.53	26.25	26.96	28.40	28.20	28.92	28.18	26.88	25.95	25.24
1967	2038	25.12	24.95	25.57	26.29	27.01	28.45	28.25	28.97	28.23	26.93	26.00	25.28
1968	2039	25.16	24.99	25.62	26.34	27.06	28.50	28.30	29.02	28.28	26.97	26.04	25.32
1969	2040	25.20	25.03	25.66	26.38	27.10	28.55	28.35	29.07	28.33	27.02	26.08	25.36
1970	2041	25.25	25.08	25.71	26.43	27.15	28.60	28.39	29.12	28.38	27.07	26.13	25.40
1971	2042	25.29	25.12	25.75	26.47	27.20	28.65	28.44	29.18	28.42	27.11	26.17	25.44
1972	2043	25.33	25.17	25.80	26.52	27.25	28.70	28.49	29.23	28.47	27.16	26.21	25.48
1973	2044	25.38	25.21	25.84	26.56	27.29	28.75	28.54	29.28	28.52	27.21	26.26	25.53
1974	2045	25.42	25.25	25.89	26.61	27.34	28.80	28.59	29.33	28.57	27.25	26.30	25.57
1975	2046	25.47	25.30	25.93	26.65	27.39	28.85	28.64	29.38	28.62	27.30	26.34	25.61
1976	2047	27.01	26.84	27.48	28.20	28.94	30.41	30.19	30.94	30.17	28.85	27.89	27.15
1977	2048	28.56	28.39	29.03	29.75	30.49	31.97	31.75	32.50	31.73	30.40	29.44	28.70
1978	2049	30.11	29.94	30.58	31.30	32.05	33.52	33.30	34.05	33.28	31.96	30.99	30.25
1979	2050	31.66	31.49	32.13	32.86	33.60	35.08	34.86	35.61	34.84	33.51	32.54	31.79
1980	2051	33.21	33.04	33.68	34.41	35.15	36.64	36.41	37.17	36.39	35.06	34.09	33.34
1981	2052	34.76	34.59	35.23	35.96	36.71	38.19	37.97	38.72	37.95	36.61	35.63	34.89
1982	2053	36.31	36.14	36.78	37.51	38.26	39.75	39.52	40.28	39.50	38.16	37.18	36.43
1983	2054	37.86	37.69	38.33	39.06	39.81	41.31	41.08	41.84	41.06	39.72	38.73	37.98
1984	2055	39.41	39.24	39.88	40.61	41.37	42.86	42.63	43.40	42.61	41.27	40.28	39.52
1985	2056	40.96	40.78	41.43	42.16	42.92	44.42	44.19	44.95	44.17	42.82	41.83	41.07
1986	2057	41.01	40.84	41.48	42.21	42.97	44.48	44.24	45.01	44.22	42.87	41.88	41.12
1987	2058	41.06	40.89	41.53	42.27	43.03	44.54	44.30	45.07	44.28	42.93	41.93	41.17
1988	2059	41.11	40.94	41.59	42.32	43.09	44.60	44.36	45.13	44.34	42.98	41.98	41.21
1989	2060	41.16	40.99	41.64	42.37	43.14	44.66	44.41	45.19	44.39	43.04	42.03	41.26
1990	2061	41.21	41.04	41.69	42.42	43.20	44.71	44.47	45.25	44.45	43.09	42.08	41.31
1991	2062	41.26	41.09	41.74	42.48	43.25	44.77	44.53	45.31	44.51	43.14	42.13	41.36
1992	2063	41.31	41.14	41.80	42.53	43.31	44.83	44.59	45.37	44.56	43.20	42.18	41.41
1993	2064	41.37	41.19	41.85	42.58	43.36	44.89	44.64	45.43	44.62	43.25	42.23	41.46
1994	2065	41.42	41.25	41.90	42.64	43.42	44.95	44.70	45.49	44.68	43.31	42.28	41.50
1995	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
1996	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
1997	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
1998	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
1999	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2000	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2001	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2002	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2003	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2004	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2005	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2006	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2007	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2008	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2009	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2010	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2011	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55

Richard B. Russell Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	16.23	16.17	18.81	16.91	15.13	14.69	14.95	15.09	14.99	14.40	14.07	16.24
1940	2011	16.45	16.40	19.08	17.14	15.34	14.89	15.15	15.28	15.19	14.59	14.26	16.47
1941	2012	16.67	16.62	19.35	17.37	15.54	15.10	15.36	15.48	15.39	14.78	14.46	16.69
1942	2013	16.89	16.84	19.62	17.60	15.74	15.31	15.57	15.67	15.59	14.97	14.65	16.92
1943	2014	17.12	17.06	19.89	17.83	15.95	15.52	15.78	15.87	15.79	15.16	14.84	17.15
1944	2015	17.34	17.29	20.16	18.06	16.15	15.72	15.98	16.06	16.00	15.34	15.04	17.38
1945	2016	17.56	17.51	20.43	18.29	16.36	15.93	16.19	16.25	16.20	15.53	15.23	17.61
1946	2017	17.82	17.76	20.74	18.55	16.59	16.17	16.43	16.47	16.43	15.75	15.45	17.87
1947	2018	18.07	18.02	21.06	18.82	16.82	16.41	16.67	16.70	16.65	15.97	15.68	18.13
1948	2019	18.33	18.28	21.37	19.09	17.05	16.64	16.91	16.92	16.88	16.19	15.90	18.40
1949	2020	18.59	18.54	21.68	19.35	17.29	16.88	17.14	17.14	17.11	16.41	16.12	18.66
1950	2021	18.85	18.79	21.99	19.62	17.52	17.12	17.38	17.37	17.34	16.63	16.35	18.93
1951	2022	19.11	19.05	22.30	19.88	17.75	17.36	17.62	17.59	17.57	16.85	16.57	19.19
1952	2023	19.36	19.31	22.61	20.15	17.98	17.60	17.86	17.81	17.80	17.07	16.79	19.45
1953	2024	19.62	19.57	22.92	20.41	18.22	17.83	18.10	18.03	18.03	17.28	17.02	19.72
1954	2025	19.88	19.82	23.23	20.68	18.45	18.07	18.33	18.26	18.26	17.50	17.24	19.98
1955	2026	20.14	20.08	23.54	20.95	18.68	18.31	18.57	18.48	18.49	17.72	17.46	20.25
1956	2027	20.38	20.32	23.83	21.19	18.90	18.53	18.79	18.69	18.70	17.93	17.67	20.49
1957	2028	20.62	20.56	24.12	21.44	19.12	18.75	19.01	18.90	18.92	18.13	17.88	20.74
1958	2029	20.87	20.80	24.41	21.69	19.33	18.98	19.24	19.11	19.13	18.34	18.09	20.99
1959	2030	21.11	21.05	24.70	21.93	19.55	19.20	19.46	19.32	19.35	18.54	18.30	21.24
1960	2031	21.35	21.29	24.98	22.18	19.76	19.42	19.68	19.52	19.56	18.74	18.51	21.48
1961	2032	21.59	21.53	25.27	22.43	19.98	19.64	19.90	19.73	19.78	18.95	18.72	21.73
1962	2033	21.84	21.77	25.56	22.68	20.20	19.86	20.12	19.94	19.99	19.15	18.93	21.98
1963	2034	22.08	22.01	25.85	22.92	20.41	20.09	20.34	20.15	20.21	19.36	19.14	22.23
1964	2035	22.32	22.25	26.14	23.17	20.63	20.31	20.56	20.36	20.42	19.56	19.35	22.47
1965	2036	22.56	22.50	26.43	23.42	20.85	20.53	20.79	20.57	20.64	19.77	19.56	22.72
1966	2037	22.84	22.77	26.76	23.70	21.09	20.78	21.04	20.81	20.88	20.00	19.80	23.01
1967	2038	23.13	23.05	27.09	23.98	21.34	21.04	21.29	21.05	21.13	20.24	20.04	23.29
1968	2039	23.41	23.33	27.42	24.26	21.59	21.29	21.55	21.29	21.38	20.47	20.29	23.57
1969	2040	23.69	23.61	27.75	24.55	21.83	21.55	21.80	21.53	21.62	20.71	20.53	23.86
1970	2041	23.97	23.89	28.08	24.83	22.08	21.80	22.05	21.77	21.87	20.94	20.77	24.14
1971	2042	24.25	24.17	28.41	25.11	22.33	22.06	22.30	22.01	22.11	21.18	21.01	24.43
1972	2043	24.53	24.44	28.74	25.39	22.58	22.31	22.56	22.25	22.36	21.41	21.25	24.71
1973	2044	24.81	24.72	29.07	25.68	22.82	22.56	22.81	22.49	22.61	21.65	21.49	25.00
1974	2045	25.09	25.00	29.40	25.96	23.07	22.82	23.06	22.73	22.85	21.88	21.74	25.28
1975	2046	25.37	25.28	29.72	26.24	23.32	23.07	23.32	22.97	23.10	22.12	21.98	25.56
1976	2047	25.63	25.54	30.02	26.49	23.54	23.30	23.54	23.19	23.33	22.33	22.20	25.83
1977	2048	25.89	25.79	30.32	26.75	23.76	23.53	23.77	23.41	23.55	22.55	22.42	26.09
1978	2049	26.15	26.05	30.62	27.00	23.99	23.76	24.00	23.63	23.78	22.76	22.65	26.35
1979	2050	26.41	26.31	30.91	27.26	24.21	24.00	24.23	23.85	24.00	22.98	22.87	26.61
1980	2051	26.67	26.56	31.21	27.51	24.43	24.23	24.46	24.07	24.23	23.19	23.09	26.87
1981	2052	26.93	26.82	31.51	27.77	24.65	24.46	24.68	24.29	24.45	23.40	23.31	27.13
1982	2053	27.19	27.08	31.80	28.02	24.87	24.69	24.91	24.51	24.68	23.62	23.54	27.39
1983	2054	27.45	27.33	32.10	28.28	25.10	24.92	25.14	24.73	24.90	23.83	23.76	27.65
1984	2055	27.71	27.59	32.40	28.53	25.32	25.15	25.37	24.95	25.13	24.05	23.98	27.91
1985	2056	27.97	27.84	32.69	28.79	25.54	25.38	25.60	25.17	25.35	24.26	24.20	28.17
1986	2057	28.27	28.14	33.03	29.08	25.80	25.65	25.86	25.43	25.61	24.51	24.46	28.48
1987	2058	28.58	28.44	33.38	29.37	26.05	25.92	26.12	25.69	25.87	24.76	24.73	28.78
1988	2059	28.88	28.74	33.72	29.67	26.31	26.19	26.38	25.95	26.14	25.01	24.99	29.09
1989	2060	29.19	29.04	34.06	29.96	26.57	26.45	26.65	26.20	26.40	25.26	25.25	29.39
1990	2061	29.49	29.34	34.40	30.26	26.82	26.72	26.91	26.46	26.66	25.51	25.51	29.69
1991	2062	29.80	29.64	34.74	30.55	27.08	26.99	27.17	26.72	26.92	25.76	25.77	30.00
1992	2063	30.11	29.94	35.09	30.84	27.34	27.26	27.44	26.97	27.18	26.00	26.03	30.30
1993	2064	30.41	30.24	35.43	31.14	27.59	27.53	27.70	27.23	27.45	26.25	26.29	30.61
1994	2065	30.72	30.54	35.77	31.43	27.85	27.79	27.96	27.49	27.71	26.50	26.55	30.91
1995	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
1996	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
1997	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
1998	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
1999	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2000	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2001	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2002	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2003	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2004	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2005	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2006	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2007	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2008	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2009	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2010	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2011	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22

J. Strom Thurmond Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	31.25	31.40	31.88	33.11	35.66	37.83	38.64	37.99	36.19	34.07	32.94	31.97
1940	2011	31.52	31.68	32.19	33.44	36.05	38.26	39.09	38.43	36.58	34.41	33.26	32.27
1941	2012	31.80	31.96	32.49	33.77	36.43	38.69	39.55	38.86	36.98	34.76	33.57	32.56
1942	2013	32.07	32.25	32.80	34.09	36.82	39.13	40.00	39.30	37.37	35.11	33.89	32.86
1943	2014	32.35	32.53	33.10	34.42	37.21	39.56	40.45	39.74	37.77	35.45	34.21	33.15
1944	2015	32.62	32.82	33.40	34.75	37.60	39.99	40.91	40.18	38.17	35.80	34.53	33.44
1945	2016	32.90	33.10	33.71	35.08	37.99	40.42	41.36	40.61	38.56	36.14	34.84	33.74
1946	2017	34.64	34.86	35.49	36.89	39.87	42.35	43.32	42.55	40.45	37.97	36.64	35.51
1947	2018	36.39	36.61	37.27	38.70	41.75	44.28	45.28	44.49	42.34	39.80	38.44	37.28
1948	2019	38.14	38.37	39.05	40.51	43.63	46.21	47.23	46.43	44.23	41.63	40.24	39.05
1949	2020	39.88	40.13	40.83	42.31	45.51	48.14	49.19	48.37	46.12	43.47	42.04	40.82
1950	2021	41.63	41.89	42.61	44.12	47.39	50.07	51.15	50.31	48.01	45.30	43.83	42.59
1951	2022	43.38	43.65	44.39	45.93	49.27	52.00	53.11	52.25	49.90	47.13	45.63	44.36
1952	2023	45.12	45.40	46.18	47.74	51.15	53.93	55.07	54.19	51.78	48.96	47.43	46.13
1953	2024	46.87	47.16	47.96	49.55	53.03	55.87	57.02	56.13	53.67	50.79	49.23	47.91
1954	2025	48.62	48.92	49.74	51.36	54.91	57.80	58.98	58.07	55.56	52.62	51.03	49.68
1955	2026	50.36	50.68	51.52	53.17	56.79	59.73	60.94	60.01	57.45	54.45	52.82	51.45
1956	2027	50.66	50.99	51.86	53.55	57.25	60.25	61.50	60.54	57.93	54.85	53.19	51.77
1957	2028	50.96	51.30	52.21	53.92	57.72	60.78	62.06	61.08	58.40	55.25	53.55	52.10
1958	2029	51.25	51.61	52.55	54.30	58.18	61.30	62.61	61.61	58.87	55.65	53.91	52.43
1959	2030	51.55	51.93	52.89	54.67	58.64	61.83	63.17	62.15	59.35	56.06	54.27	52.76
1960	2031	51.85	52.24	53.23	55.05	59.11	62.35	63.73	62.69	59.82	56.46	54.63	53.08
1961	2032	52.15	52.55	53.57	55.43	59.57	62.87	64.29	63.22	60.29	56.86	54.99	53.41
1962	2033	52.44	52.86	53.92	55.80	60.04	63.40	64.85	63.76	60.77	57.26	55.35	53.74
1963	2034	52.74	53.17	54.26	56.18	60.50	63.92	65.41	64.29	61.24	57.66	55.71	54.07
1964	2035	53.04	53.49	54.60	56.55	60.96	64.45	65.96	64.83	61.72	58.06	56.07	54.39
1965	2036	53.34	53.80	54.94	56.93	61.43	64.97	66.52	65.36	62.19	58.47	56.43	54.72
1966	2037	53.70	54.17	55.36	57.39	61.99	65.61	67.21	66.02	62.77	58.95	56.87	55.12
1967	2038	54.05	54.55	55.77	57.84	62.56	66.25	67.89	66.67	63.34	59.44	57.31	55.51
1968	2039	54.41	54.93	56.19	58.30	63.12	66.90	68.57	67.33	63.92	59.93	57.75	55.91
1969	2040	54.77	55.31	56.60	58.75	63.69	67.54	69.26	67.98	64.50	60.42	58.18	56.30
1970	2041	55.13	55.68	57.02	59.21	64.25	68.18	69.94	68.64	65.08	60.90	58.62	56.70
1971	2042	55.49	56.06	57.43	59.67	64.81	68.82	70.62	69.29	65.65	61.39	59.06	57.10
1972	2043	55.85	56.44	57.85	60.12	65.38	69.46	71.31	69.95	66.23	61.88	59.50	57.49
1973	2044	56.21	56.81	58.26	60.58	65.94	70.10	71.99	70.60	66.81	62.37	59.93	57.89
1974	2045	56.56	57.19	58.68	61.04	66.51	70.74	72.67	71.26	67.39	62.85	60.37	58.29
1975	2046	56.92	57.57	59.10	61.49	67.07	71.38	73.36	71.91	67.96	63.34	60.81	58.68
1976	2047	58.85	59.52	61.10	63.54	69.26	73.66	75.69	74.21	70.16	65.43	62.84	60.66
1977	2048	60.79	61.48	63.10	65.60	71.45	75.94	78.02	76.51	72.37	67.52	64.87	62.64
1978	2049	62.72	63.43	65.10	67.65	73.63	78.22	80.35	78.80	74.57	69.61	66.90	64.62
1979	2050	64.65	65.39	67.11	69.70	75.82	80.50	82.68	81.10	76.77	71.71	68.93	66.59
1980	2051	66.58	67.34	69.11	71.75	78.01	82.78	85.02	83.40	78.97	73.80	70.96	68.57
1981	2052	68.51	69.30	71.11	73.81	80.19	85.06	87.35	85.70	81.17	75.89	72.99	70.55
1982	2053	70.44	71.25	73.12	75.86	82.38	87.34	89.68	87.99	83.37	77.98	75.02	72.53
1983	2054	72.38	73.21	75.12	77.91	84.57	89.62	92.01	90.29	85.58	80.07	77.05	74.51
1984	2055	74.31	75.16	77.12	79.96	86.75	91.90	94.35	92.59	87.78	82.16	79.07	76.49
1985	2056	76.24	77.12	79.13	82.02	88.94	94.18	96.68	94.88	89.98	84.25	81.10	78.46
1986	2057	76.76	77.67	79.74	82.69	89.78	95.13	97.70	95.86	90.84	84.97	81.75	79.04
1987	2058	77.28	78.22	80.35	83.36	90.62	96.08	98.71	96.83	91.69	85.69	82.39	79.62
1988	2059	77.81	78.77	80.96	84.04	91.46	97.04	99.73	97.81	92.55	86.41	83.03	80.20
1989	2060	78.33	79.33	81.58	84.71	92.29	97.99	100.75	98.78	93.41	87.13	83.68	80.78
1990	2061	78.85	79.88	82.19	85.38	93.13	98.94	101.77	99.76	94.26	87.85	84.32	81.36
1991	2062	79.37	80.43	82.80	86.06	93.97	99.89	102.78	100.73	95.12	88.57	84.96	81.94
1992	2063	79.90	80.98	83.41	86.73	94.81	100.85	103.80	101.71	95.98	89.29	85.61	82.52
1993	2064	80.42	81.53	84.03	87.40	95.65	101.80	104.82	102.68	96.83	90.01	86.25	83.10
1994	2065	80.94	82.09	84.64	88.07	96.49	102.75	105.84	103.65	97.69	90.73	86.89	83.68
1995	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
1996	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
1997	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
1998	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
1999	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2000	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2001	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2002	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2003	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2004	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2005	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2006	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2007	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2008	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2009	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2010	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2011	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26

J. Strom Thurmond Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	7.37	7.46	9.68	7.98	6.29	7.99	7.28	6.67	6.66	6.94	6.09	6.74
1940	2011	7.40	7.50	9.72	8.02	6.32	8.02	7.32	6.71	6.70	6.98	6.13	6.77
1941	2012	7.44	7.54	9.76	8.06	6.36	8.06	7.36	6.75	6.74	7.02	6.17	6.81
1942	2013	7.47	7.59	9.80	8.10	6.39	8.10	7.40	6.79	6.78	7.06	6.21	6.85
1943	2014	7.51	7.63	9.84	8.14	6.42	8.14	7.44	6.82	6.82	7.10	6.25	6.88
1944	2015	7.54	7.67	9.89	8.18	6.46	8.17	7.48	6.86	6.86	7.13	6.29	6.92
1945	2016	7.58	7.71	9.93	8.22	6.49	8.21	7.52	6.90	6.90	7.17	6.33	6.96
1946	2017	7.63	7.77	9.99	8.27	6.54	8.26	7.57	6.95	6.96	7.23	6.39	7.01
1947	2018	7.68	7.83	10.04	8.32	6.59	8.31	7.62	7.00	7.01	7.28	6.44	7.06
1948	2019	7.73	7.88	10.10	8.38	6.63	8.36	7.67	7.06	7.06	7.33	6.50	7.11
1949	2020	7.78	7.94	10.16	8.43	6.68	8.41	7.72	7.11	7.11	7.38	6.55	7.16
1950	2021	7.83	8.00	10.22	8.48	6.72	8.46	7.78	7.16	7.16	7.44	6.60	7.21
1951	2022	7.88	8.05	10.27	8.53	6.77	8.52	7.83	7.21	7.21	7.49	6.66	7.26
1952	2023	7.93	8.11	10.33	8.59	6.82	8.57	7.88	7.26	7.26	7.54	6.71	7.31
1953	2024	7.98	8.17	10.39	8.64	6.86	8.62	7.93	7.31	7.31	7.59	6.77	7.36
1954	2025	8.03	8.22	10.45	8.69	6.91	8.67	7.98	7.37	7.36	7.64	6.82	7.41
1955	2026	8.08	8.28	10.50	8.74	6.96	8.72	8.03	7.42	7.41	7.70	6.88	7.46
1956	2027	8.15	8.36	10.58	8.82	7.02	8.79	8.11	7.49	7.48	7.77	6.95	7.53
1957	2028	8.22	8.43	10.66	8.89	7.09	8.86	8.18	7.56	7.55	7.84	7.02	7.60
1958	2029	8.29	8.51	10.74	8.96	7.15	8.93	8.25	7.63	7.62	7.91	7.10	7.67
1959	2030	8.36	8.59	10.82	9.04	7.22	9.00	8.32	7.70	7.70	7.98	7.17	7.74
1960	2031	8.43	8.67	10.91	9.11	7.29	9.07	8.39	7.77	7.77	8.05	7.25	7.81
1961	2032	8.50	8.75	10.99	9.18	7.35	9.14	8.46	7.84	7.84	8.13	7.32	7.88
1962	2033	8.57	8.83	11.07	9.26	7.42	9.21	8.53	7.91	7.91	8.20	7.40	7.95
1963	2034	8.64	8.90	11.15	9.33	7.48	9.28	8.60	7.98	7.98	8.27	7.47	8.02
1964	2035	8.71	8.98	11.23	9.40	7.55	9.35	8.67	8.05	8.05	8.34	7.54	8.09
1965	2036	8.78	9.06	11.31	9.48	7.61	9.42	8.75	8.13	8.12	8.41	7.62	8.17
1966	2037	8.84	9.13	11.37	9.54	7.67	9.48	8.81	8.19	8.18	8.48	7.68	8.23
1967	2038	8.89	9.19	11.44	9.60	7.73	9.54	8.87	8.25	8.24	8.54	7.75	8.28
1968	2039	8.95	9.26	11.51	9.66	7.78	9.61	8.93	8.31	8.30	8.60	7.82	8.34
1969	2040	9.01	9.32	11.58	9.73	7.84	9.67	8.99	8.37	8.36	8.67	7.88	8.40
1970	2041	9.07	9.39	11.65	9.79	7.89	9.73	9.05	8.44	8.43	8.73	7.95	8.46
1971	2042	9.12	9.46	11.71	9.85	7.95	9.79	9.11	8.50	8.49	8.79	8.01	8.52
1972	2043	9.18	9.52	11.78	9.91	8.00	9.85	9.17	8.56	8.55	8.85	8.08	8.58
1973	2044	9.24	9.59	11.85	9.98	8.06	9.91	9.24	8.62	8.61	8.92	8.15	8.64
1974	2045	9.30	9.65	11.92	10.04	8.11	9.97	9.30	8.69	8.67	8.98	8.21	8.70
1975	2046	9.35	9.72	11.98	10.10	8.17	10.03	9.36	8.75	8.74	9.04	8.28	8.76
1976	2047	9.43	9.80	12.07	10.18	8.24	10.10	9.43	8.82	8.81	9.12	8.36	8.83
1977	2048	9.50	9.88	12.15	10.25	8.31	10.18	9.51	8.90	8.89	9.20	8.44	8.91
1978	2049	9.57	9.96	12.23	10.33	8.37	10.25	9.58	8.97	8.96	9.27	8.52	8.98
1979	2050	9.64	10.04	12.31	10.40	8.44	10.32	9.66	9.05	9.04	9.35	8.60	9.05
1980	2051	9.71	10.12	12.40	10.48	8.51	10.40	9.73	9.13	9.11	9.43	8.68	9.13
1981	2052	9.78	10.20	12.48	10.56	8.58	10.47	9.81	9.20	9.19	9.50	8.76	9.20
1982	2053	9.85	10.29	12.56	10.63	8.65	10.54	9.88	9.28	9.26	9.58	8.83	9.27
1983	2054	9.92	10.37	12.65	10.71	8.71	10.62	9.96	9.35	9.34	9.66	8.91	9.34
1984	2055	9.99	10.45	12.73	10.78	8.78	10.69	10.03	9.43	9.41	9.73	8.99	9.42
1985	2056	10.06	10.53	12.81	10.86	8.85	10.77	10.11	9.50	9.49	9.81	9.07	9.49
1986	2057	10.16	10.63	12.92	10.96	8.94	10.86	10.20	9.60	9.59	9.91	9.18	9.59
1987	2058	10.25	10.74	13.03	11.06	9.03	10.96	10.30	9.70	9.68	10.01	9.28	9.68
1988	2059	10.34	10.85	13.14	11.16	9.12	11.06	10.40	9.80	9.78	10.11	9.38	9.78
1989	2060	10.44	10.95	13.25	11.26	9.21	11.15	10.50	9.89	9.88	10.21	9.49	9.87
1990	2061	10.53	11.06	13.36	11.36	9.29	11.25	10.59	9.99	9.97	10.31	9.59	9.97
1991	2062	10.63	11.16	13.47	11.46	9.38	11.35	10.69	10.09	10.07	10.41	9.70	10.07
1992	2063	10.72	11.27	13.58	11.56	9.47	11.44	10.79	10.19	10.17	10.51	9.80	10.16
1993	2064	10.81	11.37	13.68	11.66	9.56	11.54	10.89	10.29	10.27	10.60	9.90	10.26
1994	2065	10.91	11.48	13.79	11.76	9.65	11.64	10.99	10.38	10.36	10.70	10.01	10.36
1995	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
1996	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
1997	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
1998	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
1999	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2000	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2001	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2002	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2003	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2004	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2005	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2006	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2007	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2008	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2009	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2010	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2011	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45

Appendix B

Performance Measures Sheets

This page intentionally left blank.

Bad Creek Relicensing / Savannah River CHEOPS Model Performance Measures Sheet

Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Bad Creek II
	Lake Jocassee					(1939-2011)	(1939-2011)
	Elevation - Storage Availability						
1	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 1,108 ft AMSL on May 1	1-May	1-May	5	0	0
	Elevation - Recreation						
2	Minimize restricted recreation	Number of years where cove access (reservoir level below 1,090 ft AMSL) is restricted for more than 25 days (Note 3)	1-Jan	31-Dec	2	2	2
3		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) during higher use months in any calendar year (Note 3)	1-Mar	31-Oct	5	43	43
4		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) in any calendar year (Note 3)	1-Jan	31-Dec	5	104	104
5	Minimize restricted boat launching	Number of years where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months for more than 25 days (Note 4)	1-Mar	31-Oct	2	0	0
6		Greatest number of days where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months in any calendar year (Note 4)	1-Mar	31-Oct	5	0	0
7	Minimize effects on recreational boating	Number of days where reservoir level changes more than 1.0 ft in one hour	1-Jan	31-Dec	10	0	0
	Elevation - Natural Resources						
8	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 5)	1-Apr	31-May	5%	71%	100%
9		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 5)	1-Apr	31-May	5%	34%	99%
10		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 5)	1-Apr	31-May	5%	19%	89%
11		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 30 consecutive days at least once (Note 5)	1-Apr	31-May	5%	0%	59%
12		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 45 consecutive days at least once (Note 5)	1-Apr	31-May	5%	0%	0%
13	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	100%
14		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	100%
15		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	99%
16		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 30 consecutive days at least once (Note 5)	1-Apr	31-May	5%	95%	97%
17		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 45 consecutive days at least once (Note 5)	1-Apr	31-May	5%	56%	82%
18	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 5)	15-May	15-Jul	5%	45%	100%
19		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 5)	15-May	15-Jul	5%	14%	92%
20		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 5)	15-May	15-Jul	5%	0%	3%
21	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 5)	15-May	15-Jul	5%	100%	100%
22		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 5)	15-May	15-Jul	5%	100%	100%
23		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 5)	15-May	15-Jul	5%	79%	99%
24	Minimize entrainment due to Bad Creek operations	Percent of days average reservoir level at or below 1,096 ft AMSL (Note 6)	1-Jan	31-Dec	5%	1%	1%
25		Percent of days average reservoir level below 1,096 ft AMSL (Note 6)	1-Dec	31-Mar	5%	2%	2%
26	Maximize littoral habitat during growing season	Percent of days average reservoir level above 1,107 ft AMSL (Note 7)	1-Apr	30-Sep	5%	46%	42%
27		Percent of days average reservoir level above 1,105 ft AMSL (Note 7)	1-Apr	30-Sep	5%	91%	91%
28	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 1,107 ft AMSL (Note 7)	1-Apr	31-May	5%	20%	16%
29		Percent of days average reservoir level above 1,105 ft AMSL (Note 7)	1-Apr	31-May	5%	92%	92%
	Pumped Storage						
30	Minimize days below lake levels that impact Bad Creek operations	Number of days reservoir level below 1,099 ft AMSL (Note 8)	1-Jan	31-Dec	227	846	804
31	Minimize days below lake levels that impact Jocassee operations	Number of days reservoir level below 1,090 ft AMSL (Note 8)	1-Jan	31-Dec	14	147	139
32	Minimize days below lake levels that impact Bad Creek efficiency	Number of days reservoir level below 1,081 ft AMSL (Note 9)	1-Jan	31-Dec	12	0	0
	Lake Keowee						
	Elevation - Storage Availability						
33	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 798 ft AMSL on May 1	1-May	1-May	5	69	69
	Elevation - Aesthetics						
34	Maximize lake levels	Percent of time reservoir level at or above 797 ft AMSL	1-Jan	31-Dec	20%	91%	92%
35		Percent of time reservoir level at or above 795 ft AMSL	1-Jan	31-Dec	10%	97%	97%
36	Minimize significant drawdown of lake level	Number of days reservoir level below 796 ft AMSL	1-Jan	31-Dec	5	1,670	1,608
	Elevation - Recreation						
37	Minimize restricted recreation	Number of years where cove access (reservoir level below 792 ft AMSL) is restricted for more than 25 days (Note 10)	1-Jan	31-Dec	2	1	1
38		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) during higher use months in any calendar year (Note 10)	1-Mar	31-Oct	5	1	1
39		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) in any calendar year (Note 10)	1-Jan	31-Dec	5	41	41
40	Minimize restricted lake boat launching	Number of years where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months for more than 25 days (Note 11)	1-Mar	31-Oct	2	0	0
41		Greatest number of days where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months in any calendar year (Note 11)	1-Mar	31-Oct	5	0	0
42	Maximize boat dock usage	Percent of time reservoir level is at or above level where 85% of docks are usable (796.25 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 12)	1-Mar	31-Oct	5%	94%	94%
43		Percent of time reservoir level is at or above level where 70% of docks are usable (793.5 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 12)	1-Mar	31-Oct	5%	99%	99%

Bad Creek Relicensing / Savannah River CHEOPS Model Performance Measures Sheet

Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Bad Creek II
	Elevation - Natural Resources						
44	Minimize number of days water level is below toe of riprap	Number of days reservoir level below 794 ft AMSL (Note 13)	1-Jan	31-Dec	250	565	551
45	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
46		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
47		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
48	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
49		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
50		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
51	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
52		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
53		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 14)	15-May	15-Jul	5%	97%	97%
54	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
55		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
56		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 14)	15-May	15-Jul	5%	97%	97%
57	Maximize littoral habitat during growing season	Percent of days average reservoir level above 798 ft AMSL (Note 15)	1-Apr	30-Sep	5%	89%	89%
58		Percent of days average reservoir level above 797 ft AMSL (Note 15)	1-Apr	30-Sep	5%	93%	93%
59	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 798 ft AMSL (Note 15)	1-Apr	31-May	5%	94%	95%
60		Percent of days average reservoir level above 797 ft AMSL (Note 15)	1-Apr	31-May	5%	97%	97%
	Elevation - Water Supply						
61	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (775 ft AMSL) for shallowest public water supply intake operation (Note 16)	1-Jan	31-Dec	1	0	0
62		Number of days reservoir level below critical level (789.5 ft AMSL) for shallowest thermal power station operation (Note 17)	1-Jan	31-Dec	1	0	0
63		Number of days reservoir level below critical level (787.9 ft AMSL) for Keowee dam to supply backup power to ONS (Note 18)	1-Jan	31-Dec	1	0	0
	Duke Energy Hydropower & Water Quantity Management						
64	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 19)	1-Jan	31-Dec		8,728	5,102
65		Number of days in LIP Stage 0	1-Jan	31-Dec		13,972	17,584
66		Number of days in LIP Stage 1	1-Jan	31-Dec		1,351	1,351
67		Number of days in LIP Stage 2	1-Jan	31-Dec		2,185	2,199
68		Number of days in LIP Stage 3	1-Jan	31-Dec		378	378
69		Number of days in LIP Stage 4	1-Jan	31-Dec		49	49

	Background	Performance Measure has improved vs. the Baseline Scenario
	Background	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Notes	
1	For criterion that measure on an hourly or daily basis, unless stated otherwise: a. If an hourly criteria occurs during the average of four contiguous 15-minute periods, then it counts as 1 hour. b. If a daily criterion occurs for 5 contiguous 1-hour periods, then it counts as 1 day. Also, daytime flows are assumed to be flows provided between 7:00 am and 7:00 pm. To the extent possible, each criterion is defined in terms of percents and averages/yr so that the same criterion is useful
2	MISC = Minimum Increment of Significant Change. The MISC has the same units (i.e., days, days/yr, percent, etc.) as does the criterion on that same row of the spreadsheet. If the output of two scenarios for a a. As a general rule, MISC numbers are set at 10% of the possible total for that criterion considering the Start/Stop dates. b. MISC numbers for criteria that have the most adverse outcomes if reached are typically set at less than 10% of the possible total for that criterion. c. Adjustments to the MISC numbers (up or down) have also been made depending on the desires of the stakeholders that primarily have the interests that are being measured by a particular criterion.
3	Jocassee restricted recreation elevation 1,090 ft AMSL provided by Chris Starker (Upstate Forever) and confirmed by Devils Fork State Park Staff.
4	Jocassee elevation 1,077 ft AMSL is the lowest boat ramp elevation with an additional 3 ft added for boat access. Boat ramp elevations provided by Duke Energy.
5	This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.
6	Jocassee entrainment elevation (1,096 ft AMSL) provided by Bill Marshall of SCDNR.
7	Jocassee fish habitat elevations provided by Bill Marshall of SCDNR.
8	Jocassee elevation 1,099 ft AMSL is the elevation at which an MOU between Duke Energy and SCDNR requires Duke Energy to implement operational changes at Bad Creek. Jocassee elevation 1,090 ft AMSL is
9	Jocassee elevation 1,081 ft AMSL provided by Duke Energy based on impact to pumping equipment.
10	Keowee restricted recreation elevation of 792 ft AMSL provided by James McRacken (HDR) and Scott Fletcher (Duke Energy).
11	Keowee elevation 790 ft AMSL is based on the lowest boat ramp elevation of 787 ft AMSL plus 3 ft for boat access (provided by Duke Energy).
12	Percent of time is measured as the percent of 15-minute time steps at or above threshold elevation during period starting 07:00 am and period ending 7:00 pm.
13	Toe of Keowee reservoir riprap elevation 794 ft AMSL provided by Duke Energy.
14	This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.
15	Keowee fish habitat elevations provided by Bill Marshall of SCDNR.
16	Keowee elevation 775 ft AMSL was the minimum level permitted in the previous KT FERC License, and the Keowee water supply intakes present during KT relicensing were confirmed to operate at this
17	For this measure a -0.5 ft buffer was added to filter out model excursions below the Keowee reservoir elevation limit of 790.0 ft AMSL. No counts will be displayed for reservoir levels between 789.5 ft AMSL and 790.0 ft AMSL for this measure.
18	Keowee elevation 787.9 ft AMSL is the critical elevation for Keowee to provide backup power to ONS elevation provided by Duke Energy.
19	There are 26,663 days in the POR.

Bad Creek Relicensing /Savannah River CHEOPS Model Performance Measures Sheet

Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline_ccLow	Bad Creek II_ccLow
	Lake Jocassee					(1939-2011)	(1939-2011)
	Elevation - Storage Availability						
1	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 1,108 ft AMSL on May 1	1-May	1-May	5	0	0
	Elevation - Recreation						
2	Minimize restricted recreation	Number of years where cove access (reservoir level below 1,090 ft AMSL) is restricted for more than 25 days (Note 3)	1-Jan	31-Dec	2	2	1
3		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) during higher use months in any calendar year (Note 3)	1-Mar	31-Oct	5	53	47
4		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) in any calendar year (Note 3)	1-Jan	31-Dec	5	114	108
5	Minimize restricted boat launching	Number of years where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months for more than 25 days (Note 4)	1-Mar	31-Oct	2	0	0
6		Greatest number of days where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months in any calendar year (Note 4)	1-Mar	31-Oct	5	0	0
7	Minimize effects on recreational boating	Number of days where reservoir level changes more than 1.0 ft in one hour	1-Jan	31-Dec	10	0	0
	Elevation - Natural Resources						
8	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 5)	1-Apr	31-May	5%	67%	100%
9		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 5)	1-Apr	31-May	5%	33%	97%
10		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 5)	1-Apr	31-May	5%	21%	86%
11		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 30 consecutive days at least once (Note 5)	1-Apr	31-May	5%	0%	59%
12		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 45 consecutive days at least once (Note 5)	1-Apr	31-May	5%	0%	0%
13	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	100%
14		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	100%
15		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 5)	1-Apr	31-May	5%	99%	100%
16		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 30 consecutive days at least once (Note 5)	1-Apr	31-May	5%	93%	93%
17		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 45 consecutive days at least once (Note 5)	1-Apr	31-May	5%	55%	82%
18	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 5)	15-May	15-Jul	5%	41%	100%
19		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 5)	15-May	15-Jul	5%	14%	86%
20		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 5)	15-May	15-Jul	5%	0%	1%
21	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 5)	15-May	15-Jul	5%	100%	100%
22		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 5)	15-May	15-Jul	5%	100%	100%
23		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 5)	15-May	15-Jul	5%	78%	96%
24	Minimize entrainment due to Bad Creek operations	Percent of days average reservoir level at or below 1,096 ft AMSL (Note 6)	1-Jan	31-Dec	5%	1%	1%
25		Percent of days average reservoir level below 1,096 ft AMSL (Note 6)	1-Dec	31-Mar	5%	2%	2%
26	Maximize littoral habitat during growing season	Percent of days average reservoir level above 1,107 ft AMSL (Note 7)	1-Apr	30-Sep	5%	46%	42%
27		Percent of days average reservoir level above 1,105 ft AMSL (Note 7)	1-Apr	30-Sep	5%	91%	91%
28	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 1,107 ft AMSL (Note 7)	1-Apr	31-May	5%	20%	16%
29		Percent of days average reservoir level above 1,105 ft AMSL (Note 7)	1-Apr	31-May	5%	91%	91%
	Pumped Storage						
30	Minimize days below lake levels that impact Bad Creek operations	Number of days reservoir level below 1,099 ft AMSL (Note 8)	1-Jan	31-Dec	227	907	884
31	Minimize days below lake levels that impact Jocassee operations	Number of days reservoir level below 1,090 ft AMSL (Note 8)	1-Jan	31-Dec	14	156	128
32	Minimize days below lake levels that impact Bad Creek efficiency	Number of days reservoir level below 1,081 ft AMSL (Note 9)	1-Jan	31-Dec	12	0	0
	Lake Keowee						
	Elevation - Storage Availability						
33	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 798 ft AMSL on May 1	1-May	1-May	5	69	69
	Elevation - Aesthetics						
34	Maximize lake levels	Percent of time reservoir level at or above 797 ft AMSL	1-Jan	31-Dec	20%	91%	91%
35		Percent of time reservoir level at or above 795 ft AMSL	1-Jan	31-Dec	10%	97%	97%
36	Minimize significant drawdown of lake level	Number of days reservoir level below 796 ft AMSL	1-Jan	31-Dec	5	1,782	1,731
	Elevation - Recreation						
37	Minimize restricted recreation	Number of years where cove access (reservoir level below 792 ft AMSL) is restricted for more than 25 days (Note 10)	1-Jan	31-Dec	2	1	1
38		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) during higher use months in any calendar year (Note 10)	1-Mar	31-Oct	5	1	1
39		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) in any calendar year (Note 10)	1-Jan	31-Dec	5	41	35
40	Minimize restricted lake boat launching	Number of years where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months for more than 25 days (Note 11)	1-Mar	31-Oct	2	0	0
41		Greatest number of days where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months in any calendar year (Note 11)	1-Mar	31-Oct	5	0	0
42	Maximize boat dock usage	Percent of time reservoir level is at or above level where 85% of docks are usable (796.25 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 12)	1-Mar	31-Oct	5%	93%	94%
43		Percent of time reservoir level is at or above level where 70% of docks are usable (793.5 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 12)	1-Mar	31-Oct	5%	99%	99%

Bad Creek Relicensing /Savannah River CHEOPS Model Performance Measures Sheet

Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline_ccLow	Bad Creek II_ccLow
	Elevation - Natural Resources						
44	Minimize number of days water level is below toe of riprap	Number of days reservoir level below 794 ft AMSL (Note 13)	1-Jan	31-Dec	250	619	580
45	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
46		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
47		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
48	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
49		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
50		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
51	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
52		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
53		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 14)	15-May	15-Jul	5%	99%	99%
54	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
55		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
56		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 14)	15-May	15-Jul	5%	99%	99%
57	Maximize littoral habitat during growing season	Percent of days average reservoir level above 798 ft AMSL (Note 15)	1-Apr	30-Sep	5%	89%	89%
58		Percent of days average reservoir level above 797 ft AMSL (Note 15)	1-Apr	30-Sep	5%	92%	93%
59	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 798 ft AMSL (Note 15)	1-Apr	31-May	5%	94%	94%
60		Percent of days average reservoir level above 797 ft AMSL (Note 15)	1-Apr	31-May	5%	97%	97%
	Elevation - Water Supply						
61	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (775 ft AMSL) for shallowest public water supply intake operation (Note 16)	1-Jan	31-Dec	1	0	0
62		Number of days reservoir level below critical level (789.5 ft AMSL) for shallowest thermal power station operation (Note 17)	1-Jan	31-Dec	1	0	0
63		Number of days reservoir level below critical level (787.9 ft AMSL) for Keowee dam to supply backup power to ONS (Note 18)	1-Jan	31-Dec	1	0	0
	Duke Energy Hydropower & Water Quantity Management						
64	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 19)	1-Jan	31-Dec		8,707	3,366
65		Number of days in LIP Stage 0	1-Jan	31-Dec		13,860	19,187
66		Number of days in LIP Stage 1	1-Jan	31-Dec		1,421	1,435
67		Number of days in LIP Stage 2	1-Jan	31-Dec		2,241	2,227
68		Number of days in LIP Stage 3	1-Jan	31-Dec		385	399
69		Number of days in LIP Stage 4	1-Jan	31-Dec		49	49

	Background	Performance Measure has improved vs. the Baseline Scenario
	Background	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Notes	
1	For criterion that measure on an hourly or daily basis, unless stated otherwise:
	a. If an hourly criteria occurs during the average of four contiguous 15-minute periods, then it counts as 1 hour.
	b. If a daily criterion occurs for 5 contiguous 1-hour periods, then it counts as 1 day.
	Also, daytime flows are assumed to be flows provided between 7:00 am and 7:00 pm. To the extent possible, each criterion is defined in terms of percents and averages/yr so that the same criterion is useful regardless of the
2	MISC = Minimum Increment of Significant Change. The MISC has the same units (i.e., days, days/yr, percent, etc.) as does the criterion on that same row of the spreadsheet. If the output of two scenarios for a particular
	a. As a general rule, MISC numbers are set at 10% of the possible total for that criterion considering the Start/Stop dates.
	b. MISC numbers for criteria that have the most adverse outcomes if reached are typically set at less than 10% of the possible total for that criterion.
	c. Adjustments to the MISC numbers (up or down) have also been made depending on the desires of the stakeholders that primarily have the interests that are being measured by a particular criterion.
3	Jocassee restricted recreation elevation 1,090 ft AMSL provided by Chris Starker (Upstate Forever) and confirmed by Devils Fork State Park Staff.
4	Jocassee elevation 1,077 ft AMSL is the lowest boat ramp elevation with an additional 3 ft added for boat access. Boat ramp elevations provided by Duke Energy.
5	This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.
6	Jocassee entrainment elevation (1,096 ft AMSL) provided by Bill Marshall of SCDNR.
7	Jocassee fish habitat elevations provided by Bill Marshall of SCDNR.
8	Jocassee elevation 1,099 ft AMSL is the elevation at which an MOU between Duke Energy and SCDNR requires Duke Energy to implement operational changes at Bad Creek. Jocassee elevation 1,090 ft AMSL is the elevation at
9	Jocassee elevation 1,081 ft AMSL provided by Duke Energy based on impact to pumping equipment.
10	Keowee restricted recreation elevation of 792 ft AMSL provided by James McRacken (HDR) and Scott Fletcher (Duke Energy).
11	Keowee elevation 790 ft AMSL is based on the lowest boat ramp elevation of 787 ft AMSL plus 3 ft for boat access (provided by Duke Energy).
12	Percent of time is measured as the percent of 15-minute time steps at or above threshold elevation during period starting 07:00 am and period ending 7:00 pm.
13	Toe of Keowee reservoir riprap elevation 794 ft AMSL provided by Duke Energy.
14	This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.
15	Keowee fish habitat elevations provided by Bill Marshall of SCDNR.
16	Keowee elevation 775 ft AMSL was the minimum level permitted in the previous KT FERC License, and the Keowee water supply intakes present during KT relicensing were confirmed to operate at this reservoir level.
17	For this measure a -0.5 ft buffer was added to filter out model excursions below the Keowee reservoir elevation limit of 790.0 ft AMSL. No counts will be displayed for reservoir levels between 789.5 ft AMSL and 790.0 ft AMSL for this measure.
18	Keowee elevation 787.9 ft AMSL is the critical elevation for Keowee to provide backup power to ONS elevation provided by Duke Energy.
19	There are 26,663 days in the POR.

Bad Creek Relicensing / Savannah River CHEOPS Model Performance Measures Sheet

Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline_ccHigh	Bad Creek II_ccHigh
	Lake Jocassee					(1939-2011)	(1939-2011)
	Elevation - Storage Availability						
1	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 1,108 ft AMSL on May 1	1-May	1-May	5	0	0
	Elevation - Recreation						
2	Minimize restricted recreation	Number of years where cove access (reservoir level below 1,090 ft AMSL) is restricted for more than 25 days (Note 3)	1-Jan	31-Dec	2	3	2
3		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) during higher use months in any calendar year (Note 3)	1-Mar	31-Oct	5	86	85
4		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) in any calendar year (Note 3)	1-Jan	31-Dec	5	128	131
5	Minimize restricted boat launching	Number of years where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months for more than 25 days (Note 4)	1-Mar	31-Oct	2	0	0
6		Greatest number of days where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months in any calendar year (Note 4)	1-Mar	31-Oct	5	0	0
7	Minimize effects on recreational boating	Number of days where reservoir level changes more than 1.0 ft in one hour	1-Jan	31-Dec	10	0	0
	Elevation - Natural Resources						
8	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 5)	1-Apr	31-May	5%	73%	100%
9		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 5)	1-Apr	31-May	5%	40%	95%
10		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 5)	1-Apr	31-May	5%	23%	86%
11		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 30 consecutive days at least once (Note 5)	1-Apr	31-May	5%	1%	63%
12		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 45 consecutive days at least once (Note 5)	1-Apr	31-May	5%	0%	0%
13	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	100%
14		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	100%
15		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 5)	1-Apr	31-May	5%	99%	100%
16		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 30 consecutive days at least once (Note 5)	1-Apr	31-May	5%	92%	92%
17		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 45 consecutive days at least once (Note 5)	1-Apr	31-May	5%	56%	79%
18	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 5)	15-May	15-Jul	5%	55%	100%
19		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 5)	15-May	15-Jul	5%	19%	85%
20		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 5)	15-May	15-Jul	5%	3%	3%
21	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 5)	15-May	15-Jul	5%	100%	100%
22		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 5)	15-May	15-Jul	5%	100%	100%
23		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 5)	15-May	15-Jul	5%	82%	96%
24	Minimize entrainment due to Bad Creek operations	Percent of days average reservoir level at or below 1,096 ft AMSL (Note 6)	1-Jan	31-Dec	5%	5%	5%
25		Percent of days average reservoir level below 1,096 ft AMSL (Note 6)	1-Dec	31-Mar	5%	6%	6%
26	Maximize littoral habitat during growing season	Percent of days average reservoir level above 1,107 ft AMSL (Note 7)	1-Apr	30-Sep	5%	43%	38%
27		Percent of days average reservoir level above 1,105 ft AMSL (Note 7)	1-Apr	30-Sep	5%	87%	87%
28	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 1,107 ft AMSL (Note 7)	1-Apr	31-May	5%	19%	14%
29		Percent of days average reservoir level above 1,105 ft AMSL (Note 7)	1-Apr	31-May	5%	90%	90%
	Pumped Storage						
30	Minimize days below lake levels that impact Bad Creek operations	Number of days reservoir level below 1,099 ft AMSL (Note 8)	1-Jan	31-Dec	227	2,272	2,086
31	Minimize days below lake levels that impact Jocassee operations	Number of days reservoir level below 1,090 ft AMSL (Note 8)	1-Jan	31-Dec	14	224	246
32	Minimize days below lake levels that impact Bad Creek efficiency	Number of days reservoir level below 1,081 ft AMSL (Note 9)	1-Jan	31-Dec	12	0	10
	Lake Keowee						
	Elevation - Storage Availability						
33	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 798 ft AMSL on May 1	1-May	1-May	5	67	67
	Elevation - Aesthetics						
34	Maximize lake levels	Percent of time reservoir level at or above 797 ft AMSL	1-Jan	31-Dec	20%	87%	87%
35		Percent of time reservoir level at or above 795 ft AMSL	1-Jan	31-Dec	10%	95%	95%
36	Minimize significant drawdown of lake level	Number of days reservoir level below 796 ft AMSL	1-Jan	31-Dec	5	2,886	2,761
	Elevation - Recreation						
37	Minimize restricted recreation	Number of years where cove access (reservoir level below 792 ft AMSL) is restricted for more than 25 days (Note 10)	1-Jan	31-Dec	2	0	0
38		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) during higher use months in any calendar year (Note 10)	1-Mar	31-Oct	5	0	14
39		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) in any calendar year (Note 10)	1-Jan	31-Dec	5	0	23
40	Minimize restricted lake boat launching	Number of years where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months for more than 25 days (Note 11)	1-Mar	31-Oct	2	0	0
41		Greatest number of days where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months in any calendar year (Note 11)	1-Mar	31-Oct	5	0	0
42	Maximize boat dock usage	Percent of time reservoir level is at or above level where 85% of docks are usable (796.25 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 12)	1-Mar	31-Oct	5%	90%	90%
43		Percent of time reservoir level is at or above level where 70% of docks are usable (793.5 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 12)	1-Mar	31-Oct	5%	99%	99%

Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline_ccHigh	Bad Creek II_ccHigh
	Elevation - Natural Resources						
44	Minimize number of days water level is below toe of riprap	Number of days reservoir level below 794 ft AMSL (Note 13)	1-Jan	31-Dec	250	869	858
45	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
46		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
47		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
48	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
49		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
50		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 14)	15-Mar	31-May	5%	100%	100%
51	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
52		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
53		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 14)	15-May	15-Jul	5%	99%	99%
54	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
55		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 14)	15-May	15-Jul	5%	100%	100%
56		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 14)	15-May	15-Jul	5%	99%	99%
57	Maximize littoral habitat during growing season	Percent of days average reservoir level above 798 ft AMSL (Note 15)	1-Apr	30-Sep	5%	84%	84%
58		Percent of days average reservoir level above 797 ft AMSL (Note 15)	1-Apr	30-Sep	5%	88%	88%
59	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 798 ft AMSL (Note 15)	1-Apr	31-May	5%	90%	91%
60		Percent of days average reservoir level above 797 ft AMSL (Note 15)	1-Apr	31-May	5%	92%	93%
	Elevation - Water Supply						
61	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (775 ft AMSL) for shallowest public water supply intake operation (Note 16)	1-Jan	31-Dec	1	0	0
62		Number of days reservoir level below critical level (789.5 ft AMSL) for shallowest thermal power station operation (Note 17)	1-Jan	31-Dec	1	0	0
63		Number of days reservoir level below critical level (787.9 ft AMSL) for Keowee dam to supply backup power to ONS (Note 18)	1-Jan	31-Dec	1	0	0
	Duke Energy Hydropower & Water Quantity Management						
64	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 19)	1-Jan	31-Dec		7,860	4,276
65		Number of days in LIP Stage 0	1-Jan	31-Dec		13,160	16,793
66		Number of days in LIP Stage 1	1-Jan	31-Dec		2,625	2,527
67		Number of days in LIP Stage 2	1-Jan	31-Dec		2,213	2,304
68		Number of days in LIP Stage 3	1-Jan	31-Dec		805	728
69		Number of days in LIP Stage 4	1-Jan	31-Dec		0	35

	Background	Performance Measure has improved vs. the Baseline Scenario
	Background	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Notes	
1	For criterion that measure on an hourly or daily basis, unless stated otherwise: a. If an hourly criteria occurs during the average of four contiguous 15-minute periods, then it counts as 1 hour. b. If a daily criterion occurs for 5 contiguous 1-hour periods, then it counts as 1 day. Also, daytime flows are assumed to be flows provided between 7:00 am and 7:00 pm. To the extent possible, each criterion is defined in terms of percents and averages/yr so that the same criterion is useful regardless of the length
2	MISC = Minimum Increment of Significant Change. The MISC has the same units (i.e., days, days/yr, percent, etc.) as does the criterion on that same row of the spreadsheet. If the output of two scenarios for a particular criterion a. As a general rule, MISC numbers are set at 10% of the possible total for that criterion considering the Start/Stop dates. b. MISC numbers for criteria that have the most adverse outcomes if reached are typically set at less than 10% of the possible total for that criterion. c. Adjustments to the MISC numbers (up or down) have also been made depending on the desires of the stakeholders that primarily have the interests that are being measured by a particular criterion.
3	Jocassee restricted recreation elevation 1,090 ft AMSL provided by Chris Starker (Upstate Forever) and confirmed by Devils Fork State Park Staff.
4	Jocassee elevation 1,077 ft AMSL is the lowest boat ramp elevation with an additional 3 ft added for boat access. Boat ramp elevations provided by Duke Energy.
5	This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.
6	Jocassee entrainment elevation (1,096 ft AMSL) provided by Bill Marshall of SCDNR.
7	Jocassee fish habitat elevations provided by Bill Marshall of SCDNR.
8	Jocassee elevation 1,099 ft AMSL is the elevation at which an MOU between Duke Energy and SCDNR requires Duke Energy to implement operational changes at Bad Creek. Jocassee elevation 1,090 ft AMSL is the elevation at
9	Jocassee elevation 1,081 ft AMSL provided by Duke Energy based on impact to pumping equipment.
10	Keowee restricted recreation elevation of 792 ft AMSL provided by James McRacken (HDR) and Scott Fletcher (Duke Energy).
11	Keowee elevation 790 ft AMSL is based on the lowest boat ramp elevation of 787 ft AMSL plus 3 ft for boat access (provided by Duke Energy).
12	Percent of time is measured as the percent of 15-minute time steps at or above threshold elevation during period starting 07:00 am and period ending 7:00 pm.
13	Toe of Keowee reservoir riprap elevation 794 ft AMSL provided by Duke Energy.
14	This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.
15	Keowee fish habitat elevations provided by Bill Marshall of SCDNR.
16	Keowee elevation 775 ft AMSL was the minimum level permitted in the previous KT FERC License, and the Keowee water supply intakes present during KT relicensing were confirmed to operate at this reservoir level.
17	For this measure a -0.5 ft buffer was added to filter out model excursions below the Keowee reservoir elevation limit of 790.0 ft AMSL. No counts will be displayed for reservoir levels between 789.5 ft AMSL and 790.0 ft AMSL for this measure.
18	Keowee elevation 787.9 ft AMSL is the critical elevation for Keowee to provide backup power to ONS elevation provided by Duke Energy.
19	There are 26,663 days in the POR.

Attachment 5

Water Quality Monitoring Plan

This page intentionally left blank.

BAD CREEK II POWER COMPLEX
WATER QUALITY MONITORING PLAN

DRAFT REPORT

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

November 11, 2024

This page intentionally left blank.

DRAFT WATER QUALITY MONITORING PLAN
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
TABLE OF CONTENTS

Section **Title** **Page No.**

Table of Contents
Continued

List of Tables

List of Figures

Attachments

ACRONYMS AND ABBREVIATIONS

Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II or Complex	Bad Creek II Power Complex
Bad Creek Reservoir	upper reservoir
BMP	best management practice
CWA	Clean Water Act
DO	dissolved oxygen
Duke Energy or Licensee	Duke Energy Carolinas, LLC
ESC	Erosion and Sediment Control
ft	feet/foot
ft msl	feet above mean sea level
FERC or Commission	Federal Energy Regulatory Commission
KT Project	Keowee-Toxaway Project
LOD	limits of disturbance
mg/L	milligrams per liter
mi^2	square miles
MOU	Memorandum of Understanding
NCSAM	North Carolina Stream Assessment Method
NPDES	National Pollutant Discharge Elimination Program
NTU	Nephelometric Turbidity Units
PM&E	protection, mitigation and enhancement
I/O structure	inlet/outlet structure
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SCDES	South Carolina Department of Environmental Services
SQT	South Carolina Stream Quantification Tool
SOP	Standard Operating Procedures
C-SWPPP	Comprehensive Stormwater Pollution Prevention Plan
O-SWPPP	Onsite Stormwater Pollution Protection Plan
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
ug/L	micrograms per liter
WOTUS	Waters of the U.S.
WQMP or Plan	Bad Creek II Complex Water Quality Monitoring Plan

1 Project Introduction

Duke Energy Carolinas, LLC (Duke Energy or Licensee) is the owner and operator of the 1,400-megawatt Bad Creek Pumped Storage Project (Project) (FERC 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 Hydroelectric Project (KT 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]

Given the need for additional significant 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 would 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-megawatt Bad Creek II Power Complex (Bad Creek II or Bad Creek II Complex) is an alternative relicensing proposal presently being evaluated by Duke Energy.

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

2 Plan Description and Format

The development of the Bad Creek II Complex and construction activities associated with the new facility components could result in temporary and permanent impacts to water resources at the Project. As part of the relicensing studies, Duke Energy proposed to develop a Water Quality Monitoring Plan (WQMP or Plan) in consultation with agencies focused on water quality impacts associated with the Bad Creek II Complex as part of the new license. Development of this plan was described in the Revised Study Plan filed with the Commission in accordance with 18 CFR §5.15 and was listed as one of the protection, mitigation, and enhancement (PM&E) measures for potential impacts in the Pre-Application Document (Duke Energy 2022):

- *Development of a Water Quality Monitoring Plan in consultation with agencies, including monitoring locations, methods, and reporting criteria for major parameters such as DO, temperature, pH, specific conductance, and turbidity for Project construction (pre-, during, and post-construction) and operation.*

The WQMP considers water quality and monitoring methods in the Whitewater River cove of Lake Jocassee as well as stream conditions in upland areas that will potentially be affected by Bad Creek II construction activities. Site-specific monitoring prior to Bad Creek II construction (i.e., pre-construction phase), during construction (i.e., construction phase), and following construction (i.e., post-construction) to document operational conditions is proposed.

This Plan describes two different monitoring strategies to assess Project waters depending on location (i.e., Lake Jocassee vs. upland areas). As further discussed in Section 5, select water quality parameters in the Whitewater River cove of Lake Jocassee will be measured via a multi-parameter sonde, while upland surface waters will be monitored downstream of impacted areas via stream habitat quality surveys. These stream assessments will consider stream conditions, aquatic resources, and habitat function and will be supported by routine monitoring of storm events and best management practices (BMPs), which will be developed and implemented though the Erosion and Sediment Control (ESC) permitting process (i.e., National Pollutant Discharge Elimination Program [NPDES] for Construction Stormwater). Efforts carried out during Plan development will also aid information gathering in support of Clean Water Act (CWA) 404/401 permitting related to potential impacts to surface waters down gradient from upland spoil locations and access roads as well as potential impacts to Lake Jocassee from construction activities and proposed submerged weir expansion.

This Plan presents relevant background information, objectives, monitoring rationale, and methods for monitoring and serves as a supplemental information document to the WQMP Standard Operating Procedures (SOP) document (Attachment 1 [forthcoming]). The SOP is a separate technical document presenting detailed aspects of field monitoring including sampling locations and maps, sampling methods, instrumentation specifications, and field data collection forms. The SOP provides procedures for consistent and scientifically valid quantitative and qualitative monitoring in support of water and aquatic resources for Bad Creek II Complex construction.

3 Objectives

Development of the WQMP was proposed as Task 5 of the Water Resources Study (*Future Water Quality Monitoring Plan Development*) and is intended to provide sufficient information to support an analysis of the potential Project-related effects on water resources with nexus to the Project and proposed Bad Creek II Complex. The draft Plan will be developed in consultation with agencies and stakeholders focused on the proposed Bad Creek II Complex with the main goal of identifying applicable water quality parameters and/or surface water conditions to monitor associated with construction as well as appropriate monitoring methods for compliance with the South Carolina Department of Environmental Services (SCDES)[2] regulations and protection of existing uses.

[2] SCDES was established on July 1, 2024, when the South Carolina Department of Health and Environmental Control (SCDHEC) became two separate agencies.

4 Project Background

The Project is located in the Blue Ridge physiographic province in the headwaters of the Savannah River basin. The Savannah River basin has an area of approximately 10,577 square miles (mi^2) and drains portions of the Blue Ridge, Piedmont, and Coastal Plain regions.

The Project uses the Bad Creek Reservoir as its upper reservoir, which has a drainage area of approximately 1.5 mi^2. Construction of the Project began in December 1985 and major work was completed by December 1990; initial filling of the Bad Creek Reservoir began in January 1991. Prior to impoundment, Bad Creek and West Bad Creek were tributaries of Howard Creek (a tributary to Lake Jocassee) located near the toe of the Main Dam and West Dam, respectively. Howard Creek flows from its headwaters (northwest of the Project) 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 limited to no effect on water quality or Project operations.

Lake Jocassee, which operates as the lower reservoir for the 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]). Water from Lake Jocassee flows directly into Lake Keowee, which was formed by impounding the Keowee River and the Little River.

During Project construction, excavated rockfill was hauled to the western shore of Whitewater River cove (also called Whitewater River arm), transported out into the lake on barges, and placed in the water to construct an underwater weir approximately 1,800 ft downstream of the Project inlet/outlet (I/O) structure (weir midpoint lat/long coordinates 35.0015, -82.991509). The existing submerged weir is approximately 567 ft wide and 455 ft long with a crest elevation of approximately 1,060 ft msl. It was constructed to help minimize the effects of Project operations on the natural stratification of Lake Jocassee downstream of the weir and dissipate the energy of the discharging water from the Project's I/O structure. Duke Energy is proposing to expand the existing submerged weir in the downstream direction (weir crest will have same elevation) with newly excavated rockfill from the proposed Bad Creek II Complex. Results of recent modeling efforts in the Whitewater River cove indicate stratification is maintained downstream of the proposed expanded weir similar to current conditions.[3]

4.1 Original License Requirements

As a condition of the Original License for the Project, Duke Energy entered into a Memorandum of Understanding (MOU) with the South Carolina Department of Natural Resources (SCDNR) for the long-term management and maintenance of high-quality fishery resources in Lake Keowee, Lake Jocassee, and their tributary streams (Duke Power and SCDNR 1996). The MOU called for successive 10-Year Work Plans[4] (i.e., 1996 – 2005; 2006 – 2015; and 2017 – 2027). Each Work Plan identifies specific management activities, funding initiatives, and communications protocols which both Duke Energy and SCDNR believe are important to the effective management of the KT area's fishery resources.

Major PM&E measures for original Project construction as well as ongoing Project operation were primarily focused on fisheries, water quality, and recreation, and are established by the following:

- Bad Creek Project License Exhibit S (Environmental Study Plans)[5]
- Duke Energy and SCDNR MOU and 10-Year Work Plans
- KT Project Relicensing Agreement
- Recreation Plan (Exhibit R)

---

[3] Three-dimensional Computational Fluid Dynamics modeling methods and results are included in final report *Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse* filed with the Initial Study Report. Available at FERC eLibrary: https://elibrary.ferc.gov/eLibrary/filelist?accession_num=20240104-5044.

[4] The first two Ten-Year Work Plans were titled "Keowee-Toxaway Fishery Resources Work Plan." However, several activities conducted under these work plans were identified as PM&E measures for the KT Project and were included in the KT Relicensing Agreement. As a result, those measures were not included in the 2017-2027 Work Plan and it is now titled "Bad Creek Fishery Resources Work Plan."

[5] License Article #32 (as amended on May 2, 1978, August 15, 1979, and October 2, 1995) required Duke Energy to file a revised Exhibit S within one year of license issuance to address fish and wildlife PM&E measures.

The MOU and first 10-Year Work Plan were approved pursuant to Article 32(b)(1) of the license for the Bad Creek Project on May 1, 1997. 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. Several activities under the 10-Year Work Plans were later identified as PM&E measures appropriate for transfer to the KT Project and are now addressed under the KT Project 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, as well as a requirement to monitor dissolved oxygen (DO) concentrations in the tailwaters of the Jocassee and Keowee Developments each August for the term of the KT Project license to demonstrate compliance with South Carolina's water quality standards regulated by SCDES.

The current 10-Year Work Plan continues many of the management activities implemented in prior work plans. The current Work Plan is composed of five main elements and will continue until 2027:

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

Duke Energy's trout habitat monitoring program addresses two different license articles for the Bad Creek Project. License Article #32(b)(2) covers Lake Jocassee pelagic trout habitat and License Article #34 covers Lake Jocassee water quality (both articles required Duke Energy to conduct a water quality and trout habitat monitoring program for a 5-year period (i.e., 1995 – 1999)[6] to capture conditions upon Project start-up.

[6] The pelagic trout habitat monitoring program in Lake Jocassee began in 1973 to coincide with operations at the Jocassee Pumped Storage Station. Under the existing monitoring program, if trout habitat is projected to be less than 10 meters thick (based on water temperatures and DO concentrations) by September of each year, Duke Energy will measure water temperature and DO in June and August to monitor thickness, as well as consult with SCDNR regarding potential modifications to hydropower operations; however, this situation has yet to arise based on monitoring. This condition has never been triggered during the Original License term.

Although Lake Jocassee water quality meets all state water quality standards, SCDES's water quality certification (CWA Section 401; SCDHEC 1995) requires Duke Energy to monitor DO, therefore, this parameter (as well as temperature) is still routinely monitored in the Keowee Hydro Station and Jocassee Pumped Storage Station tailwaters. In 2008, Duke Energy installed water quality monitors (temperature, DO, conductivity, and water level) in the tailraces of both Jocassee and Keowee hydroelectric stations. A summary of data is included in Section 6.3 of the Pre-Application Document (Duke Energy 2022).

As indicated above, activities associated with water quality monitoring in Lake Jocassee (trout habitat, DO and temperature monitoring) will continue throughout the remainder of the KT Project license term, which extends until August 31, 2046.

4.2 Historic Water Quality Monitoring

Bad Creek Reservoir is used only for Project operations; it is not designated for any other uses and therefore has no applicable state or federal water quality standards. While there are no state or federal water quality standards applicable to the waters of the upper reservoir, Lake Jocassee is included in the highest water quality classification (i.e., excellent rating) as designated by SCDES and preservation of existing conditions is recommended, with most tributaries within the watershed fully supporting their designated uses. Lake Jocassee is one of only a few reservoirs in South Carolina that possesses the necessary aquatic habitat (water temperature and DO) to support both a warmwater and a coldwater (salmonid [trout]) fishery year-round (USACE 2014) and Duke Energy has monitored water quality conditions in Lake Jocassee since its formation (1974). Streams affected by the original construction of the Project include Bad Creek and West Bad Creek, which were dammed to create the upper reservoir, and Howard Creek, which flows immediately downstream of the Project's main dam and enters Lake Jocassee.

As part of the ongoing relicensing effort for the Project, Duke Energy carried out a comprehensive desktop analysis of historic water quality in Lake Jocassee that included DO concentration, DO saturation, water temperature, conductivity, phosphorus, and nitrogen data from 12 water quality monitoring stations. Data were compared between pre-Project and post-Project operations. Turbidity values (vertical profiles) were also assessed at the three Whitewater River cove locations (Stations 564.1, 564.0, and 560.0) to identify potential relationships between past project construction activities and increased turbidity as well as downstream extent of turbidity impacts (from original construction) in Whitewater River cove. Turbidity data were compiled and presented in a format that shows pre-construction, construction, and post-construction conditions to help inform future potential water quality/turbidity impacts from the construction of Bad Creek II. Additionally, historic water quality data collected by Clemson University on Howard Creek was compiled. Results from these desktop analyses (i.e., Lake Jocassee and Howard Creek) were developed in collaboration with relicensing stakeholders and State resource and regulatory agencies and were provided in the *Existing Water Quality Summary Final Report*[7], which was submitted with the Initial Study Report as Appendix A, Attachment 1 (Duke Energy 2024).

4.3 Recent Monitoring and Stream Surveys

4.3.1 Lake Jocassee Water Quality Monitoring

Under Task 2 of the Water Resources Study for Project relicensing, locations associated with the three historic water quality stations in Whitewater River cove were monitored to support an analysis of the potential Project-related effects on water resources in the Whitewater River arm (also called the Whitewater River cove) under existing and upgraded unit operations. Specifically, the effectiveness of the existing submerged weir, vertical mixing upstream and downstream of the weir, and the effects of Project discharge on stratification in the Whitewater River cove were evaluated. During study year 1 (2023), objectives were met through continuous and bi-weekly water quality monitoring of water temperature and DO at three historic monitoring stations in the Whitewater River cove of Lake Jocassee. Data collection was carried out from June 1 through September 30 when water temperatures are expected to be warmest and stratification is at its peak. Water quality monitoring efforts are being repeated in the summer of 2024 to capture conditions in the Whitewater River cove with all four existing Bad Creek unit upgrades complete.

In the absence of water quality data or monitoring in Bad Creek Reservoir (upper reservoir), water quality results from this effort provide representative water quality conditions in the upper

[7] Bad Creek Pumped Storage Project Initial Study Report, FERC eLibrary Accession Number 20240104-5044. URL: https://elibrary.ferc.gov/eLibrary/filelist?accession_num=20240104-5044.

reservoir, as water is exchanged directly between the upper reservoir and the Whitewater River arm of Lake Jocassee.[8] Additionally, while proposed Project operations are not expected to impose adverse effects on water quality, these baseline water quality data can be used to compare existing conditions to conditions under future construction and operation of Bad Creek II.

4.3.2 Stream Surveys

Disposal of overburden material in upland locations would result in potential impacts to surface waters and will require an individual permit from the U.S. Army Corps of Engineers (USACE) and water quality certification from SCDES under the authorities of Sections 404 and 401 of the CWA. In preparation for these expected regulatory processes (if Bad Creek II Complex is pursued), stream habitat quality surveys were completed to provide a physical assessment of existing conditions of streams that have the potential to be impacted.

Under Task 3 (*Impacts to Surface Waters and Associated Aquatic Fauna)* of the Aquatic Resources Study (Duke Energy 2024), stream assessment surveys were conducted as part of the ongoing relicensing for the Project. The goal of this task was to evaluate existing aquatic habitat in waters that have the potential for direct impact from Bad Creek II construction activities by quantifying and characterizing surface waters, including resource quality. In addition to assessing surface waters having the potential to be impacted by construction as described in the Revised Study Plan, Duke Energy evaluated surface waters that would be crossed by the proposed temporary access road (Fisher Knob Access Road). Stream survey approach methods were developed in consultation with the SCDNR and implemented the South Carolina Stream Quantification Tool. Additional details are included in Section 5.2.3.

---

[8] Note that water quality monitoring in the Bad Creek Reservoir is not safe (due to rapid, large fluctuations in water level elevation and typically continuous Project operation) nor is it considered meaningful, given the short retention time of the Bad Creek Reservoir. Due to pumping and generating cycles, retention time is approximately three days if only a single pump-turbine unit is operating. There are no existing water quality data in the upper reservoir; it is used only for Project operations and there is no public access.

4.4 SCDES State Water Quality Standards

Under the authority of the South Carolina Pollution Control Act, SCDES Water Classification and Standards[9] establishes 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. South Carolina's water quality standards are promulgated in S.C. Regulation 61-68, Water Classifications and Standards. This regulation sets forth the classifications of state waters and establishes water quality standards that protect and maintain the existing and classified uses of those waters. Those beneficial uses, criteria set to protect and maintain those uses, and antidegradation policy are all required components of the water quality standards as set forth in the CWA.

A summary of water quality standards for South Carolina applicable to Project waters (i.e., Blue Ridge; trout waters) is included in Table 3-1. Note that nutrient criteria (i.e., phosphorous, nitrogen, chlorophyll a) in the state of South Carolina apply only to lakes and reservoirs, not rivers and streams. Numeric nutrient criteria are based on an ecoregional approach which considers the geographic location of the lake and are applicable to lakes of 40 acres or more in surface area. In evaluating the effects of nutrients on the quality of lakes and other waters of the state, SCDES may consider, but not be limited to, such factors as the hydrology and morphometry of the waterbody, the existing and projected trophic state, characteristics of the loadings, and other control mechanisms to protect the existing and classified uses of the waters (SCDHEC 2023a).

An important goal of the CWA, South Carolina Pollution Control Act, and the State Water Quality Classifications and Standards is to maintain the quality of surface waters to provide for the survival and propagation of a balanced indigenous aquatic community of fauna and flora (SCDHEC n.d.). The degree to which aquatic life is protected is assessed by comparing important water quality characteristics and the concentrations of potentially toxic pollutants with numeric criteria. Support of aquatic life uses is determined based on the percentage of numeric criteria excursions and, where data are available, the composition and functional integrity of the

[9] Regulation 61-68 Water Classification and Standards: https://scdhec.gov/sites/default/files/Library/Regulations/R.61-68.pdf

biological community (SCDHEC n.d.). Most named streams in the Project vicinity are classified as trout waters by the SCDES and Lake Jocassee is designated as Trout, Put, Grow, and Take (TPGT) (SCDEHC 2023b)[10]. TPGT waters 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.

Table 3-1. South Carolina Numeric State Water Quality Standards for Parameters Assessed in 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 milligrams per liter (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	Freshwater Lakes Only: Not to exceed 25 NTU provided existing uses are maintained. Trout Waters: Not to exceed 10 NTU 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 2023a; mg/L=milligrams per liter; NTU=Nephelometric Turbidity Units; ug/L=micrograms per liter

[10]Regulation 61-69: Classified waters: https://scdhec.gov/sites/default/files/Library/Regulations/R.61-69.pdf

5 Water Quality Monitoring Plan Development

Potential impacts to water resources are anticipated associated with the construction and operation of the proposed Bad Creek II Complex. Development of the Bad Creek II Complex WQMP is a collaborative effort between Duke Energy, the State regulatory agency (i.e., SCDES), and other relicensing stakeholders and documents methods for monitoring site conditions to maintain project compliance with SCDES ESC requirements in upland watersheds and turbidity water quality standards in the Whitewater River arm of Lake Jocassee.

This Plan is applicable for waters covered under a CWA USACE Section 404 permit/SCDES Section 401 Water Quality Certification and identifies and documents frequency and location of water quality sampling/monitoring for in-water work (Lake Jocassee) as well as locations for qualitative monitoring of upland waters that would be applicable under a SCDES NPDES Construction Stormwater Permit.[11] Potential impacts and monitoring rationale, proposed methods, proposed water quality thresholds, and proposed BMPs are discussed in the following sections to support requirements under both the CWA and SC Pollution Control Act. As indicated in Section 2, the Plan includes temporary and permanent construction activities associated with potential impacts to the lake environment as well as the upland environment and considers separate phases associated with construction. These activities are discussed individually as monitoring methods, environmental setting (streams vs. lake), and types of impact and mitigation for each vary considerably.

Section 5.1 documents potential impacts and monitoring methods in Lake Jocassee, and Section 5.2 considers potential impacts and monitoring methods in upland area surface waters, including those potentially affected by upland spoil disposal sites, site construction activities, and road construction.

Duke Energy will continue to consult with SCDES and other Project stakeholders through the relicensing process and settlement agreement negotiations to determine PM&E measures for the protection of water quality appropriate for construction and operation of the proposed Bad Creek II Complex.

[11] Note that *quantitative* water quality monitoring in upland areas is not required or proposed under this WQMP during the construction phase for the purposes of land disturbance.

5.1 Lake Jocassee

5.1.1 Potential Impacts and Monitoring Rationale

<u>Potential Impacts</u>

- Similar to construction-related impacts for the existing Project, temporarily elevated turbidity levels are anticipated in the Whitewater River arm of Lake Jocassee during construction activities associated with the I/O structure and expansion of the existing submerged weir. Additionally, temporarily elevated turbidity levels in Lake Jocassee due to surface runoff have the potential to occur during high precipitation events impacting construction areas. Therefore, the primary (temporary) impact to surface water quality in Lake Jocassee is increased turbidity caused by potential sediment loading from construction activities (e.g., proposed lower reservoir I/O and cofferdam, bank excavation, expansion of the submerged weir), as well as overland runoff due to temporary land disturbance.
- No long-term degradation of water quality is expected to result from construction and operation of the Bad Creek II Complex.

<u>Monitoring Rationale</u>

- Construction activities could result in temporarily elevated turbidity from sediment loading, which could in turn reduce quality of aquatic habitat. While water quality impacts would be temporary (during construction phase only) and occur in a very localized area likely limited to Whitewater River cove, monitoring water quality at a consistent location in Lake Jocassee during and after construction of the Bad Creek II Complex is proposed to maintain and document compliance with SCDES water quality standards for turbidity. The turbidity water quality standard for trout waters under S.C. Reg.61-69, is not to exceed 10 NTU or 10 percent above natural conditions, provided existing uses are maintained. However, Duke Energy seeks a temporary variance from SCDES during construction of Bad Creek II to meet the turbidity compliance criteria standard for South Carolina freshwater lakes (i.e., 25 NTU). Additional details, including Duke Energy's rationale for seeking a temporary turbidity variance, are included in Section 5.1.3.

5.1.2 Existing Data and Background Information

5.1.2.1 Water Quality in Whitewater River Cove

As indicated above, Duke Energy has monitored water quality conditions in Lake Jocassee in some capacity since its formation (1974). There are 12 historical water quality stations in the lake; two stations (Stations 564.1 and 564.0) are located in Whitewater River cove and one station (Station 560.0) is located downstream of the cove, as shown on Figure 5-1. A summary of surface water quality conditions for the entire lake (from approximately 1976 through 2022) is provided below for a general description of the waterbody. A summary of turbidity results from the previous desktop study for the three stations closest to the Project (Station 564.1, 564.0, 560.0) is also included below to provide information on turbidity trends in the Whitewater River cove before, during, and after original construction.[12]

[12] Recent modeling results indicate the extent of proposed Bad Creek II project effects is confined to the upstream portion of the Whitewater River cove, therefore, Duke Energy does not propose to monitor historic locations in the reservoir.

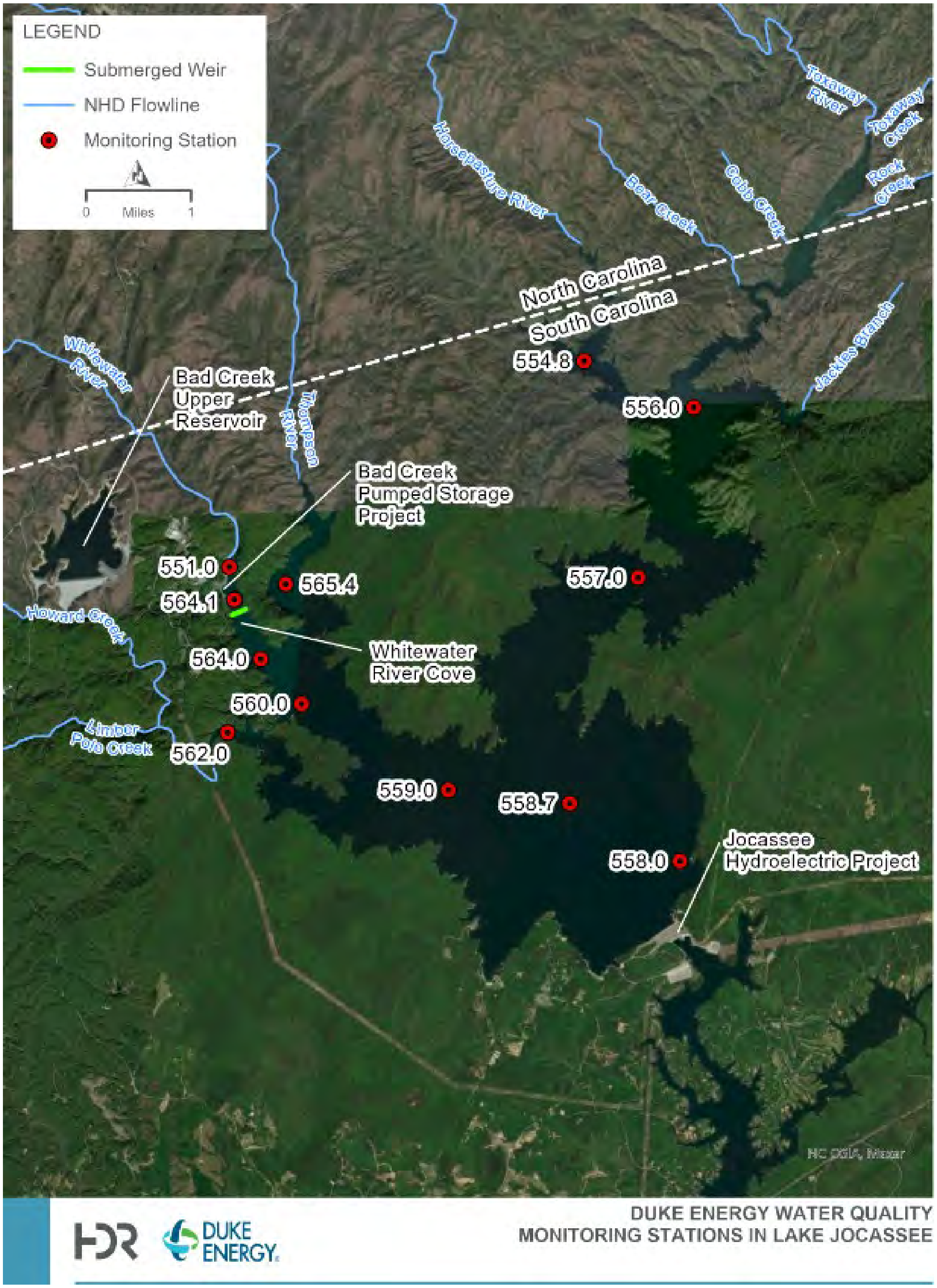


Figure 5-1. Duke Energy Water Quality Monitoring Stations Lake Jocassee

Dissolved Oxygen

In general, DO concentrations in Lake Jocassee are a function of the extent of the previous winter mixing – colder winter temperatures result in deeper mixing within the reservoir, which results in higher DO concentrations the following year.

The state standard for DO in trout waters is > 6.0 mg/L (instantaneous minimum). Before 1991 there were two instances of surface DO measuring less than 6.0 mg/L: 4.6 mg/L at monitoring Station 558.0 in 1973 and 5.4 mg/L at monitoring Station 556.0 in 1976, which correspond to the first few years after Lake Jocassee was filled in 1973. There have been no instances of surface DO values less than 6.0 mg/L since Project operations started in 1991.

Over the entire dataset (entire lake), there were 4,241 surface measurements; only five measurements (0.12 percent) were below the state standard (Table 5-1). Surface water DO concentrations in Lake Jocassee fully support the designated use classification (i.e., less than 10 percent criterion excursions).

Table 5-1. Dissolved Oxygen in Surface Waters of Lake Jocassee

Lake Jocassee Surface DO (mg/L)			
Station	Minimum	Average	Maximum
558.7	6.8	8.7	11.2
558.0	4.6	8.7	11.2
559.0	6.9	8.7	11.1
560.0*	6.1	8.7	11.8
562.0	6.9	8.8	11.3
565.4	7.4	8.8	11.2
551.0	7.2	9.9	14.4
564.0*	6.6	8.8	12.2
564.1*	6.6	8.6	11.1
557.0	6.7	8.9	11.6
554.8	6.7	8.9	11.2
556.0	5.4	9.0	11.6

* Whitewater River cove monitoring station

Bad Creek operational impacts to DO are limited to monitoring Station 564.1 between the I/O structure and submerged weir. Monthly average DO concentrations within the water column at this location are nearly uniform after 1991 (post Bad Creek operation). Vertical mixing from Bad Creek operations does not allow for stratification at this monitoring location regardless of season. DO stratification does occur at monitoring Station 564.0 (downstream of the weir), and there is very little difference in DO profiles between pre and post Bad Creek operation indicating the submerged weir is functioning as intended.

Temperature

Water temperature dictates the types of biota that can survive in a waterbody, affects metabolic rates and photosynthesis, influences the rates of chemical reactions, and impacts the physical capacity of water to hold DO. Historical surface water temperature minimum, average, and maximum values for all stations are included in Table 5-2. Discrete water quality data assessed in Lake Jocassee consistently met South Carolina water quality standards for trout waters for temperature. There is no numeric threshold for temperature, however, for trout waters, narrative criteria indicate water temperatures should not vary from levels existing under natural conditions (unless determined some other temperature shall protect the classified uses), which is supported by study findings.

Table 5-2. Water Temperature in Surface Waters of Lake Jocassee

Lake Jocassee Surface Temperature (degrees C)			
Station	Minimum	Average	Maximum
558.7	8.20	18.59	29.02
558.0	7.10	18.44	28.22
559.0	8.10	18.81	28.90
560.0*	7.10	18.87	28.47
562.0	8.10	19.23	29.20
565.4	8.50	18.84	28.50
551.0	0.20	13.48	27.24
564.0*	7.40	19.15	28.61
564.1*	8.50	18.99	28.40
557.0	7.10	18.81	29.23
554.8	7.70	19.24	29.15
556.0	7.30	19.04	29.12

* Whitewater River cove monitoring station

Similar to DO vertical profile trends, Bad Creek operational impacts to temperature are limited to monitoring Station 564.1 upstream of the weir. Vertical mixing from Bad Creek operations does not allow for stratification at this monitoring location regardless of season. DO stratification does occur at monitoring Station 564.0 (downstream of the weir), and there is very little difference in temperature profiles between pre and post Bad Creek operation indicating the submerged weir is functioning as intended.

pH

Surface pH values for all stations are included in Table 5-3. Instantaneous pH surface readings were compared against the pH state standard for trout waters (6.0-8.0 Standard Units). Over the entire dataset, there were 4,253 samples assessed; two samples were above the state standard (i.e., less than 1 percent of the dataset) and 255 samples were below the state standard (i.e., 6 percent of the dataset). Therefore, surface water pH levels in Lake Jocassee fully support the designated use classification (i.e., within 10 percent criterion excursions).

Table 5-3. pH in Surface Waters of Lake Jocassee

Surface Phosphorous (Standard Units)			
Station	**Minimum**	**Average**	**Maximum**
558.7	5.50	6.67	7.60
558.0	5.20	6.56	8.00
559.0	5.30	6.67	7.71
560.0*	5.60	6.69	7.80
562.0	5.60	6.76	7.90
565.4	5.60	6.50	8.10
551.0	5.50	6.53	7.90
564.0*	5.60	6.78	7.90
564.1*	5.60	6.73	7.90
557.0	5.50	6.73	7.80
554.8	5.60	6.84	8.10
556.0	5.63	6.80	7.90

* Whitewater River cove monitoring station

Turbidity

Turbidity is a measure of the amount of suspended particles in water (determined by the amount of light scattered); because turbidity is simply the amount of light that can pass through water, turbidity values can increase due to any solid particles in the water, including organic material and microscopic organisms. While turbidity is not an inherent property of water like temperature and DO, it is recognized as an indicator of environmental health of a waterbody (USGS 2018). Turbidity levels in a waterbody are typically episodic in nature and are not spatially or temporally consistent. Under natural conditions, suspended sediment load contribution to a receiving waterbody increases during a rainstorm/runoff event where sediment is eroded from upland areas or stream banks and flows into surface waters. Another major contributor to upland soil/sediment erosion is construction activities; these activities are often short-lived but can result in large amounts of soil released from the land that is subsequently transported to adjacent waterbodies. Depending on the magnitude of the rain event, amount and grainsize of sediment, proximity to the point of entry, and character of a waterbody, sediment can settle out quickly after the event or may remain suspended in the water column for some time after the event.

During original Project construction, turbidity levels in the Whitewater River cove of Lake Jocassee were impacted by construction activities. During recent relicensing study efforts, a desktop study was carried out to evaluate historical turbidity data in the Whitewater River cove at the three monitoring stations closest downstream of the Project and determine if original construction activities resulted in a noticeable increase in turbidity values and if so, estimate how far downstream impacts extended and for how long turbidity was elevated. This was done by comparing turbidity values from pre-construction (<1985), construction (1985-1991)[13], and post-construction (1992-2015). Note that, unlike temperature and DO, turbidity does not show spatial trends or stratification patterns; turbidity measurements represent a snapshot in time and are typically driven by external factors.

Surface turbidity values were assessed over the entire dataset (1976-2015) for stations 560.0, 564.0, and 564.1 (Table 5-4). A boxplot of surface turbidity data over all time periods is also provided in Figure 5-2 to show the distribution of surface turbidity at these stations. Over the entire dataset, there were 550 surface samples assessed; 9 samples were above the state standard (i.e., 10 NTU), which accounts for 0.02 percent of the dataset (this also includes data collected during construction). Surface water turbidity levels in Lake Jocassee fully supported the designated use classification (i.e., less than 10 percent criterion excursions).

Table 5-4. Turbidity in Surface Waters of Whitewater River Cove

Turbidity (NTU)			
Station	Minimum	Average	Maximum
560.0	0.00	1.90	17.00
564.0	0.00	1.96	47.00
564.1	0.00	1.61	19.00

[13] Duke Energy is proposing to expand the existing submerged weir with newly excavated rockfill from the proposed Bad Creek II Complex in part to help mitigate the impacts of a second I/O structure in Whitewater River cove. Assessing pre-construction turbidity data and estimating impacts to turbidity during original construction may help inform water quality conditions during proposed construction of the Bad Creek II Complex.

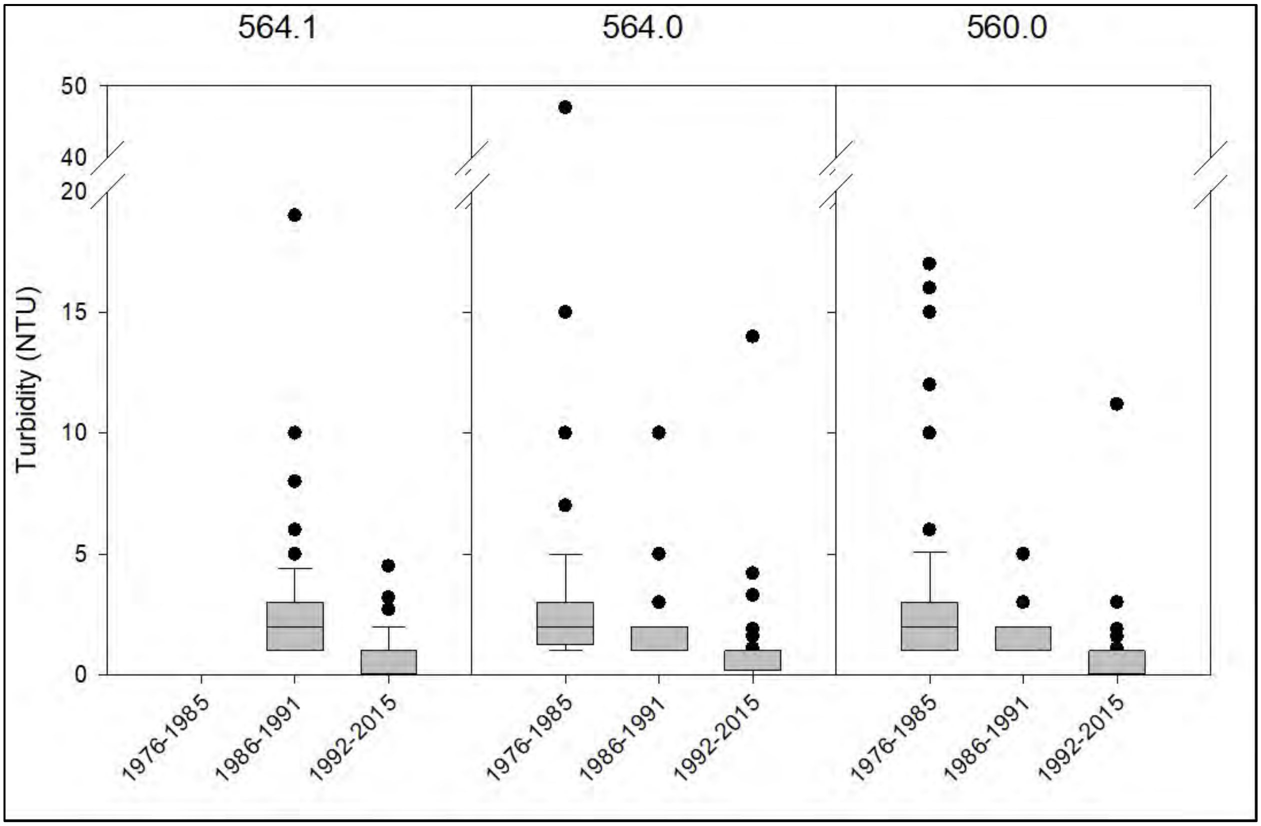


Figure 5-2. Surface Turbidity in the Whitewater River Arm during Pre-Construction, Construction, and Post-Construction Periods

5.1.2.2 Lake Jocassee Reservoir Level Fluctuation Effects on Water Quality

Additional pumping and generating capacity 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. Modeling carried out through relicensing efforts[14] showed that scenarios under Bad Creek II resulted in a decreased reservoir fluctuation band indicating more consistent water levels than under current conditions. These changes in water level fluctuation are not expected to affect water quality in Lake Jocassee.

[14] Details from the modeling effort are included in the *Water Exchange Rates and Lake Jocassee Reservoir Levels Final Report* and the *Effects of Bad Creek II complex and Expanded Weir on Aquatic Habitat Final Report* developed in coordination with relicensing stakeholders and submitted with the Updated Study Report.

5.1.3 Proposed Methods

5.1.3.1 Proposed Water Quality Parameters and Temporary Turbidity Variance

Water quality monitoring in the Whitewater River cove of Lake Jocassee will follow established Duke Energy procedures and standard methodology. Duke Energy proposes to monitor the following water quality parameters during the construction and post-construction phases:

- Turbidity
- DO
- Temperature
- pH

Data will be compared to State water quality criteria (Table 3-1). During the construction phase, all four parameters will be measured, but only turbidity data will be used to inform construction activities, since increased suspended loading is the proposed impact. The turbidity water quality standard for trout waters (e.g., TPGT) under S.C. Reg.61-69 is *not to exceed 10 NTU or 10 percent above natural conditions*, provided existing uses are maintained. However, Duke Energy seeks a temporary variance from SCDES at the proposed point of compliance (see Section 5.1.3.4 for proposed monitoring location) during construction of Bad Creek II to meet the turbidity compliance standard for South Carolina freshwater lakes (i.e., 25 NTU). According to S.C. Reg.61-69, a temporary variance is “a short-term exemption from meeting certain otherwise applicable water quality standards” and may be granted by the SCDES provided the following apply:

a. The variance is granted to an individual discharger for a specific pollutant(s) or parameter(s) and does not otherwise modify water quality standards; and
b. The variance identifies and justifies the criterion that shall apply during the existence of the variance; and
c. The variance is established as close to the underlying criterion as is possible and, upon expiration of the variance, the underlying criterion shall become the effective water quality standard for the waterbody; and
d. The variance is reviewed every three (3) years, at a minimum, and extended only where the conditions for granting the variance still apply; and
e. The variance does not exempt the discharger from compliance with any applicable technology or other water quality-based permit effluent limitations; and
f. The variance does not affect permit effluent limitations for other dischargers.

Duke Energy understands that prior to removing any uses or granting a variance, notice and an opportunity for a public hearing shall be provided by SCDES.

As mentioned above, a turbidity threshold of 25 NTU is considered protective of water and aquatic resources in freshwater lakes in South Carolina; however, since Lake Jocassee is considered TPGT waters, the state criteria is 10 NTU. In general, elevated suspended sediment can have behavioral, physical, and habitat effects on fish in a waterbody. Fish response to suspended sediment is dependent on many environmental factors such as (Bash and Berman 2001; Servizi and Martens 1992):

- duration and frequency of exposure
- water temperature
- fish life stage
- particle characteristic (e.g., angularity, size, toxicity, type)
- magnitude of turbidity pulse
- timing of turbidity pulse (e.g., season)
- natural background turbidity and
- availability of refugia.

Research has found that duration of suspended sediment exposure plays a more dominant role than suspended sediment concentration (Anderson et al. 1996). Non-salmonid species (e.g. bluegill) are considered tolerant of turbidity levels of up to approximately 50 NTU (Gardner 1981). Lloyd (1987) indicated that for salmonids, which are more sensitive to water quality conditions, a "moderate" level of protection (suspended solids concentration up to 100 mg/l) roughly translates to turbidity values up to 23 NTU. Avoidance is the primary fish behavioral response to locally turbid water; species more sensitive to sediment loads may be forced to move to other areas of the system to avoid negative effects on survival driven by direct effects of water quality conditions, or indirect effects such as decreased visual detection of predators and prey. Fish may seek out "turbidity refugia" when subjected to short-term pulses of sediment, and salmonids will move laterally (Servizi and Martens 1992) or downstream to avoid turbid areas (McLeay et al. 1987). In laboratory experiments, it has also been shown that salmonids will move to less turbid waters, if available, after a short-term pulse (of sediment) (Berg and Northcote 1985). Bisson and Bilby (1982) illustrated the displacement of some salmonids in water with turbidities greater than 70 NTU, while Sigler et al. (1984) and Lloyd (1987) noted avoidance of turbid water may begin as turbidity approaches 30 NTU. Regardless of the type or magnitude of the impact, it is important that areas of refugia are available and accessible for more sensitive populations. While the Whitewater River cove could potentially be affected by pulses of increased suspended sediment during certain construction activities (e.g., cofferdam removal, weir construction); this area accounts for just 1.5 percent of the total area of Lake Jocassee, therefore a large turbidity refugia (98.5 percent of the lake) would be available to sensitive species.

During original construction activities, historical data indicate consistently low turbidity levels in surface waters downstream of the Project during construction, however, historic turbidity measurements were collected prior to project operations. Duke Energy anticipates higher turbidity levels with the construction of Bad Creek II (compared to original construction) because the existing Project will be operating, thereby moving water upstream and downstream through the Whitewater River cove during pumping and generation cycles, respectively. It is not presently known what sort of impact construction or operations will have on turbidity levels at the water surface. Therefore, because (1) sensitive populations will be able to avoid areas of higher turbidity and move into other areas of Lake Jocassee (i.e., abundant availability and accessibility to turbidity refugia exists) and (2) potentially increased turbidity levels will be temporary (i.e., fish that do move out of the Whitewater River cove to avoid higher turbidities are expected to return following the impact), a more conservative turbidity threshold of 25 NTU for compliance reporting, which would still be protective of natural resources, would allow Duke Energy to construct the new facility while maintaining compliance with state regulations, which is a critical focus of Duke Energy for any project.

5.1.3.2 Data Collection and Evaluation

SCDES guidance states that grab samples or samples collected at a depth of 0.3 meters are considered for the purpose of water quality assessment, and only surface samples should be used in standards comparisons and trend assessments (SCDHEC n.d.). The SCDES and U.S. Environmental Protection Agency (USEPA) do not define the sampling method or frequency of sampling for water quality to compare to criteria, other than indicating it should be "representative" (SCDHEC n.d.).

To ensure compliance with SCDES water quality requirements for turbidity, Duke Energy will measure surface water conditions approximately 0.3 meters below the surface. A new monitoring station (see Section 5.1.3.4) will be instrumented with a multi-parameter water quality sonde and high-visibility buoy at the downstream end of Whitewater River cove near the proposed boat barrier. The data sonde will record water quality parameters daily (i.e., turbidity, DO, temperature, and pH) and store readings on an internal memory drive; data collection may require minor modification depending on field conditions. Data will be transmitted and received electronically (by Duke Energy personnel) via telemetry or by manual download in the field if telemetry is not available.

Data will be reviewed routinely (weekly) during construction and bi-weekly to monthly post-construction. If telemetry options are not available for data transmission, data will be manually downloaded in the field weekly during active construction period and bi-weekly to monthly during the post-construction monitoring period. Duke Energy-owned equipment will be used to collect the water quality data, and either Duke Energy or a consultant to Duke Energy will be responsible for retrieving and analyzing the data.

5.1.3.3 Excursions

The purpose of the State Water Quality Classification and Standards (SCDHEC 2023a) is to maintain the quality of surface waters to provide for the survival and propagation of a balanced indigenous aquatic community of fauna and flora and the degree to which aquatic life is protected (Aquatic Life Use Support) is assessed by comparing important water quality parameters with numeric criteria (SCDHEC n.d.). Support of aquatic life uses is determined based on the percentage of numeric criteria excursions. The term excursion is used to describe a measured pollutant concentration that is outside of the acceptable range as defined by the appropriate criterion (see Table 3-1). Per SCDHES standards for turbidity in surface waters (SCDHEC n.d.), if criteria are exceeded in more than 25 percent of the samples over 30 days, the criterion is not supported and it constitutes a violation of water quality. If the criterion is exceeded in more than 10 but less than 25 percent of the samples, sites are evaluated on a case-by-case basis to determine if local conditions indicate that classified uses are impaired. If the criterion is exceeded in less than 10 percent of the samples, then the criterion is fully supported. Some waters may exhibit characteristics outside the appropriate criteria due to natural conditions. Such natural conditions do not constitute a violation of the water quality criteria. Duke Energy proposes to adapt this sampling strategy for the Bad Creek II WQMP for monitoring in Lake Jocassee, as described below.

As indicated in Section 5.1.3.1, turbidity will be used to inform construction activities. The criteria for identifying an excursion and actions to be taken if turbidity readings exceed the compliance threshold are as follows:

- An excursion is defined as any surface reading above the State water quality standard for turbidity (compliance threshold) (e.g., 25 NTU).
- If daily readings exceed the turbidity compliance threshold more than 10 percent (but less than 25 percent) of readings over a rolling 30-day period, Duke Energy will investigate to determine if excursions are the direct result of construction activities (e.g., lower I/O and cofferdam construction, weir expansion) or rain events.[15]
- If elevated turbidity is determined to be the result of a rainfall event (i.e., overland flow and runoff), data characterizing the rain event (timing and amount of precipitation) will be documented using the nearest weather station along with corresponding turbidity data.
- If turbidity excursions are not clearly linked to a rainfall event (i.e., attributable to construction-related activities), Duke Energy will consult with SCDES if daily readings exceed the turbidity compliance threshold of more than 10 percent but less than 25 percent of readings over a rolling 30-day period. Similarly, Duke Energy will consult with SCDES if daily readings exceed 25 percent of readings over a 30-day period.

5.1.3.4 Proposed Monitoring Location

Duke Energy proposes to install a new water quality monitoring station located near the confluence of Whitewater River arm with the main portion of the lake (Station 563.0; see Figure 5-3). A proposed positive boat barrier will be deployed across the width of the Whitewater River cove at the confluence during the construction phase to prevent recreational boating in Whitewater River cove, therefore, the proposed point of compliance for water quality monitoring

[15] Historical data shows turbidity in Whitewater River Cove naturally increases during large storm events due to run off from tributaries and overland flow. For example, on August 16, 1994, rainfall associated with Tropical Storm Beryl resulted in consistently high turbidity readings for several days.

will be near the boat barrier to safely facilitate boat access to the water quality station for maintenance and data downloading. A photo-rendering of the temporary boat barrier extending across Whitewater River cove is shown on Figure 5-4.

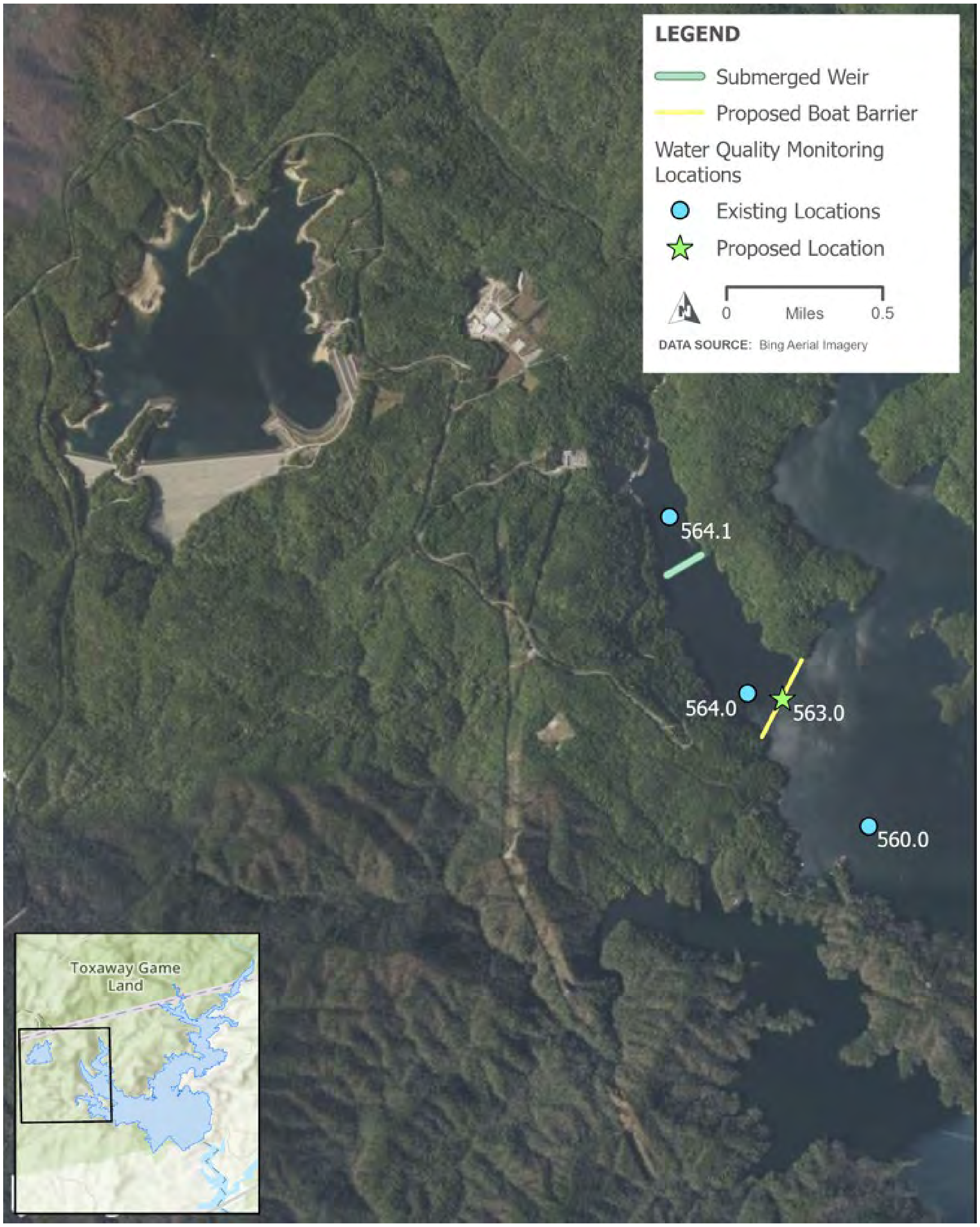


Figure 5-3. Proposed Compliance Point (Station 563.0) and Proposed Temporary Boat Barrier

The proposed location is near Station 564.0, which has many years of turbidity data associated with it from before, during, and after original Project construction, and is also near locations assessed during the 2023 and 2024 water quality relicensing study.

The proposed monitoring station is approximately 4,225 ft (0.8 mile) downstream from the proposed I/O structure and 2,370 ft (0.45 mile) downstream of the upstream end of the submerged weir. Duke Energy believes this location would be close enough to adequately monitor potential water quality impacts associated with Bad Creek II major construction activities (i.e., cofferdam construction, I/O structure and bank disturbance, submerged weir expansion) in Lake Jocassee.

Figure 5-4. Rendering of Proposed Boat Barrier downstream of the Lower Reservoir I/O for Water Quality Compliance Monitoring

5.1.3.5 Proposed Sampling Frequency

While the Revised Study Plan suggested a general pre-construction monitoring task, it was determined during Plan development that for water quality monitoring in the Whitewater River cove, SCDES surface water quality standards are more relevant for evaluating water quality criteria thresholds than comparing against existing water quality data, therefore, pre-construction monitoring was deemed unnecessary in Lake Jocassee (i.e., the objective is to remain in compliance with state water quality standards, not to ensure recovery to an existing condition). SCDES water quality criteria are designed to be protective of aquatic habitat, therefore compliance with water quality standards is anticipated to be protective of aquatic life in the lake. Construction and post-construction monitoring will also benefit the extensive historical water quality data collection in Lake Jocassee.

Pre-construction

Pre-construction monitoring will not be performed as documentation of recovery to an existing condition and is not an objective of this WQMP.[16]

Construction

Water quality parameters will be recorded daily for the duration of Bad Creek II construction phase via a multi-parameter sonde deployed at the proposed point of compliance (see Section 5.1.3.4). Data will be reviewed weekly.

Post-construction

Water quality parameters will be recorded daily for one year (365 days) following commencement of Bad Creek II commercial operation via a multi-parameter sonde deployed at the proposed point of compliance (see Section 5.1.3.4). Data will be reviewed bi-weekly to monthly.

[16] As described above, Duke Energy has historical and current water quality data for the Whitewater River cove; a summary of existing data is included in the ISR (Duke Energy 2024).

5.1.4 Proposed Reporting Criteria

Water quality data will be reported per requirements of the SCDES 401 Water Quality Permit and appropriate agencies would be consulted. An annual report will be developed by April 15 each year for filing with SCDES with a courtesy copy to FERC.

5.1.5 Summary

Temporary, short-term effects (associated with elevated turbidity) are possible in the Whitewater River cove associated with construction activities on land, overland runoff, and the expansion of the submerged weir. BMPs will be implemented (on land) to reduce sedimentation into waters of the U.S. (WOTUS).

No long-term effects on the population, abundance, or distribution of forage fish in Lake Jocassee are anticipated as a result of the proposed Bad Creek II Complex construction or operations. Similarly, no long-term effects on the littoral fish populations or changes in suitable habitat are anticipated as a result of the proposed Bad Creek II Complex operations (see Section 5.1.2.2). As indicated in Section 4.1, certain water quality activities will continue in Lake Jocassee throughout the KT license term including the agreement to maintain pelagic trout habitat in Lake Jocassee and continuance of water quality monitoring in the tailrace.

Duke Energy's proposed monitoring strategy addresses potential challenges in meeting SCDES water quality standards during construction by reviewing turbidity data routinely (weekly) during construction immediately downstream of the Project so that any turbidity-related issues can be identified quickly and mitigative management controls applied if necessary. Because there is abundant availability and accessibility to turbidity refugia and potentially increased turbidity levels will be temporary, Duke Energy is seeking a temporary water quality turbidity variance of 25 NTU at the Whitewater River cove compliance point downstream of Bad Creek II for the duration of construction activities.

5.2 Upland Areas Surface Waters

5.2.1 Potential Impacts and Monitoring Rationale

<u>Potential Impacts</u>

- Construction of the Bad Creek II Complex would impact existing upland surface waters. Overburden (i.e., soil and rock) material from the construction activities are proposed to be deposited in several spoil locations throughout the site; locations are currently under evaluation. Construction activities could potentially lead to temporary impacts to water quality due to increased turbidity from sediment loading. Due to the estimated amount of spoil material, 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 and downstream waters.
- Estimates for proposed material removed from underground excavations indicate approximately 4.4 million cubic yards of spoil material for the Project infrastructure will need to be deposited into on-site spoil locations or along the submerged weir in Lake Jocassee. 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 to be placed at upland disposal sites, thereby reducing potential impacts to upland waters.
- Traffic on access roads during construction has the potential to increase sediment runoff which can be mitigated through BMPs (e.g., vegetation, silt fence, or matting) installed near haul roads and access roads. BMP inspections and the ESC Plan will be developed and implemented through the NPDES construction permitting process.

<u>Monitoring Rationale</u>

- Increased sediment loading during rainfall runoff events could impact existing streams and waterbodies during construction activities. While no long-term degradation of water quality is expected to result from construction of the Bad Creek II Complex, activities could potentially lead to temporary impacts to water quality due to increased turbidity, therefore Duke Energy proposes to install and maintain BMPs in accordance with

SCDES permit requirements to mitigate risks to streams impacted by spoil placement associated with Bad Creek II construction activities.

- Upland placement of spoil materials will result in potential impacts to surface waters. Therefore, an individual permit from the USACE will be required as well as a water quality certification from SCDES under the authorities of Sections 404 and 401 of the CWA[17]. Note that the upland disposal areas (e.g., spoil areas) will also be located within the overall Project Limits of Disturbance (LOD) and the construction phase activities and temporary land disturbance impacts will be covered under the SCDES NPDES Construction General permit (e.g. erosion and sediment control permit). The LOD will be planned with perimeter and internal BMPs such that the overland stormwater flow / water quantity will be managed. Water quality monitoring is not required or proposed as part of the SCDES Construction General NPDES permit.
- During construction, temporary BMPs (e.g., sediment basins, silt fences, waddles, etc.) proposed under the SCDES Construction General Permit will be installed, regularly inspected, and maintained to control runoff from affected areas into surface waters.
- While no long-term degradation of water quality is expected to result from construction of the Bad Creek II Complex, these activities could result in temporary impacts, therefore, Duke Energy proposes to conduct stream habitat quality assessment surveys in perennial streams associated with drainage from spoil areas. These would consist of (year-round) accessible downstream reaches where the cumulative effect of construction activities can be observed. These locations would be used to document stream conditions and function where water has flowed from the construction area, through a BMP, and into WOTUS. Pre-construction monitoring in these areas will be compared with similar post-construction monitoring to document construction-related impacts and also determine when these areas have recovered to pre-construction conditions and to help plan for site restoration / stabilization.

[17] This process has been initiated in parallel with the relicensing process.

5.2.2 Existing Data and Background Information

During 2021, 2022, and 2023 efforts for the relicensing and advancement of the proposed project, on-site streams were assessed in coordination with the SCDNR and other relicensing stakeholders. In addition, WOTUS surveys were carried out in summer 2024 in support of identifying waters of the U.S. and USACE permitting.

5.2.2.1 Stream Habitat Quality and Macroinvertebrate Surveys

As stated above, the disposal of overburden material in upland locations would result in impacts to surface waters and will require authorization under an individual permit from the USACE and water quality certification from SCDES under the authorities of Sections 404 and 401 of the CWA. In preparation for these expected regulatory processes, stream habitat quality surveys were completed to provide a physical assessment of the existing conditions of streams that have the potential to be impacted.

In accordance with the FERC-approved Aquatic Resources Revised Study Plan, the stream habitat assessment portion of the USEPA Rapid Bioassessment Protocol was completed for streams within potential spoil locations. Streams and creeks crossed by the proposed temporary access road (Fisher Knob access road) were also assessed. The North Carolina Stream Assessment Method (NCSAM) [18] was completed for streams within potential spoil locations and streams or creeks crossed by the temporary access road. The SC Stream Quantification Tool (SQT) was developed in a collaborative effort between federal and state representatives to provide a tool for assessing and quantifying functional lift and loss of streams in South Carolina. In May 2023, the SCDNR requested that Duke Energy apply the SQT methods to streams within potential spoil locations and streams crossed by the temporary access road. Duke Energy consulted with the SCDNR in May and June 2023 regarding the applicability and methodology of the SQT for stream assessments. In July 2023, Duke Energy and the SCDNR conducted a site visit to two potential spoil locations representative of conditions across the site. It was agreed

[18] While the Project is located in South Carolina, the site is close to the border of North Carolina and many of the streams in the Project vicinity have headwaters in North Carolina. Implementation of the NCSAM is appropriate for assessing Project waters as this method is based on valley shape, watershed size, and physiographic region; these characteristics are consistent between streams in the mountainous area surround the Project, regardless of the state.

among the SCDNR staff and Duke Energy personnel that streams within potential spoil locations are generally high functioning with limited (if any) anthropogenically caused degradation, and that field data collection to support SQT analysis for other similar streams in these areas were not likely to produce significantly different results (i.e., lower functionality scores) than an assumption of fully functional. Therefore, Duke Energy proposed to conduct field surveys on streams potentially crossed by the temporary access road, only. Documentation of all consultation for the Aquatic Resources study is included in Attachment 4 of Appendix B of the Initial Study Report.

In addition, macroinvertebrate surveys of Limber Pole Creek and Howard Creek found abundant Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (also referred to as EPT) taxa and habitat conditions, also resulted in a high bioclassification score indicating a fully supporting system.[19]

Detailed results from the stream assessments are included in the *Impacts to Surface Waters and Associated Aquatic Fauna* final report, which was developed in collaboration with relicensing stakeholders and State resource and regulatory agencies and submitted with the Initial Study Report as Appendix A, Attachment 1 (Duke Energy 2024).

5.2.2.2 WOTUS Surveys

In 2024, HDR as a consultant to Duke Energy, delineated potential WOTUS according to the USEPA and USACE operative definition of Pre-2015 Regulatory Regime consistent with Sackett vs. Environmental Protection Agency to provide an opinion on the jurisdictional status of the identified features (effective on August 29, 2023). Field efforts were planned and informed based on previous field reconnaissance and natural resource assessments, as well as review of existing publicly available information, including data from U.S. Geological Survey (USGS) 1:24,000 topographic quadrangles, the USGS National Hydrography Dataset, and USFWS National Wetland Inventory, as well as Natural Resources Conservation Service soil maps. HDR conducted on-site delineations of jurisdictional WOTUS, including wetlands and waterbodies.

[19] During electrofishing fish sampling activities, water quality parameters included temperature, DO, specific conductivity, pH, salinity, and turbidity and were collected in July, September, and October on Limber Pole Creek and Howard Creek.

Natural resources assessments to identify surface waters and wetlands within potential spoil locations were completed in September 2021 and September 2023 along the proposed temporary access road (Fisher Knob temporary access road). The 2023 results indicated the proposed access road would potentially cross Howard Creek and Limber Pole Creek and several of their tributaries.

The combined 2021 and 2024 waters delineations revealed the potential of over 120 streams, 43 wetlands, and several open waters located within the proposed expanded FERC Project Boundary. In the fall of 2024, Duke Energy plans to prepare and submit a Jurisdictional Determination request for the entire expanded FERC Boundary (approximately 1,733 acres) to the USACE Charleston Regulatory Office to determine the presence or absence of WOTUS and their accurate locations and boundaries.

5.2.3 Proposed Methods

5.2.3.1 Data Collection and Processing Methods

BMP Monitoring and Inspections

During construction, temporary BMPs (e.g., sediment basins, silt fences, waddles, etc.) proposed under the SCDES Construction General Permit will be installed and maintained to control runoff from affected areas into surface waters. These BMPs will be sized according to elevated standards (i.e., sediment basins and rock dams shall be designed to treat the peak runoff from at least the 25-year[20] storm and may have larger dimensions than typical devices for standard areas), including an added layer of 18-inch compost socks on the low side of sites draining to wetlands or streams. BMPs will be located within site drainage areas and intermediate BMPs placed within areas of expected flow and retention to attenuate water quantity. An additional 50-foot undisturbed buffer beyond the regulatory-required buffers for wetland and stream will be implemented. Land disturbance will be restricted within the proposed LODs to include the proposed construction features, construction access, and materials staging / laydown, as well as the locations of BMPs to manage construction runoff from these areas. Based on required

[20] Per Duke Energy's Construction Stormwater Planning Manual for Operations in Environmentally Sensitive Areas (Duke Energy 2019). Environmentally Sensitive Areas are surface waters and their surrounding riparian areas that require special protection during construction due to the sensitive nature of the resource.

compliance monitoring under the SCDES Construction General Permit, weekly and post-storm (e.g., rainfall greater than 1 inch within a 24-hour period) inspections of the LOD will be conducted. These inspections are based on functionality of the BMPs and maintenance actions are commonly identified for future tracking and/or verification of completion. A copy of the SCDES Construction General Permit and the Onsite-Stormwater Pollution Protection Plan (OS-SWPPP) will be kept onsite in accordance with permit requirements.

If additional BMPs or adjustment of BMPs are required based on onsite observations and inspections, the OS-SWPPP will be red-lined for tracking.[21] Determining the location of BMPs and proposed LODs is not an objective of this WQMP.

Stream Habitat Quality Surveys

Several stream assessment methods will be implemented to carry out stream habitat quality surveys to provide information on conditions of streams that have the potential to be impacted by construction activities and spoils placement. These methods are in alignment with methods carried out for previous studies performed for the relicensing (as described above) and include the following:

- USEPA Rapid Bioassessment Protocol (Barbour et al. 1999)
- NCSAM (N.C. Stream Functional Assessment Team 2013)
- SQT (South Carolina Steering Committee 2022)
- Macroinvertebrate sampling (SCDHEC 2017)

[21] SCDES's Construction Permit, also referred to as the Erosion and Sediment Control / Construction Stormwater Permit, requires submittal of a Notice of Intent for permit coverage for clearing, grading, or excavating activities disturbing >1 acre. Permit application must include a Comprehensive Stormwater Pollution Prevention Plan (C-SWPPP) and an Onsite (OS)-SWPPP during the construction phase. Emissions and dust control measures must also conform to regulatory requirements (Fugitive Dust Control [61-62.6]) and can be incorporated into the Erosion and Sediment Control permit. (See SC Code Sections 48-14-10 et seq., SC Regulation 72-300 – 72-316 for additional information.)

5.2.3.2 Proposed Monitoring Location(s)

Upland Spoil Areas

- For perennial streams associated with drainage from spoil areas, the point of compliance will be in an accessible downstream reach where the cumulative effect of the construction can be observed. This location will be used to document stream conditions and function where water has flowed from the construction area, through a BMP, and into a WOTUS. Proposed monitoring locations are shown on Figure 5-5. (Note that some areas preclude monitoring stations due to steep terrain, e.g., downstream of Spoil Area C).

Access Roads

- For streams associated with the potential Fisher Knob Access Road (Howard Creek and Limber Pole Creek), the area immediately upstream and downstream of the proposed crossings will be monitored (four locations in total). See Figure 5-6.
- Streams associated with the transmission line corridor access roads will not be monitored as part of this Plan; transmission line areas will have standard Duke Energy BMP measures installed.

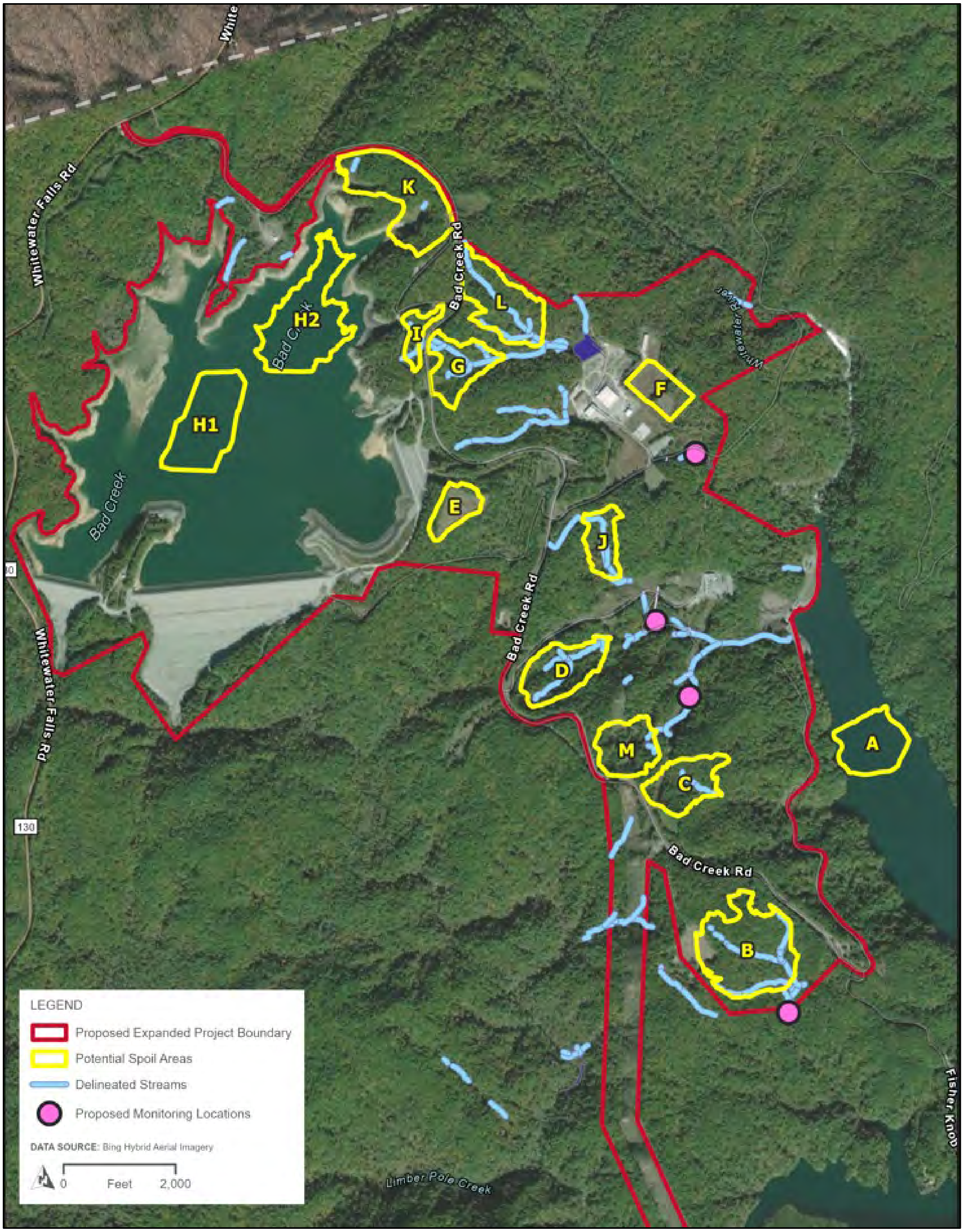


Figure 5-5. Proposed Stream Habitat Quality Monitoring Locations (Spoil Areas)

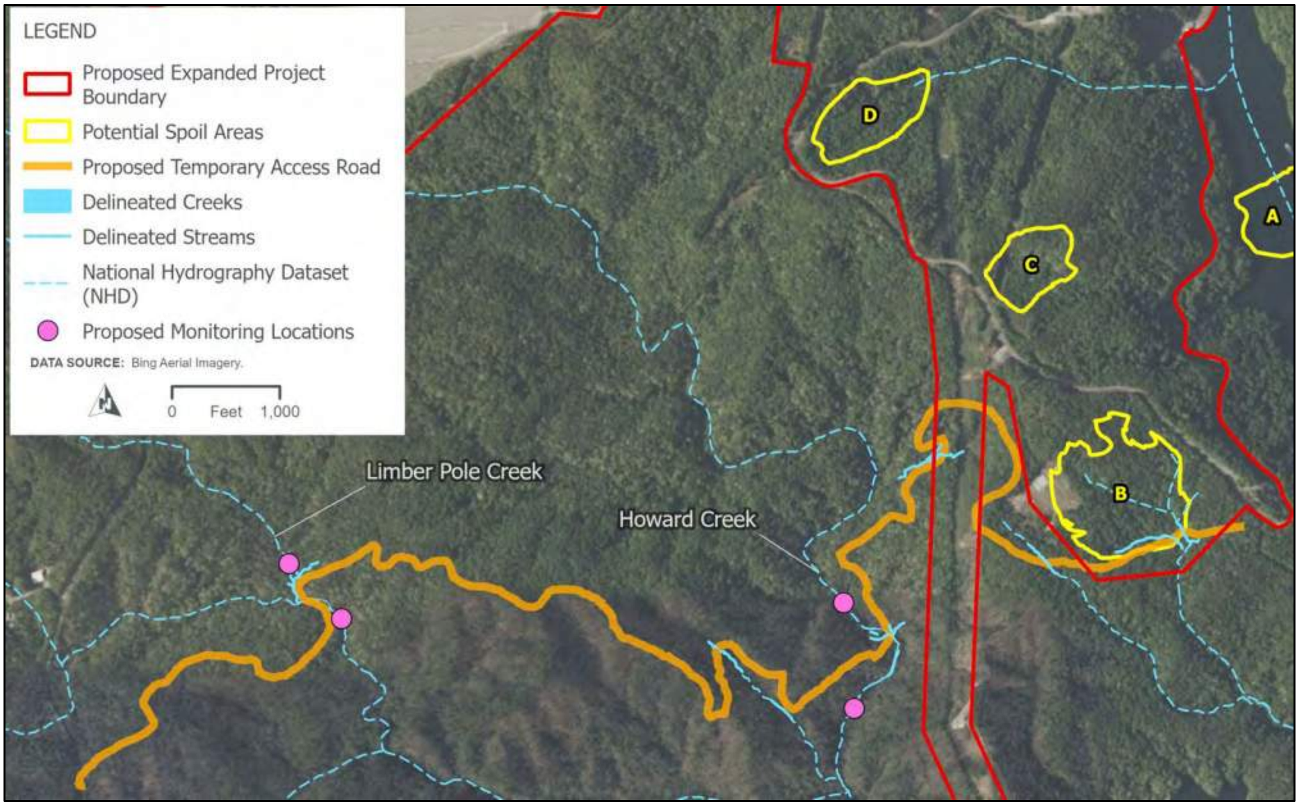


Figure 5-6. Proposed Stream Habitat Quality Monitoring Locations (Fisher Knob Temporary Access Road)

5.2.3.3 Sampling Frequency

Pre-construction

Pre-construction stream habitat quality surveys of upland surface waters that will be impacted by spoils placement and site construction activities will be conducted to document existing conditions and function. Pre-construction surveys will be carried out prior to installation of BMPs.

Construction

Construction phase stream assessment surveys will not be carried out in areas that are protected by BMPs required by SCDES environmental permits. Duke Energy will regularly inspect and maintain BMPs to help minimize downstream potential impacts to surface waters. Based on required compliance monitoring under the SCDES Construction General Permit, weekly and post-storm (e.g., rainfall greater than 1 inch within a 24-hour period) inspections of the LOD will be conducted.

Post-construction

Post-construction stream quality habitat surveys of upland surface waters impacted by spoils placement and site construction activities will be performed to document post-construction conditions and function. Duke Energy proposes surveys at 1-year, 3-years, and 5-years following commencement of Bad Creek II operations. If necessary, an additional survey will be carried out at 7 years post-construction to ensure streams provide fully functioning and supportive habitat and replicate original (existing) stream conditions.

5.2.4 Proposed Reporting Criteria

Inspections and maintenance of BMPs during construction will be carried out per NPDES construction permit requirements. Weekly and post-storm inspections inform whether maintenance and/or replacement of BMPs, such as silt fence, rock outlets, compost filter socks, or areas of stone, need to be conducted. Based on the condition of the BMP and level of work required to keep functionality, the inspector will work with Duke Energy's environmental oversight team to identify the timing of the work. In an instance of a BMP failure, typically, the BMP is repaired or replaced, and timing is based on proximity to environmental sensitive areas as well as availability of materials.

For post-construction stream habitat quality surveys, areas that have not recovered to pre-construction conditions and function within one year of commercial operation will be evaluated for additional monitoring in consultation with SCDES. Appropriate agencies would also be notified and consulted to determine the next steps. An annual report will be developed by April 15 each year for filing with SCDES with a courtesy copy to FERC.

5.2.5 Summary

A comprehensive ESC Plan and C-SWPPP will be developed and implemented for all construction phases of the Bad Creek II Complex. BMPs will be sized and sited to manage overland stormwater flow within the LOD as part of the ESC Plan. Additionally, under the NPDES permitting process, a prevention, control, and safety management plan to prevent vehicle spilled fluids from entering the watersheds and harming water quality will be developed and implemented.

6 Stakeholder and Agency Coordination

This draft Plan was developed in consultation with the South Carolina state permitting and regulatory agency (SCDES) and is being submitted to the Bad Creek Relicensing Water and Aquatic Resources Committees for review and comment prior to filing the Draft License Application. Stakeholder feedback will be incorporated with the version filed with the Final License Application.

7 References

Anderson, P.G., B.R. Taylor, and G.C. Balch. 1996. Quantifying the Effects of Sediment Release on Fish and their Habitats. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2346, Department of Fisheries and Oceans, Vancouver, B.C. and Winnipeg, Manitoba, 1996.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behaviour in juvenile coho salmon (*Oncohynchus kisutch*) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

Bisson, P.A. and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. North American Journal of Fisheries Management 4: 371-374.

Bolton, S., Bash, J. and Berman, C. 2001. Effects of Turbidity and Suspended Solids on Salmonids. Washington State Transportation Commission and U.S. Department of Transportation. November 2001.

Duke Energy Carolinas, LLC (Duke Energy). 2019. Construction Stormwater Planning Manual for Duke Energy North and South Carolina Operations in Environmentally Sensitive Areas. Prepared by AECOM. May 2017, Updated March 2019.

______. 2022. Pre-Application Document. Bad Creek Pumped Storage Station. FERC No. 2740. February 23, 2022.

______. 2024. Initial Study Report. Bad Creek Pumped Storage Project, FERC No. 2740. FERC eLibrary Accession Number 20240104-5044. URL: https://elibrary.ferc.gov/eLibrary/filelist?accession_num=20240104-5044.

Gardner, M.B. 1981. Effects of turbidity on feeding rates and selectivity of bluegills. Transactions of the American Fisheries Society 110: 446-450.

Lloyd, D.S. 1987. Turbidity as a water quality standard for salmonid habitats in Alaska. North American Journal of Fisheries Management 7: 34-45.

McLeay, D.J., I.K. Birtwell, G.F. Hartman, and G.L. Ennis. 1987. Responses of Arctic Grayling (*Thymallus arcticus*) to Acute and Prolonged Exposure to Yukon Placer Mining Sediment. Canadian Journal of Fisheries and Aquatic Sciences 44: 658-673.

North Carolina Stream Functional Assessment Team. 2013. N.C. Stream Assessment Method (NCSAM) Draft User Manual. March 2013. [URL]: https://www.saw.usace.army.mil/Portals/59/docs/regulatory/publicnotices/2013/NCSAM_Draft_User_Manual_130318.pdf. Accessed October 2023.

Servizi, J.A. and D.W. Martens. 1992. Sublethal responses of coho salmon (Oncorhynchus kisutch) to suspended sediments. Can. J. Fish. Aquat. Sci., Vol. 49: 1389-1395.

Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of Chronic Turbidity on Density and Growth of Steelheads and Coho Salmon. Transactions of the American Fisheries Society113: 142-150.

South Carolina Department of Health and Environmental Control (SCDHEC). 1995. Regulation 61-101. Water Quality Certification. Columbia, SC. [URL]: https://scdhec.gov/sites/default/files/Library/Regulations/R.61-101.pdf#page=3. Accessed July 2024.

______. 2017. Standard Operating and Quality Control Procedures for Macroinvertebrate Sampling. Technical Report No. 0914-17. Bureau of Water. Columbia, South Carolina.

______. 2023a. Regulation 61-68. Water Classifications and Standards. Columbia, SC. [URL] https://scdhec.gov/sites/default/files/Library/Regulations/R.61-68.pdf. Updated May, 2023. Accessed July 2024.

______. 2023b. Regulation 61-69. Classified Waters. Columbia, SC. [URL]: https://scdhec.gov/sites/default/files/Library/Regulations/R.61-69.pdf. Accessed July 2024.

______. n.d.. SCDHEC Surface Water Quality and Assessment Methodology. [URL] https://scdhec.gov/sites/default/files/media/document/Surface%20Water%20Quality.pdf. Accessed July 2024.

South Carolina Department of Natural Resources and Duke Energy (SCDNR and Duke Energy). 1996. Keowee-Toxaway Fishery Resources Ten Year Work Plan January 1996 – December 2005.

South Carolina Steering Committee. 2022. South Carolina Stream Quantification Tool: Data Collection and Analysis Manual, SC SQT v1.1. South Carolina Department of Natural Resources, Columbia, SC.

U.S. Geological Survey (USGS). 2018. Turbidity and Water. Water Science School; June 6, 2018. [URL] https://www.usgs.gov/special-topics/water-science-school/science/turbidity-and-water#:~:text=Turbidity%20is%20the%20measure%20of,light%2C%20the%20higher%20the%20turbidity. Accessed July 2024.

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.

U.S. Environmental Protection Agency (USEPA). 2020. National Rivers and Streams Assessment 2013-2014: A Collaborative Survey. December 2020. EPA 841-R-19-001. Washington, DC. Accessed January 2021. [URL]: https://www.epa.gov/national-aquatic-resource-surveys/nrsa.

Attachment 1

Water Quality Monitoring Plan Standard Operating Procedures Document

(To be developed pending further consultation)

This page intentionally left blank.

Attachment 6

Consultation Documentation

This page intentionally left blank.

From:	Crutchfield Jr., John U
To:	Alex Pellett; Alison Jakupca; Amy Breedlove; Andrew Grosse; Austen Attaway; bereskind; Wes Cooler; Dan Rankin; Andy Douglas; Greg Mixon; jhains@g.clemson.edu; Erika Hollis; Jeff Phillips; Jennifer Kindel; jtk7140@me.com; Keith A. Bradley; Kelly Kirven; Ken Forrester; Kulpa, Sarah; quattrol; Dunn, Lynne; Raber, Maverick James; McCarney-Castle, Kerry; Abney, Michael A; Elizabeth Miller; lputnammitchell@gmail.com; Amedee, Morgan D.; Morgan Kern; Mularski, Eric; Wahl, Nick; Olds, Melanie J; Pat Cloninger; More, Priyanka; Bill Ranson-Retired; SelfR; Rowdy Harris; Salazar, Maggie; Samantha Tessel; Fletcher, Scott T; Scott Harder; Settevendemio, Erin; Chris Starker; Stuart, Alan Witten; Tom Daniel; Dale Wilde; William T. Wood; suewilliams130@gmail.com; simmonsw@dnr.sc.gov; gcyantis2@yahoo.com; Kevin Nebiolo
Cc:	Lineberger, Jeff
Subject:	Bad Creek Relicensing Joint Resource Committees Meeting- CHEOPS Modeling Results (Water Resources Task No. 4)--SAVE THE DATE
Date:	Wednesday, February 21, 2024 5:40:02 PM
Importance:	High

Dear Bad Creek Relicensing Resource Committee Stakeholders:

Duke Energy would like to convene a joint meeting of the Water Resources, Aquatic Resources, Recreation & Visual Resources and Operations Resources Committees to review the CHEOPS modeling results including the previously established Performance Measures.

The meeting will be a virtual Teams meeting scheduled for Thursday, April 4, 9 am-12 pm.

A meeting notice will be sent to you in the next few days.

Please let Alan or me know if you have any questions.

Regards,

John Crutchfield

Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

McCarney-Castle, Kerry

Subject:	Bad Creek Relicensing Joint Resource Committees Meeting- CHEOPS Modeling Results (Water Resources Task No. 4)
Location:	Microsoft Teams Meeting
Start:	Thu 4/4/2024 9:00 AM
End:	Thu 4/4/2024 12:00 PM
Show Time As:	Tentative
Recurrence:	(none)
Meeting Status:	Not yet responded
Organizer:	Crutchfield Jr., John U
Importance:	High

-----Original Appointment-----
From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Wednesday, March 6, 2024 10:43 AM
To: Crutchfield Jr., John U; Huff, Jen
Subject: Bad Creek Relicensing Joint Resource Committees Meeting- CHEOPS Modeling Results (Water Resources Task No. 4)
When: Thursday, April 4, 2024 9:00 AM-12:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: Microsoft Teams Meeting
Importance: High

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Dear Bad Creek Relicensing Resource Committee Stakeholders:

Duke Energy would like to convene a joint meeting of the Water Resources, Aquatic Resources, Recreation & Visual Resources and Operations Resources Committees to review the CHEOPS modeling results including the previously established Performance Measures.

The meeting will be a virtual Teams meeting scheduled for Thursday, April 4, 9 am-12 pm. The Teams meeting link is given below.

An agenda will be sent to you prior to the meeting.

Thanks, John Crutchfield

Microsoft Teams meeting

Join on your computer, mobile app or room device
Click here to join the meeting

Meeting ID: 287 441 250 204
Passcode: sWCCrk
Download Teams | Join on the web

Join with a video conferencing device

duke-energy@m.webex.com
Video Conference ID: 112 202 243 4
Alternate VTC instructions

Or call in (audio only)

+1 704-659-4701,,740976269#   United States, Charlotte

Phone Conference ID: 740 976 269#
Find a local number | Reset PIN

Learn More | Help | Meeting options

____

From:	Crutchfield Jr., John U
To:	Alex Pellett; Alison Jakupca; Amy Breedlove; Andrew Grosse; Austen Attaway; bereskind; Wes Cooler; Dan Rankin; Andy Douglas; Greg Mixon; jhains@g.clemson.edu; Erika Hollis; Jeff Phillips; Jennifer Kindel; jtk7140@me.com; Keith A. Bradley; Kelly Kirven; Ken Forrester; quattrol; Dunn, Lynne; Raber, Maverick James; McCarney-Castle, Kerry; Abney, Michael A; Elizabeth Miller; lputnammitchell; Amedee, Morgan D.; Morgan Kern; Mularski, Eric; Wahl, Nick; Olds, Melanie J; Pat Cloninger; More, Priyanka; Bill Ranson-Retired; SelfR; Charles (Rowdy) B Harris; Salazar, Maggie; Samantha Tessel; Fletcher, Scott T; Scott Harder; Settevendemio, Erin; Chris Starker; Stuart, Alan Witten; Tom Daniel; Dale Wilde; William T. Wood; suewilliams130@gmail.com; simmonsw@dnr.sc.gov; gcyantis2; Kevin Nebiolo; Huff, Jen; Andrew Gleason; glenn@hilliardgrp.com; phil.mitchell@gmail.com
Cc:	Lineberger, Jeff; Kulpa, Sarah; Scangas, Angie; Ziegler, Ty
Subject:	Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda
Date:	Wednesday, March 27, 2024 7:23:03 AM
Attachments:	image001.png 2024 04 04 joint rc mtg agenda.docx

Dear Bad Creek Resource Committee members:

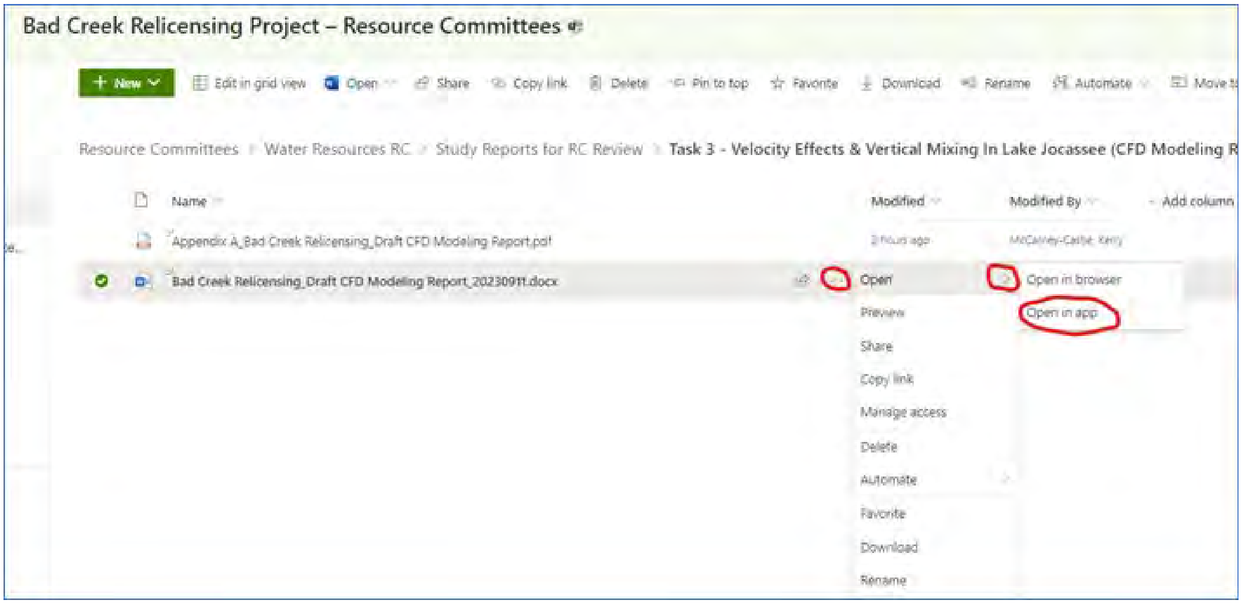
Duke Energy is pleased to distribute the draft Water Resources – Task 4 (i.e., CHEOPS Modeling) report for your review. This draft includes the results from CHEOPS modeling for the Baseline and Bad Creek II scenarios as well as populated Performance Measures sheets. The draft report is available on the SharePoint site using this link: Bad Creek Relicensing Project – Resource Committees - Draft CHEOPS report - All Documents (sharepoint.com).

Please provide your comments within the draft report using Track Changes as explained further below within 30 days (**April 26, 2024).** When you have completed your review – even if you have no comments – I would appreciate an email stating that is the case.

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy is providing relicensing deliverables on the SharePoint site for relicensing participants to access, review, and comment on files. Please provide all comments in the SharePoint Word document using tracked changes. This will eliminate version control issues, enable relicensing participants to gain insight into one another's comments, and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



We will be discussing the draft report and report findings during the April 4, 2024, Joint Resource Committee meeting. I have attached the meeting agenda for your reference.

If you have questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

Agenda

Project: Bad Creek Pumped Storage Project Relicensing

Subject: Water Resources, Operations, Aquatic Resources, and Recreation Resources Resource Committees Meeting

Date: Thursday, April 04, 2024

Location: Virtual

Introduction

- Welcome and Meeting Purpose
- Safety Moment

Water Resources, Task 4 - Water Exchange Rates and Lake Jocassee Reservoir Levels (CHEOPS Modeling)

- CHEOPS Model Refresher
- Scenario Descriptions
- Results
- Next Steps

Water Resources, Task 3 – Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse (CFD Modeling)

- Additional CFD Modeling Results

Closing

- Next steps
- Action item review

From:	Crutchfield Jr., John U
To:	Stuart, Alan Witten; Kulpa, Sarah; Huff, Jen; McCarney-Castle, Kerry
Cc:	Salazar, Maggie
Subject:	FW: [EXTERNAL] RE: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda
Date:	Thursday, April 4, 2024 10:28:13 AM
Attachments:	image001.png

FYI, original email sent to Maggie.

From: gcyantis2@yahoo.com <gcyantis2@yahoo.com>
Sent: Thursday, April 4, 2024 9:28 AM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Cc: 'Sue Williams' <suewilliams130@gmail.com>
Subject: [EXTERNAL] RE: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda

John,
I've reviewed the draft CHEOPS report and have no comments.
I've copied Sue in case she has comments to represent from AQD.
Thank you,
Gerry

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Wednesday, March 27, 2024 7:23 AM
To: PellettC@dnr.sc.gov; Alison.Jakupca@KleinschmidtGroup.com; BreedloveA@dnr.sc.gov; grossea@dnr.sc.gov; attawaya@dnr.sc.gov; bereskind@greenvillewater.com; wes.cooler@mac.com; RankinD@dnr.sc.gov; adoug41@att.net; mixong@dnr.sc.gov; jhains@g.clemson.edu; ehollis@upstateforever.org; jphillips@greenvillewater.com; kindelj@dnr.sc.gov; jtk7140@me.com; bradleyk@dnr.sc.gov; Kelly.Kirven@KleinschmidtGroup.com; forresterk@dnr.sc.gov; quattrol@dnr.sc.gov; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Kerry.McCarney-Castle@hdrinc.com; Abney, Michael A <Michael.Abney@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; lputnammitchell@gmail.com; amedeemd@dhec.sc.gov; kernm@dnr.sc.gov; Mularski, Eric -HDRInc <Eric.Mularski@HDRInc.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; melanie_olds@fws.gov; cloningerp@dnr.sc.gov; morep@dnr.sc.gov; bill.ranson@retiree.furman.edu; SelfR@dnr.sc.gov; charris@scprt.com; Maggie.Salazar@hdrinc.com; Tessels@dnr.sc.gov; Fletcher, Scott T <Scott.Fletcher@duke-energy.com>; harders@dnr.sc.gov; Erin.Settevendemio@hdrinc.com; cstarker@upstateforever.org; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; danielt@dnr.sc.gov; dwilde@keoweefolks.org; woodw@dnr.sc.gov; suewilliams130@gmail.com; simmonsw@dnr.sc.gov; gcyantis2@yahoo.com; Kevin Nebiolo <Kevin.Nebiolo@KleinschmidtGroup.com>; Jen Huff <jen.huff@hdrinc.com>; Andrew Gleason <andrewandwilla@hotmail.com>; Glenn Hilliard <glenn@hilliardgrp.com>; phil.mitchell@gmail.com
Cc: Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Sarah Kulpa <Sarah.Kulpa@hdrinc.com>; angie.scangas@hdrinc.com; Ziegler, Ty <ty.ziegler@hdrinc.com>
Subject: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda

Dear Bad Creek Resource Committee members:

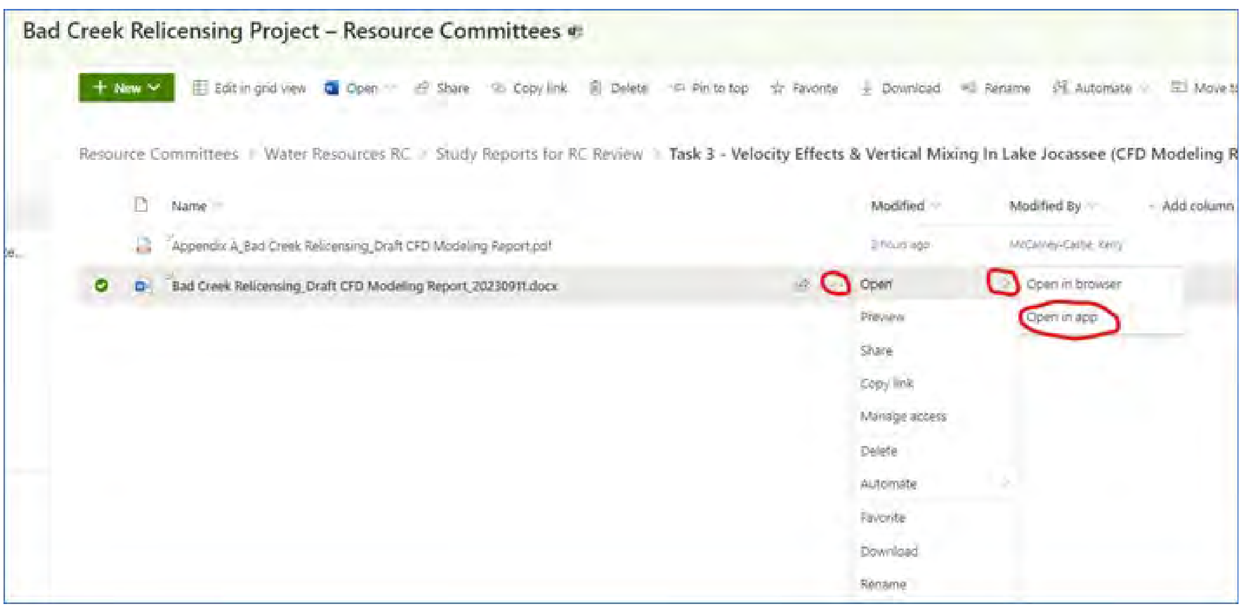
Duke Energy is pleased to distribute the draft Water Resources – Task 4 (i.e., CHEOPS Modeling) report for your review. This draft includes the results from CHEOPS modeling for the Baseline and Bad Creek II scenarios as well as populated Performance Measures sheets. The draft report is available on the SharePoint site using this link: [Bad Creek Relicensing Project – Resource Committees - Draft CHEOPS report - All Documents (sharepoint.com)].

Please provide your comments within the draft report using Track Changes as explained further below within 30 days (**April 26, 2024).** When you have completed your review – even if you have no comments – I would appreciate an email stating that is the case.

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy is providing relicensing deliverables on the SharePoint site for relicensing participants to access, review, and comment on files. Please provide all comments in the SharePoint Word document using tracked changes. This will eliminate version control issues, enable relicensing participants to gain insight into one another's comments, and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

    (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



We will be discussing the draft report and report findings during the April 4, 2024, Joint Resource Committee meeting. I have attached the meeting agenda for your reference.

If you have questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	Stuart, Alan Witten; Kulpa, Sarah; Huff, Jen; McCarney-Castle, Kerry
Cc:	Salazar, Maggie
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda
Date:	Thursday, April 4, 2024 10:33:27 AM

FYI, original email forwarded to Maggie for consultation record.

From: Sue Williams <suewilliams130@gmail.com>
Sent: Thursday, April 4, 2024 10:28 AM
To: gcyantis2@yahoo.com
Cc: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda

I also have no comments. Today's presentation was very helpful in understanding the report.

Sue Williams
Six Mile, SC

On Apr 4, 2024, at 09:28, gcyantis2@yahoo.com wrote:

John,
I've reviewed the draft CHEOPS report and have no comments.
I've copied Sue in case she has comments to represent from AQD.
Thank you,
Gerry

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Wednesday, March 27, 2024 7:23 AM
To: PellettC@dnr.sc.gov; Alison.Jakupca@KleinschmidtGroup.com; BreedloveA@dnr.sc.gov; grossea@dnr.sc.gov; attawaya@dnr.sc.gov; bereskind@greenvillewater.com; wes.cooler@mac.com; RankinD@dnr.sc.gov; adoug41@att.net; mixong@dnr.sc.gov; jhains@g.clemson.edu;

ehollis@upstateforever.org; jphillips@greenvillewater.com; kindelj@dnr.sc.gov; jtk7140@me.com; bradleyk@dnr.sc.gov; Kelly.Kirven@KleinschmidtGroup.com; forresterk@dnr.sc.gov; quattrol@dnr.sc.gov; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Kerry.McCarney-Castle@hdrinc.com; Abney, Michael A <Michael.Abney@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; lputnammitchell@gmail.com; amedeemd@dhec.sc.gov; kernm@dnr.sc.gov; Mularski, Eric -HDRInc <Eric.Mularski@HDRInc.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; melanie_olds@fws.gov; cloningerp@dnr.sc.gov; morep@dnr.sc.gov; bill.ranson@retiree.furman.edu; SelfR@dnr.sc.gov; charris@scprt.com; Maggie.Salazar@hdrinc.com; Tessels@dnr.sc.gov; Fletcher, Scott T <Scott.Fletcher@duke-energy.com>; harders@dnr.sc.gov; Erin.Settevendemio@hdrinc.com; cstarker@upstateforever.org; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; danielt@dnr.sc.gov; dwilde@keoweefolks.org; woodw@dnr.sc.gov; suewilliams130@gmail.com; simmonsw@dnr.sc.gov; gcyantis2@yahoo.com; Kevin Nebiolo <Kevin.Nebiolo@KleinschmidtGroup.com>; Jen Huff <jen.huff@hdrinc.com>; Andrew Gleason <andrewandwilla@hotmail.com>; Glenn Hilliard <glenn@hilliardgrp.com>; phil.mitchell@gmail.com
Cc: Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Sarah Kulpa <Sarah.Kulpa@hdrinc.com>; angie.scangas@hdrinc.com; Ziegler, Ty <ty.ziegler@hdrinc.com>
Subject: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda

Dear Bad Creek Resource Committee members:

Duke Energy is pleased to distribute the draft Water Resources – Task 4 (i.e., CHEOPS Modeling) report for your review. This draft includes the results from CHEOPS modeling for the Baseline and Bad Creek II scenarios as well as populated Performance Measures sheets. The draft report is available on the SharePoint site using this link: Bad Creek Relicensing Project – Resource Committees - Draft CHEOPS report - All Documents (sharepoint.com).

Please provide your comments within the draft report using Track Changes as explained further below within 30 days (**April 26, 2024).** When you have completed your review – even if you have no comments – I would appreciate an email stating that is the case.

Important – Please Read!

1. As discussed in the kick-off meeting (July 2022), Duke Energy is providing relicensing deliverables on the SharePoint site for relicensing participants to access, review, and comment on files. Please provide all comments in the SharePoint Word document using tracked changes. This will eliminate version control issues, enable relicensing participants to gain insight into one another’s comments, and result in a consolidated document for comment response.

2. We strongly recommend opening the document in Word; otherwise the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose “Open”, then choose “Open in app”. This will open the document in Word and you’ll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

    (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **“**Editing a Document in SharePoint”. This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)

<image001.png>

We will be discussing the draft report and report findings during the April 4, 2024, Joint Resource Committee meeting. I have attached the meeting agenda for your reference.

If you have questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda
Date:	Tuesday, April 9, 2024 8:15:22 AM
Attachments:	image001.png

From: Erika Hollis <ehollis@upstateforever.org>
Sent: Monday, April 8, 2024 3:43 PM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda

John,

I have completed my review of the CHEOPS model and have no comments to offer.

Best regards,
Erika

Erika J. Hollis
Clean Water Director
Upstate Forever
507 Pettigru St
Greenville, SC 29601
(864) 250-0500 ext. 117
ehollis@upstateforever.org

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Date: Wednesday, March 27, 2024 at 7:23 AM
To: PellettC@dnr.sc.gov <PellettC@dnr.sc.gov>, Alison.Jakupca@KleinschmidtGroup.com <Alison.Jakupca@KleinschmidtGroup.com>, BreedloveA@dnr.sc.gov <BreedloveA@dnr.sc.gov>, grossea@dnr.sc.gov <grossea@dnr.sc.gov>, attawaya@dnr.sc.gov <attawaya@dnr.sc.gov>, bereskind@greenvillewater.com <bereskind@greenvillewater.com>, wes.cooler@mac.com <wes.cooler@mac.com>, RankinD@dnr.sc.gov <RankinD@dnr.sc.gov>, adoug41@att.net <adoug41@att.net>, mixong@dnr.sc.gov <mixong@dnr.sc.gov>, jhains@g.clemson.edu <jhains@g.clemson.edu>, Erika Hollis <ehollis@upstateforever.org>, jphillips@greenvillewater.com <jphillips@greenvillewater.com>, kindelj@dnr.sc.gov <kindelj@dnr.sc.gov>, jtk7140@me.com <jtk7140@me.com>, bradleyk@dnr.sc.gov <bradleyk@dnr.sc.gov>, Kelly.Kirven@KleinschmidtGroup.com <Kelly.Kirven@KleinschmidtGroup.com>, forresterk@dnr.sc.gov <forresterk@dnr.sc.gov>, quattrol@dnr.sc.gov <quattrol@dnr.sc.gov>, Dunn, Lynne <Lynne.Dunn@duke-energy.com>, Raber, Maverick James <Maverick.Raber@duke-

energy.com>, Kerry.McCarney-Castle@hdrinc.com <Kerry.McCarney-Castle@hdrinc.com>, Abney, Michael A <Michael.Abney@duke-energy.com>, Elizabeth Miller <MillerE@dnr.sc.gov>, lputnammitchell@gmail.com <lputnammitchell@gmail.com>, amedeemd@dhec.sc.gov <amedeemd@dhec.sc.gov>, kernm@dnr.sc.gov <kernm@dnr.sc.gov>, Mularski, Eric -HDRInc <Eric.Mularski@HDRInc.com>, Wahl, Nick <Nick.Wahl@duke-energy.com>, melanie_olds@fws.gov <melanie_olds@fws.gov>, cloningerp@dnr.sc.gov <cloningerp@dnr.sc.gov>, morep@dnr.sc.gov <morep@dnr.sc.gov>, bill.ranson@retiree.furman.edu <bill.ranson@retiree.furman.edu>, SelfR@dnr.sc.gov <SelfR@dnr.sc.gov>, charris@scprt.com <charris@scprt.com>, Maggie.Salazar@hdrinc.com <Maggie.Salazar@hdrinc.com>, Tessels@dnr.sc.gov <Tessels@dnr.sc.gov>, Fletcher, Scott T <Scott.Fletcher@duke-energy.com>, harders@dnr.sc.gov <harders@dnr.sc.gov>, Erin.Settevendemio@hdrinc.com <Erin.Settevendemio@hdrinc.com>, Chris Starker <cstarker@upstateforever.org>, alan.stuart@duke-energy.com <alan.stuart@duke-energy.com>, danielt@dnr.sc.gov <danielt@dnr.sc.gov>, dwilde@keoweefolks.org <dwilde@keoweefolks.org>, woodw@dnr.sc.gov <woodw@dnr.sc.gov>, suewilliams130@gmail.com <suewilliams130@gmail.com>, simmonsw@dnr.sc.gov <simmonsw@dnr.sc.gov>, gcyantis2@yahoo.com <gcyantis2@yahoo.com>, Kevin Nebiolo <Kevin.Nebiolo@KleinschmidtGroup.com>, Jen Huff <jen.huff@hdrinc.com>, Andrew Gleason <andrewandwilla@hotmail.com>, Glenn Hilliard <glenn@hilliardgrp.com>, phil.mitchell@gmail.com <phil.mitchell@gmail.com>
Cc: Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>, Sarah Kulpa <Sarah.Kulpa@hdrinc.com>, Angie.Scangas@hdrinc.com <angie.scangas@hdrinc.com>, Ziegler, Ty <ty.ziegler@hdrinc.com>
Subject: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda

Dear Bad Creek Resource Committee members:

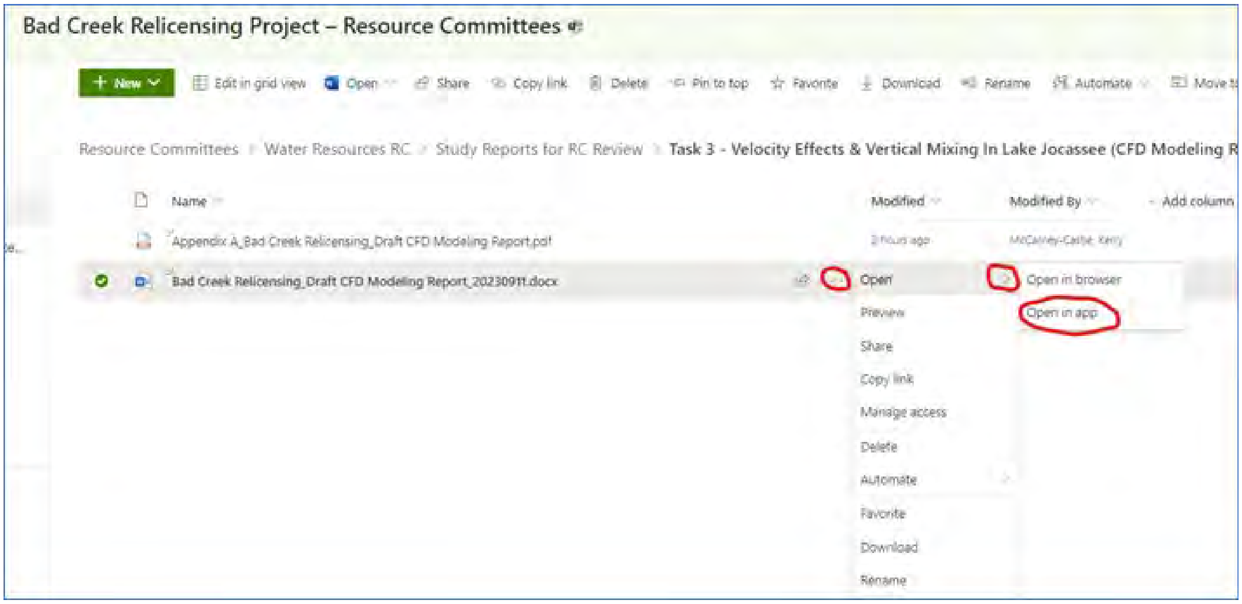
Duke Energy is pleased to distribute the draft Water Resources – Task 4 (i.e., CHEOPS Modeling) report for your review. This draft includes the results from CHEOPS modeling for the Baseline and Bad Creek II scenarios as well as populated Performance Measures sheets. The draft report is available on the SharePoint site using this link: Bad Creek Relicensing Project – Resource Committees - Draft CHEOPS report - All Documents (sharepoint.com).

Please provide your comments within the draft report using Track Changes as explained further below within 30 days (**April 26, 2024).** When you have completed your review – even if you have no comments – I would appreciate an email stating that is the case.

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy is providing relicensing deliverables on the SharePoint site for relicensing participants to access, review, and comment on files. Please provide all comments in the SharePoint Word document using tracked changes. This will eliminate version control issues, enable relicensing participants to gain insight into one another's comments, and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



We will be discussing the draft report and report findings during the April 4, 2024, Joint Resource Committee meeting. I have attached the meeting agenda for your reference.

If you have questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	Alex Pellett; Alison Jakupca; Amy Breedlove; Andrew Grosse; Austen Attaway; bereskind; Wes Cooler; Dan Rankin; Andy Douglas; Greg Mixon; jhains@g.clemson.edu; Erika Hollis; Jeff Phillips; Jennifer Kindel; jtk7140@me.com; Keith A. Bradley; Kelly Kirven; Ken Forrester; quattrol; Dunn, Lynne; Raber, Maverick James; McCarney-Castle, Kerry; Abney, Michael A; Elizabeth Miller; lputnammitchell; Amedee, Morgan D.; Morgan Kern; Mularski, Eric; Wahl, Nick; Olds, Melanie J; Pat Cloninger; More, Priyanka; Bill Ranson-Retired; SelfR; Charles (Rowdy) B Harris; Salazar, Maggie; Samantha Tessel; Fletcher, Scott T; Scott Harder; Settevendemio, Erin; Chris Starker; Stuart, Alan Witten; Tom Daniel; Dale Wilde; William T. Wood; suewilliams130@gmail.com; simmonsw@dnr.sc.gov; gcyantis2; Kevin Nebiolo; Huff, Jen; Andrew Gleason; glenn@hilliardgrp.com; phil.mitchell@gmail.com
Cc:	Lineberger, Jeff; Kulpa, Sarah; Scangas, Angie; Ziegler, Ty
Subject:	RE: Bad Creek Relicensing - CHEOPS Modeling April 4 Meeting Summary and Materials
Date:	Thursday, April 18, 2024 9:17:43 AM
Attachments:	image001.png

Dear Bad Creek Resource Committee Members:

The meeting materials from the CHEOPS Results and CFD Addendum Meeting (virtual) held on April 4th have been uploaded to: 20240404_Water and Operations_Joint RC Meeting_CHEOPS Results and CFD Addendum. (Meeting Summary, Meeting Presentation, and Meeting Recording).

Please let Alan or me know if you have any questions about the meeting information.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

Meeting Minutes

Project:	Bad Creek Relicensing
Subject:	CHEOPS Results and CFD Addendum
Date:	Thursday, April 04, 2024
Location:	Teams

Attendees:

Sue Williams (AQD)
Gerry Yantis (AQD)
John Crutchfield (Duke Energy)
Lynne Dunne (Duke Energy)
Alan Stuart (Duke Energy)
Glenn Hilliard (FTC)
John Hains (FOLKS)
Dale Wilde (FOLKS)
Jen Huff (HDR)
Sarah Kulpa (HDR)
Kerry McCarney-Castle (HDR)
Angie Scangas (HDR)
Ty Ziegler (HDR)
Wes Cooler (Naturaland Trust)
Morgan Amedee (SCDHEC)
Amy Chastain (SCDNR)
Elizabeth Miller (SCNDR)
Rowdy Harris (SCDPRT)

Introduction

John Crutchfield opened the meeting, facilitated introductions, shared the agenda, and provided a safety moment on safe driving through work zones.

CHEOPS Modeling Discussion

Jen Huff provided opening remarks for the CHEOPS discussion, noting that HDR's lead modeler Angie Scangas has limited connectivity (due to snowstorm in New England) so J. Huff will cover the presentation, but A. Scangas will be available to answer technical questions. J. Huff then presented a refresher on the CHEOPS model and the Savannah River CHEOPS model developed for Keowee-Toxaway Project (KT) relicensing. The Savannah River CHEOPS model includes the 2014 Operating Agreement between Duke Energy, U.S. Army Corps of Engineers (USACE), and Southeastern Power Administration (SEPA) as well as the requirements of the KT Low Inflow Protocol (LIP).

Adjustments to the Savannah River model for Bad Creek relicensing included updating the generation and pumping load shapes for Bad Creek Pumped Storage Station (Bad Creek) and Jocassee Pumped Storage Station (Jocassee). J. Huff presented a graph for an example day (July 6, 2011) with the original pump/gen cycle used during KT relicensing and the updated pump/gen cycle used for Bad Creek relicensing (Slide 9). During KT relicensing, Bad Creek and Jocassee typically generated during the day and pumped at night. Now, however, increased renewables on the Duke Energy system cause pumping during the afternoon with generation needed at night. Generating and pumping is also influenced by how much water is available and FERC license requirements.

No changes were made to the hydrology dataset which includes 1939 - 2011 daily unimpaired inflow (UIF) hydrology. Operations under two climate change conditions were also modeled: (1) CCLow represents a 3°F temperature increase (with 10% increase in evaporation) and (2) CCHigh represents a 6°F degree temperature increase (with 20% increase in evaporation) plus 10% decrease in inflow to the system.

The two model scenarios were: (1) Baseline (existing facilities and FERC license requirements) and (2) Baseline + Bad Creek II (i.e., the alternative).

J. Huff explained under typical operations, Bad Creek and Jocassee operate together in sync (i.e., when one pumps, the other pumps, and when one generates, the other generates). Therefore, the Bad Creek and Jocassee reservoir elevations have generally risen and fallen in tandem as demonstrated on Slide 12 by the green “reservoir elevation line” on the Baseline scenario figures. Under the Bad Creek II scenario, Bad Creek pumps more water to the Upper Reservoir (UR) and exceeds the amount Jocassee pumps from Lake Keowee for a period of time (the negative inflow period shown on the graph). This causes the green reservoir elevation line for Jocassee to remain in a smaller “band”. Ty Ziegler added that the increase in generation and pumping capability with Bad Creek II will have a more dramatic effect on UR elevations and less of an effect on the lower reservoir (Lake Jocassee elevation).

Dale Wilde asked if the green line (elevation) on the upper right figure (Slide 12) goes down to 30,000. J. Huff explained the green line is aligned with the right-hand axis (elevation in feet). A. Scangas added that hydroelectric operations (blue line) correlates to the left-hand axis (flow in cubic feet per second). T. Ziegler noted that with Bad Creek II the hydraulic capacity is essentially doubled so the UR will be better utilized with Bad Creek II operations; only a portion of the capacity of the UR is currently used. Accordingly, the model shows more water fluctuation in the UR and less fluctuation in Lake Jocassee under the Bad Creek II scenario. Approximately 0.5 feet less fluctuation occurs at Jocassee under the Bad Creek II scenario.

J. Huff showed simulated reservoir elevations for Bad Creek under Baseline and Bad Creek II under climate change scenarios, noting that under CCHigh conditions, the model simulated Bad Creek reservoir near maximum drawdown at times. However, during these times pumping and generating was still simulated as water moves within the Duke Energy system.

Glenn Hilliard asked if there could be a situation in the future with extreme (high) temperatures and full use of Bad Creek II, where there is a risk for power production problems such that power may not be available on subsequent days and Duke Energy would not be able to operate. J. Huff noted that the 2014 Operating Agreement dictates how much water can be used/stored in Duke Energy reservoirs during times of low-inflow periods (i.e., droughts) versus the downstream USACE reservoirs. Duke Energy cannot stop releases from Keowee such that lower reservoirs (downstream) don’t have enough water to continue releases into the Savannah River. The 2014 Operating Agreement ensures that the amount of usable storage in the system remains in balance. A specified volume of water can be kept in the upper reservoirs during severe drought conditions.

T. Ziegler added that the 73-year hydrology dataset used for CHEOPS captures the most severe drought that has occurred in the basin.

J. Huff discussed Lake Jocassee reservoir elevations, showing there is very little difference between maximum, minimum, median, and operating band under both scenarios. Differences between Bad Creek II and Baseline scenarios are minor and the largest difference between Baseline and Bad Creek II water levels is observed under CCHigh, as expected.

Spawning performance measures for black bass and blueback herring (under normal hydrology) have seasonal requirements. Lake Jocassee's water surface fluctuation band needs to be held within 2.5 feet during spawning season such that dewatering of nests does not occur. Performance Measures and MISCs[1] were determined in collaboration with relicensing stakeholders (in the summer and fall of 2023) and a 2.5-foot fluctuation band was selected to maximize spawning conditions for targeted fish species. Under the Bad Creek II scenario, there are more years meeting the 2.5-foot fluctuation band restriction than under Baseline operations, which indicates improved chance for spawning success under Bad Creek II operations. For example, Performance Measure 8 is met 100 percent of the time under the Bad Creek II scenario versus 71 percent of the time under the Baseline scenario.

John Hains (via chat) asked why these results were considered surprising. J. Huff clarified she had not expected to see much effect to Lake Jocassee reservoir elevations under Bad Creek II operations. However, considering that Bad Creek operates in tandem with Lake Jocassee, it is actually not surprising water levels would fluctuate within a smaller range. T. Ziegler added since Bad Creek II operations double pumping and generating flows, water pumped up to the UR is essentially being replaced in Lake Jocassee from Lake Keowee. Even though the UR has an increased fluctuation band under Bad Creek II, Lake Jocassee has a smaller fluctuation band.

J. Huff showed model results for Lake Keowee, demonstrating negligible changes to the max, min, or fluctuation band would be expected under Bad Creek II operations.

D. Wilde asked why the hydrology data only goes up to 2011. J. Huff answered the hydrology data period of record includes the years 1939 through 2011. The model shifts the hydrology data into the future and then uses the historic rainfall, temperature, and evaporation conditions when it models each operational scenario. Sarah Kulpa mentioned a separate analysis was carried out (prior to modelling for Bad Creek) to ensure updating the hydrology wasn't necessary since it would be a large effort. Results from the sensitivity analysis showed incorporating data from the last 12 years would not add any different extremes for wet and dry years than what are already included in the dataset, therefore, the investment was deemed not worth the return. T. Ziegler and J. Huff added the existing 73-year hydrology dataset includes normal and wet years and also the drought of record for the Savannah River Basin, therefore, it includes the bookends for hydrologic data that can be reasonably expected over the term of the next license, especially when used in conjunction with the two modeled climate change scenarios.

J. Huff discussed the rate of change for Bad Creek and Jocassee elevation fluctuations. The rate of change in water level fluctuation, or how quickly the reservoir elevation changes, could have implications for boat launching in Lake Jocassee. Therefore, model output was evaluated

[1] Minimum increment of significant change

to see how often fluctuations of >1 foot in 1 hour might occur (representing a very slow boat launch); results showed that would never happen.

Rowdy Harris noted boat ramp use and boat launching is less of an issue than people who tie up a boat at a campground site or hiking trailhead for several hours. They can return to find their boat on dry land with no way to get it back into water. J. Huff reiterated that the model shows approximately 0.5 feet less 24-hour fluctuation under Bad Creek II operations than under the Baseline operations for Lake Jocassee. Therefore, we would expect this would be less likely under the Bad Creek II scenario compared to the Baseline scenario conditions.

J. Hains asked if Jocassee and Bad Creek always operate in tandem. J. Huff explained the model doesn't consider hydro-specific components (like outages, etc.) so there could be a time Bad Creek could operate independently of Jocassee, but generally speaking, they would operate in tandem unless there is some sort of external factor or emergency situation that can't be predicted in a model.

A. Stuart said he talked with Aaron Dale (manager of Duke Energy Operations Group) and he conveyed it would be almost impossible to operate Bad Creek and Jocassee out of sequence (i.e., one hydro pumping while the other generated). There may be occurrences where one hydro may begin pumping or generating before the other, but that would be very a short-term phenomenon and wouldn't be picked up by the CHEOPS model.

J. Hains asked if there is a scenario where Bad Creek would operate with no operation at Jocassee. A. Scangas noted that scenario was not observed in the CHEOPS model results but could happen for very short time periods as mentioned previously. Planned and unplanned outages or other grid emergencies would be the only likely cases where Bad Creek would operate out of sync with Jocassee, which are events the model cannot incorporate or predict.

J. Huff explained the goal of the KT LIP is to reduce water losses within the Duke Energy system consistent with the 2014 Operating Agreement and showed days in the KT LIP Stages under the Baseline and Bad Creek II scenarios. Under the Bad Creek II scenario, time (days) in LIP stage zero increases. This is due to the role remaining reservoir storage plays in determining LIP stage. Under Bad Creek II operations, the model releases downstream flows from Keowee that likely would not happen if a human operator were in control. As the model sees Lake Keowee fill, it releases a small amount of water into Lake Hartwell resulting in a small loss of water from the Duke Energy system. These small day-to-day changes in remaining reservoir storage can shift the system from normal LIP stage (i.e., not in the LIP) to LIP stage zero.

D. Wilde asked for confirmation if the LIP changed in 2011. A. Stuart responded there was no LIP in place prior to 2011, but the 1968 Operating Agreement between Duke Energy, the USACE, and SEPA was in place. Under the 1968 Operating Agreement, Duke Energy was required to release up to 25,000 acre-feet of water per week during droughts. The 2014 Operating Agreement developed during KT relicensing has resulted in a more equitable distribution of water during droughts. S. Kulpa reiterated the 2011 historical dataset is used as a proxy for the future; A. Scangas added historical hydrology is used to simulate under a future lens applying current operating rules. T. Ziegler noted the 1939-2011 hydrology database only provides the amount of inflow to the Duke Energy and USACE reservoirs - the CHEOPS model layers on the operational instructions and constraints.

The USACE's Lake Hartwell and Thurmond Lake cumulative discharge curves show no difference associated with Duke Energy operations between Baseline and Bad Creek II scenarios.

J. Huff then summarized the study conclusions, opened the floor for more questions, and noted the draft study report was posted on the Relicensing SharePoint site on March 26. Duke Energy kindly requests comments by April 26.

CFD Addendum Discussion

T. Ziegler briefly discussed additional CFD modeling being carried out due to design changes for the proposed Bad Creek II facility (i.e., increased hydraulic capacities due to variable speed vs. single speed pump turbines). This topic was introduced at the Initial Study Report meeting in January 2024. Generation flows increased ~2 percent which would not be dissimilar from flows already modeled using the existing CFD model, however, increased pumping capacity could result in a ~9 percent increase in flows. Therefore, additional pumping flow scenarios were modeled at Lake Jocassee minimum (1,080 feet above mean sea level [ft msl]), full (1,110 ft msl), and intermediate (1,096 ft msl) pond levels.

The CFD model used for this task is the same model used in the feasibility[2] study as it has a finer resolution that the CFD model used for the relicensing[3] study under the Water Resources Study (Task 3).

D. Wilde asked if there is an overlay image between existing submerged weir vs. the expanded weir. T. Ziegler noted there are figures of both configurations of the weir in the CFD report included in the Initial Study Report and noted the proposed expanded weir crest elevation would stay the same (as the existing weir) and would be expanded in the downstream direction (i.e., towards the main body of Lake Jocassee).

J. Crutchfield opened the floor for questions or comments.

J. Hains asked if there are any plans to restrict boating access to Whitewater River cove after construction and operation. A. Stuart said there would be no access restrictions to Whitewater River cove after construction, but Whitewater River cove would be closed during construction. Duke Energy may install a warning cable around the new intake alcove with a buoy system.

[2] The CFD report for the feasibility study was included with the Revised Study Report in Appendix I.
[3] The CFD report for the relicensing study was included with the Initial Study Report in Appendix A.

Action Items

- The draft CHEOPS report has been distributed via the relicensing SharePoint site; comments from stakeholders are requested by April 26, 2024.
- Meeting summary and slide deck will be posted to the SharePoint site in approximately 2 weeks.

Bad Creek Pumped Storage Project No. 2740

Joint Resource Committee Meeting

DUKE ENERGY.

BUILDING A SMARTER ENERGY FUTURE ©

APRIL 4, 2024

1

Agenda

- Welcome and Meeting Purpose
- Safety Moment
- Task 4 - CHEOPS™ Modeling
- Task 3 – CFD Modeling
- Adjourn

Bad Creek Pumped Storage Project Joint Resource Committee Meeting | 2

2

Safety Moment – Road Work Safety

- Summer is the busiest time of year for road work!
- Safety Tips for driving in Work Zones:
  - **Pay attention!** Eliminate distractions.
  - Be alert for work zone signs and flaggers.
  - Watch out for road debris.
  - Don't tailgate!!
  - **Be patient** and obey posted speed limits.
  - The penalty for speeding through a signed work zone is an additional $250.
  - Don't change lanes.
  - **Expect the unexpected: Keep an eye out for workers and their equipment.**
  - When possible, *use alternate routes* or travel at non-peak times to avoid traffic congestion.

3

Water Resources Study

Task 4 – Water Exchange Rates and Lake Jocassee Reservoir Levels (CHEOPS)

4

- CHEOPS™ Model Refresher
- Scenario Descriptions
- Results
- Comparison of Effects
- Next Steps

5

CHEOPS™ (Computer Hydro Electric Operations & Planning Software)

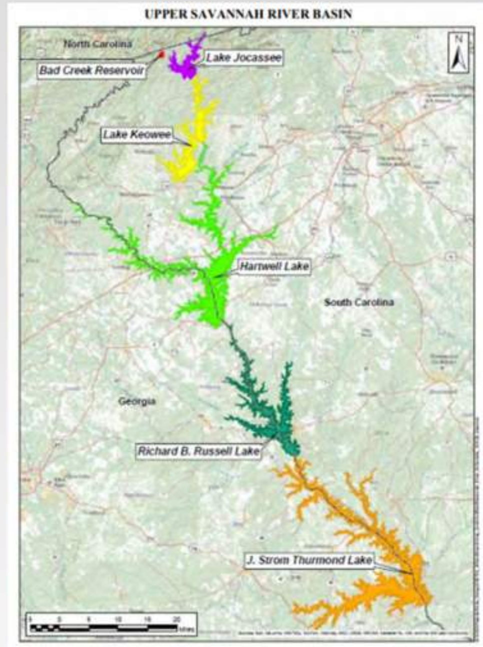
- Hydrologic water quantity simulation model used to evaluate:
  - Potential economic effects of alternative operations
  - Upgrades & modifications
  - Physical & operational changes related to FERC relicensing
- User-definable input data:
  - Energy production for peak & off-peak periods
  - Variable durations for daily peak & off-peak periods
  - Instream or bypass flows in each river reach
  - Water level variation limits in each reservoir or impoundment
  - Unit performance curves
  - Unit availability
  - Minimum flows & ramp rates
  - Hydrology from historical, typical water or calendar

Operations model - a software tool for evaluating a wide range of physical & operational constraints on a hydroelectric facility

6

Savannah River CHEOPS™ Model

- Upper Savannah River reservoirs
  - Bad Creek
  - Jocassee
  - Keowee
  - Hartwell
  - Russell
  - Thurmond
- Model Data
  - Reservoir area & volume
  - Discharge rating curves
  - Turbine & generator data
  - Pump data
  - Load shape (pumping & generation)
  - Hydrology
  - Operating rules
    - Bad Creek License
    - Keowee-Toxaway License
      - Low Inflow Protocol
    - 2014 Operating Agreement



7

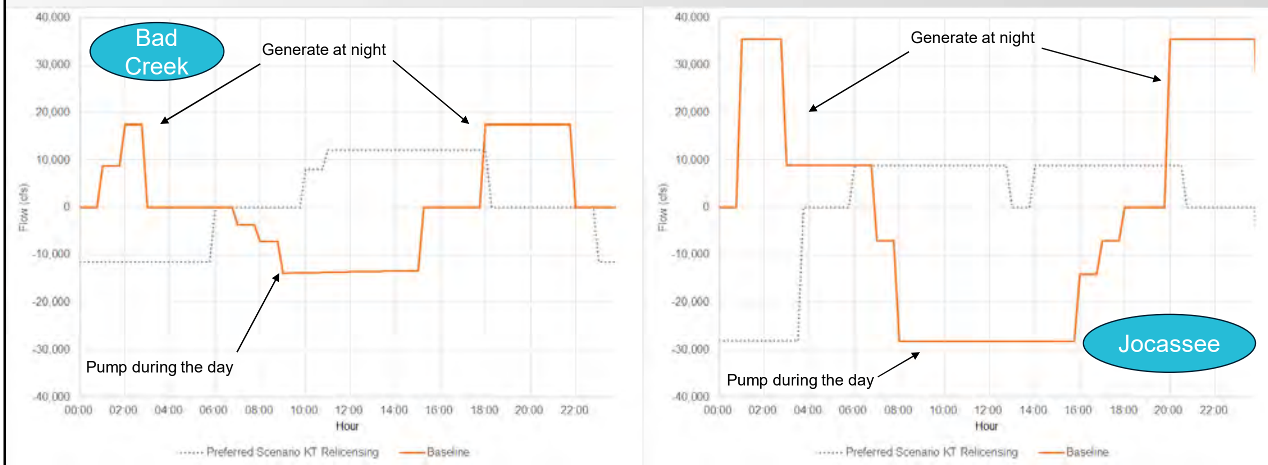
Potential Scenario Inputs

SCENARIO

- System Setting (1 per scenario)
  - Load Shape
  - Carryover
  - Forecast Length
- Physical Setting (1 per plant)
  - Reservoir Storage
  - Reservoir Area
  - Daily Evaporation
  - Tailwater Curve
  - Spillway Curve
  - Ramping Rate Curve
  - Plant Operations
- Operation Setting (1 per scenario)
  - Flood Elevation
  - Target Elevation
  - Minimum Elevation
  - Withdrawals/Returns
  - Fluctuation Limits
  - Fluctuation Rates
  - Min Instantaneous Flows
  - Min Daily Avg Flows
  - Ramping Rates
  - Bypass Flows
- Generation Setting (1 per scenario)
  - Powerhouse
    - Headloss
    - Turbines
    - Generators
    - Gate Leakage
  - Maintenance
  - Minimum Flow Unit

8

Pump/Generation Cycle – Example Day



9

Hydrological Conditions

- Normal: Daily unimpaired inflow (UIF) hydrology dataset (1939-2011)
- Climate Change – Low (ccLow)
  - 3°F temperature increase (10% increase in evaporation)
- Climate Change – High (ccHigh)
  - 6°F temperature increase (20% increase in evaporation)
  - 10% decrease in incremental reservoir inflow

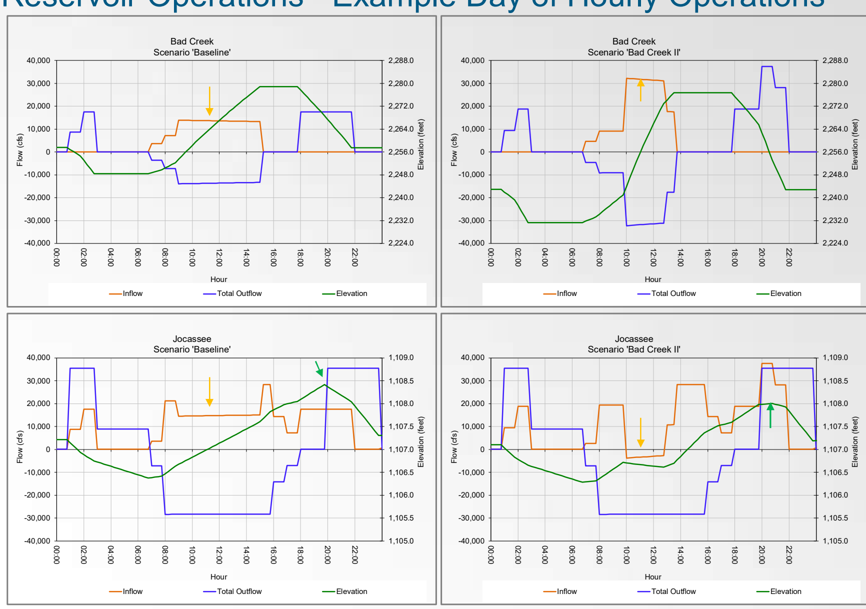
10

CHEOPS™ & Bad Creek Relicensing

- Scenarios
  - Baseline (existing facilities and FERC license requirements)
  - Alternative: Baseline + Bad Creek II
- Operational effects of scenarios
  - Lake level fluctuations at Bad Creek, Jocassee & Keowee
  - Rate of change in lake levels
  - Low Inflow Protocol (LIP) Stages
  - Keowee Releases to Lake Hartwell

11

Reservoir Operations - Example Day of Hourly Operations



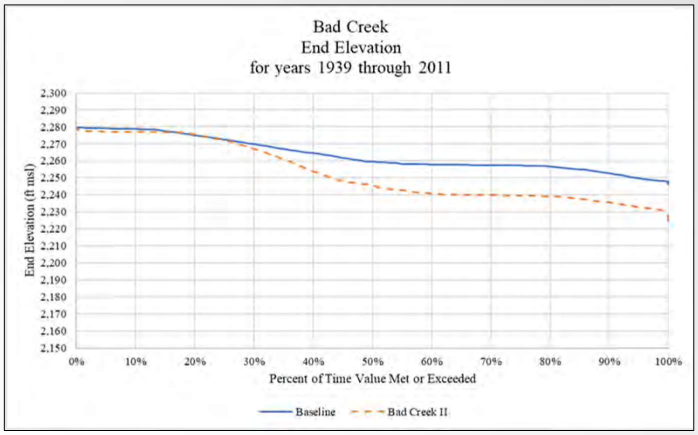
Jocassee discharge is the same for Baseline and Bad Creek II

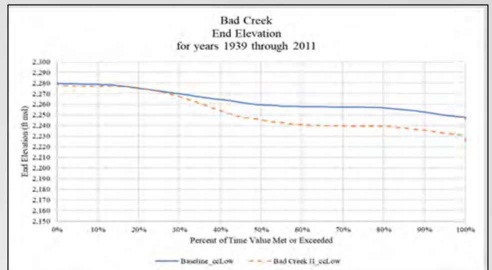
Jocassee inflow varies between scenarios with the varied Bad Creek capacity

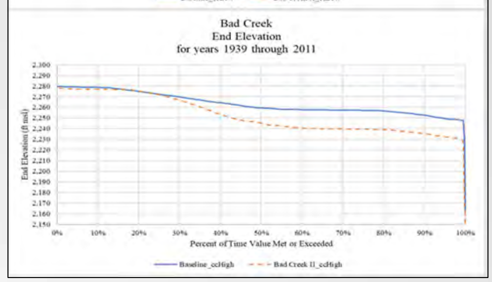
About 0.5 feet of additional fluctuation in Jocassee under Baseline example versus Bad Creek II

12

Reservoir Elevations – Bad Creek Reservoir



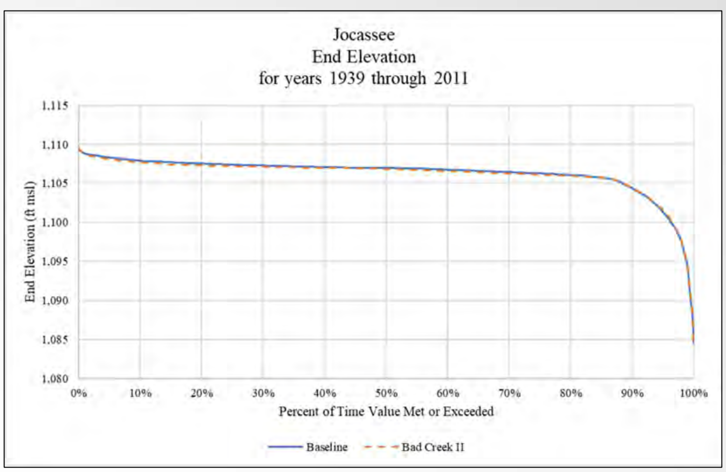


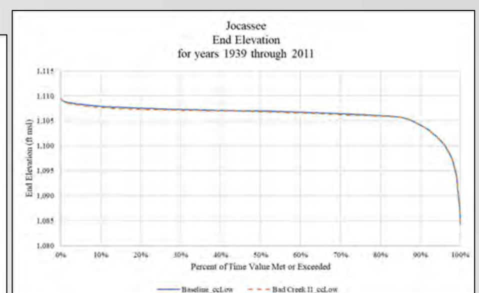


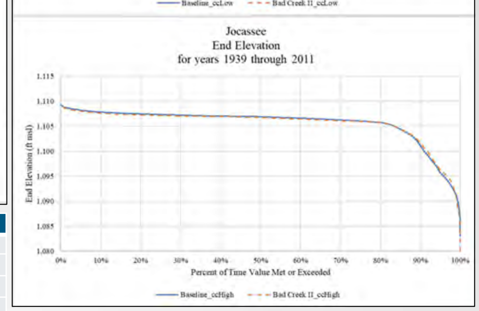
Hydrology	Baseline Elevations (ft msl)				Bad Creek II Elevations (ft msl)			
	Min	Median	Max	Band (ft)	Min	Median	Max	Band (ft)
Normal	2,246.1	2,259.5	2,280.0	33.9	2,224.7	2,245.6	2,280.0	55.3
ccLow	2,246.1	2,259.5	2,280.0	33.9	2,224.7	2,245.6	2,280.0	55.3
ccHigh	2,160.0	2,259.5	2,280.0	120.0	2,151.6	2,245.3	2,280.0	128.4

13

Reservoir Elevations – Lake Jocassee







	Baseline Elevations (ft msl)				Bad Creek II Elevations (ft msl)			
	Min	Median	Max	Band (ft)	Min	Median	Max	Band (ft)
Normal	1,084.1	1,107.0	1,110.0	25.9	1,084.5	1,106.8	1,110.0	25.5
ccLow	1,083.8	1,107.0	1,110.0	26.2	1,084.2	1,106.8	1,110.0	25.8
ccHigh	1,083.0	1,106.9	1,109.5	26.5	1,080.0	1,106.7	1,109.9	29.9

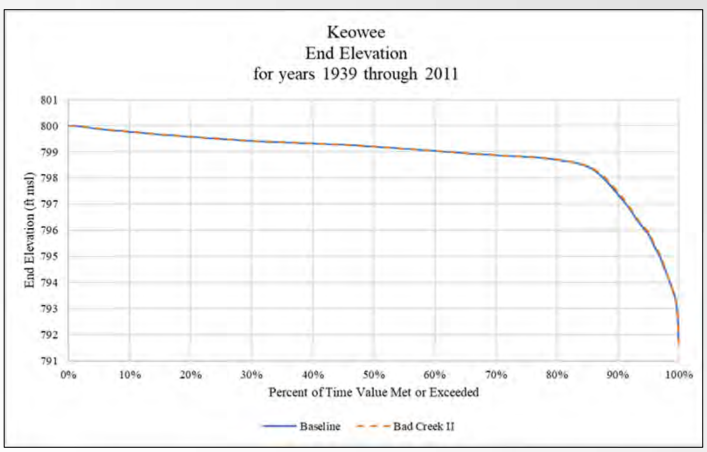
14

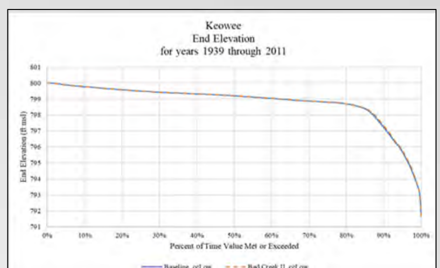
Lake Jocassee Reservoir Levels – Spawning Performance Measures (Normal Hydrology)

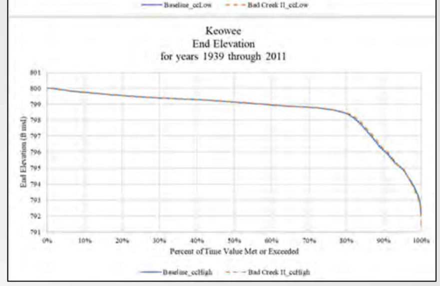
Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Bad Creek II
	Lake Jocassee					(1939-2011)	(1939-2011)
	Elevation - Natural Resources						
8	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 5)	1-Apr	31-May	5%	71%	100%
9		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 5)	1-Apr	31-May	5%	34%	99%
10		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 5)	1-Apr	31-May	5%	19%	89%
11		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 30 consecutive days at least once (Note 5)	1-Apr	31-May	5%	0%	59%
12		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 45 consecutive days at least once (Note 5)	1-Apr	31-May	5%	0%	0%
13	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	100%
14		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	100%
15		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 5)	1-Apr	31-May	5%	100%	99%
16		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 30 consecutive days at least once (Note 5)	1-Apr	31-May	5%	95%	97%
17		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 45 consecutive days at least once (Note 5)	1-Apr	31-May	5%	56%	82%
18	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 5)	15-May	15-Jul	5%	45%	100%
19		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 5)	15-May	15-Jul	5%	14%	92%
20		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 5)	15-May	15-Jul	5%	0%	3%
21	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 5)	15-May	15-Jul	5%	100%	100%
22		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 5)	15-May	15-Jul	5%	100%	100%
23		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 5)	15-May	15-Jul	5%	79%	99%

15

Reservoir Elevations – Lake Keowee





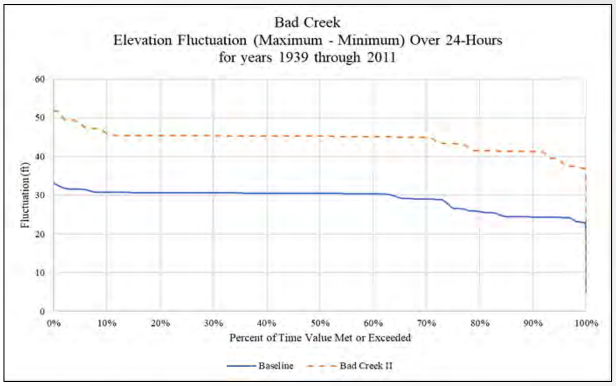


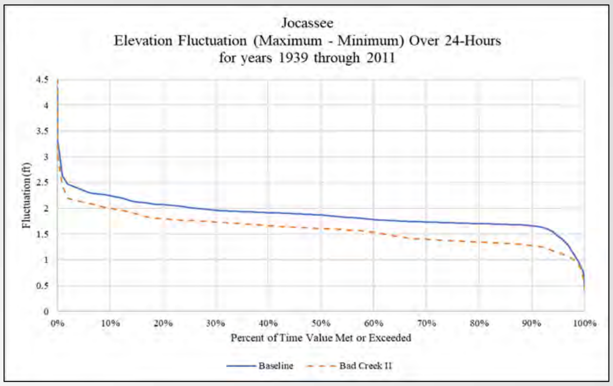
	Baseline Elevations (ft msl)				Bad Creek II Elevations (ft msl)			
	Min	Median	Max	Band (ft)	Min	Median	Max	Band (ft)
Normal	791.6	799.2	800.0	8.4	791.6	799.2	800.0	8.4
ccLow	791.6	799.2	800.0	8.4	791.7	799.2	800.0	8.3
ccHigh	792.0	799.1	800.0	8.0	791.4	799.1	800.0	8.6

16

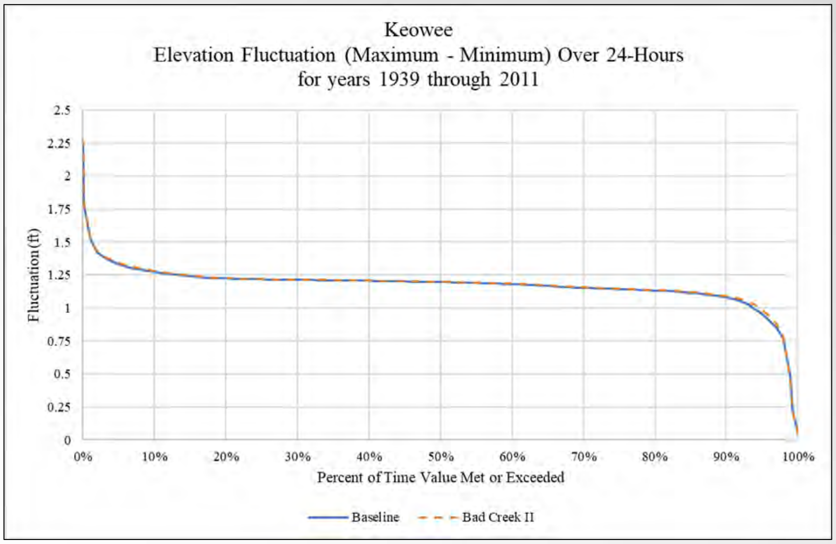
Bad Creek and Jocassee Elevation Fluctuations – Rate of Change

Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Bad Creek II
	Lake Jocassee					(1939-2011)	(1939-2011)
7	Minimize effects on recreational boating	Number of days where reservoir level changes more than 1.0 ft in one hour	1-Jan	31-Dec	10	0	0

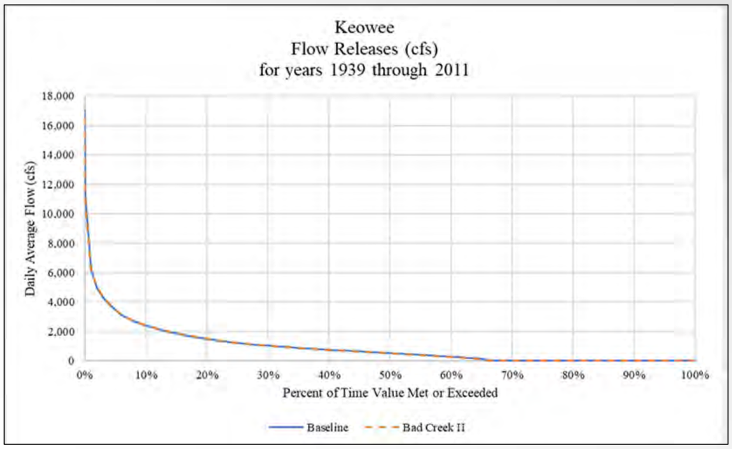


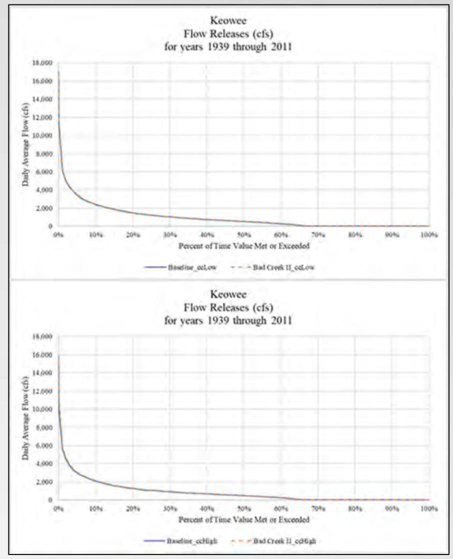


Keowee Elevation Fluctuations – Rate of Change



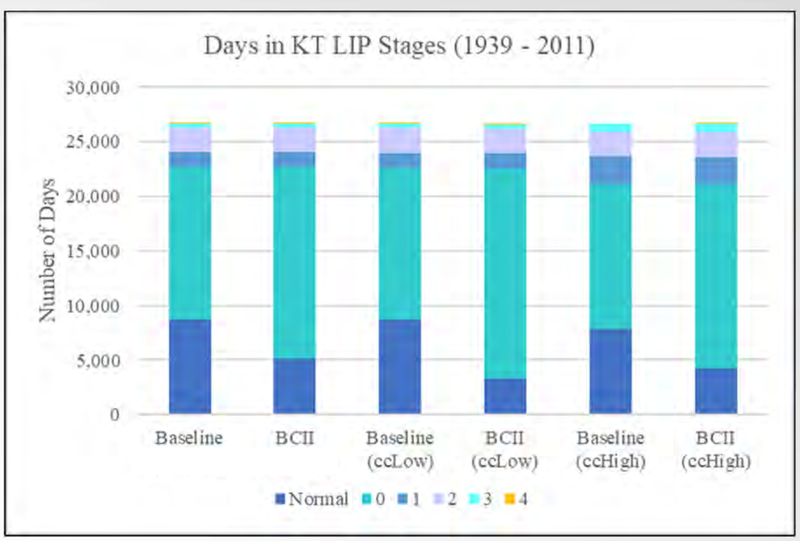
Keowee Downstream Flow Releases





19

Low Inflow Protocol Stages



20

LIP Stages – Performance Measures

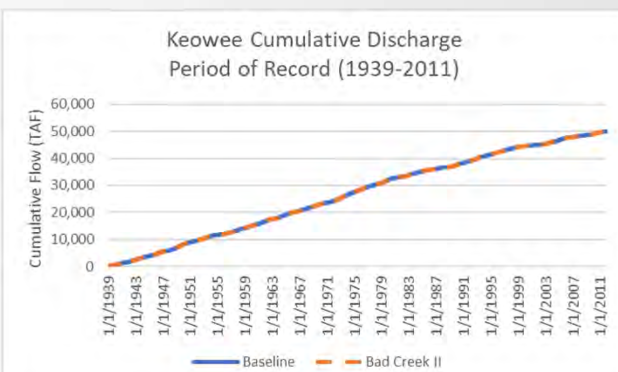
Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Bad Creek II
	Duke Energy Hydropower & Water Quantity Management						
64	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 19)	1-Jan	31-Dec		8,728	5,102
65		Number of days in LIP Stage 0	1-Jan	31-Dec		13,972	17,584
66		Number of days in LIP Stage 1	1-Jan	31-Dec		1,351	1,351
67		Number of days in LIP Stage 2	1-Jan	31-Dec		2,185	2,199
68		Number of days in LIP Stage 3	1-Jan	31-Dec		378	378
69		Number of days in LIP Stage 4	1-Jan	31-Dec		49	49

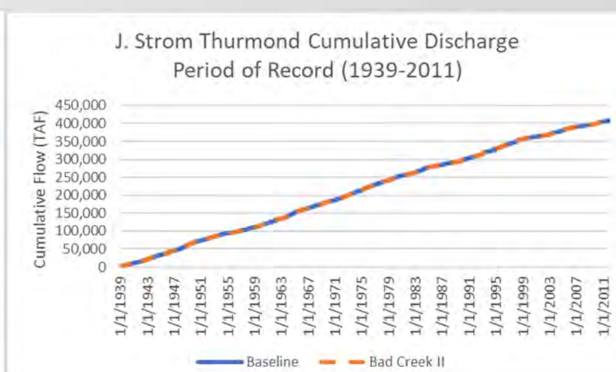
Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline_ccLow	Bad Creek II_ccLow
	Duke Energy Hydropower & Water Quantity Management						
64	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 19)	1-Jan	31-Dec		8,707	3,366
65		Number of days in LIP Stage 0	1-Jan	31-Dec		13,860	19,187
66		Number of days in LIP Stage 1	1-Jan	31-Dec		1,421	1,435
67		Number of days in LIP Stage 2	1-Jan	31-Dec		2,241	2,227
68		Number of days in LIP Stage 3	1-Jan	31-Dec		385	399
69		Number of days in LIP Stage 4	1-Jan	31-Dec		49	49

Measure Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline_ccHigh	Bad Creek II_ccHigh
	Duke Energy Hydropower & Water Quantity Management						
64	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 19)	1-Jan	31-Dec		7,860	4,276
65		Number of days in LIP Stage 0	1-Jan	31-Dec		13,160	16,793
66		Number of days in LIP Stage 1	1-Jan	31-Dec		2,625	2,527
67		Number of days in LIP Stage 2	1-Jan	31-Dec		2,213	2,304
68		Number of days in LIP Stage 3	1-Jan	31-Dec		805	728
69		Number of days in LIP Stage 4	1-Jan	31-Dec		0	35

21

Keowee & Thurmond Cumulative Flow (1939 – 2011; Normal hydrology)





22

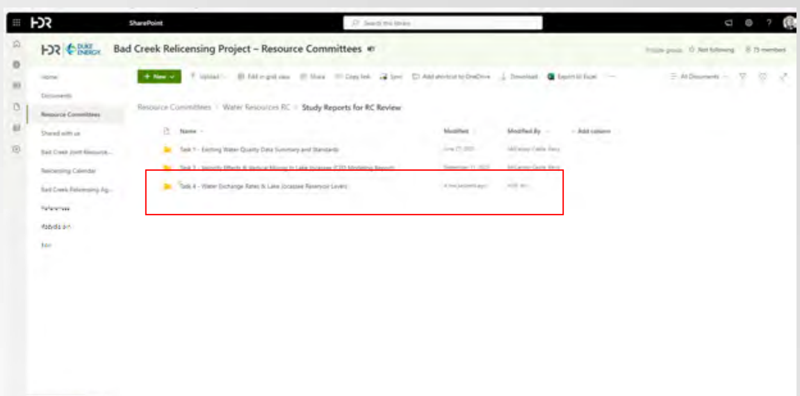
Summary Conclusions – Bad Creek II Effects

- Bad Creek Reservoir elevation: Wider operating band
- Lake Keowee and Lake Jocassee elevations: Comparable to Baseline
- Lake Jocassee reservoir level fluctuations rate of change (24-hour period): Smaller than Baseline
- Lake Keowee water intakes: No effect
- Keowee-Toxaway Low Inflow Protocol (LIP)
  - Stage 0 frequency increases
  - Differences diminish in the more advanced stages of the KT LIP
- USACE reservoirs, Savannah River flows: Minimal effect

23

Next Steps

- Review draft study report
  - Posted to SharePoint site
  - Comments due: April 26, 2024



24

Questions

25

Additional CFD Modeling

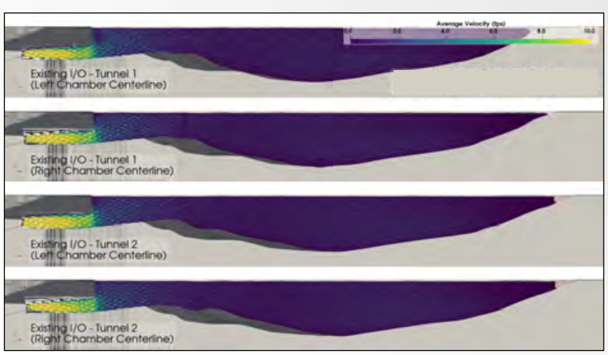
26

Additional CFD Modeling – Overview

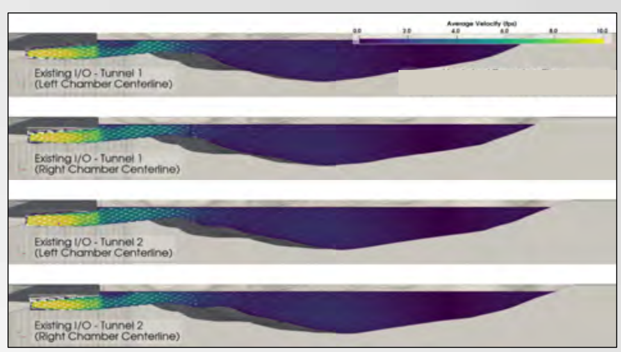
- Additional CFD modeling is ongoing to incorporate recent design changes (from single-speed to variable speed turbines) at Bad Creek II, which will **result in slightly higher hydraulic capacities** than originally modeled
- Generation flows will increase by just ~2 percent while flows under pumping will increase by ~9 percent; therefore, **only updated pumping capacities will be modeled**
- Three scenarios will be modeled: full pond (1,110 ft msl), max drawdown (1,080 ft msl), and intermediate (1,096 ft msl); these elevations are consistent with those modeled during the feasibility study
- Because focus is on near-field flows (i.e., vicinity of inlet/outlet structure), the same CFD model used for the **feasibility study** will be used for updated modeling instead of the CFD model used for the relicensing study (which focused on flows downstream of the weir)
- Findings will be drafted **as an addendum** to the previous CFD Report and will be distributed to stakeholders for review in Q2

Previous Results (Feasibility Study) - Existing Operations

- Similar figures will be developed for updated pumping at Bad Creek II with proposed I/O structure

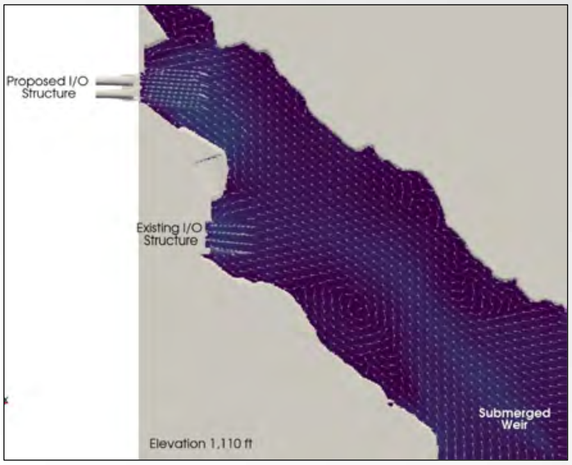


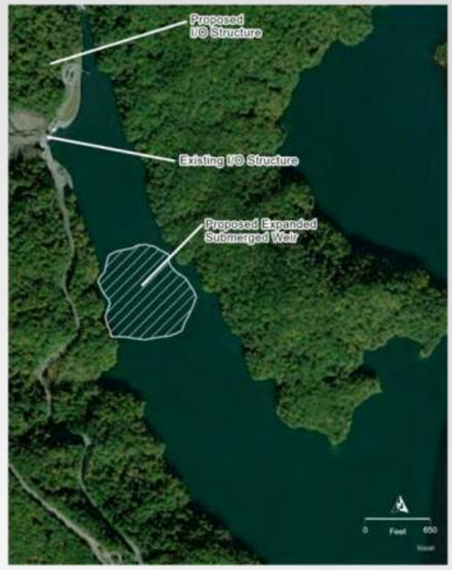
Existing I/O Pumping at 1,110 ft msl



Existing I/O Pumping at 1,080 ft msl

Proposed I/O Structure Location – Set back from shoreline ~200 ft





29

Action Items

30

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Cc:	Stuart, Alan Witten
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda (COMMENTS DUE 4/26)
Date:	Friday, April 19, 2024 4:41:30 PM
Attachments:	image001.png

From: Charles (Rowdy) B Harris <charris@scprt.com>
Sent: Friday, April 19, 2024 4:35 PM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>; Adin T Fell <afell@scprt.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda (COMMENTS DUE 4/26)

SCPRT has no comments.

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Friday, April 19, 2024 7:52 AM
To: PellettC@dnr.sc.gov <PellettC@dnr.sc.gov>; Alison.Jakupca@KleinschmidtGroup.com <Alison.Jakupca@KleinschmidtGroup.com>; BreedloveA@dnr.sc.gov <BreedloveA@dnr.sc.gov>; grossea@dnr.sc.gov <grossea@dnr.sc.gov>; attawaya@dnr.sc.gov <attawaya@dnr.sc.gov>; bereskind@greenvillewater.com <bereskind@greenvillewater.com>; wes.cooler@mac.com <wes.cooler@mac.com>; RankinD@dnr.sc.gov <RankinD@dnr.sc.gov>; adoug41@att.net <adoug41@att.net>; mixong@dnr.sc.gov <mixong@dnr.sc.gov>; jhains@g.clemson.edu <jhains@g.clemson.edu>; ehollis@upstateforever.org <ehollis@upstateforever.org>; jphillips@greenvillewater.com <jphillips@greenvillewater.com>; kindelj@dnr.sc.gov <kindelj@dnr.sc.gov>; jtk7140@me.com <jtk7140@me.com>; bradleyk@dnr.sc.gov <bradleyk@dnr.sc.gov>; Kelly.Kirven@KleinschmidtGroup.com <Kelly.Kirven@KleinschmidtGroup.com>; forresterk@dnr.sc.gov <forresterk@dnr.sc.gov>; quattrol@dnr.sc.gov <quattrol@dnr.sc.gov>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Kerry.McCarney-Castle@hdrinc.com <Kerry.McCarney-Castle@hdrinc.com>; Abney, Michael A <Michael.Abney@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; lputnammitchell@gmail.com <lputnammitchell@gmail.com>; amedeemd@dhec.sc.gov <amedeemd@dhec.sc.gov>; kernm@dnr.sc.gov <kernm@dnr.sc.gov>; Mularski, Eric -HDRInc <Eric.Mularski@HDRInc.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; melanie_olds@fws.gov <melanie_olds@fws.gov>; cloningerp@dnr.sc.gov <cloningerp@dnr.sc.gov>; morep@dnr.sc.gov <morep@dnr.sc.gov>; bill.ranson@retiree.furman.edu <bill.ranson@retiree.furman.edu>; SelfR@dnr.sc.gov <SelfR@dnr.sc.gov>; Charles (Rowdy) B Harris <charris@scprt.com>; Maggie.Salazar@hdrinc.com <Maggie.Salazar@hdrinc.com>; Tessels@dnr.sc.gov <Tessels@dnr.sc.gov>; Fletcher, Scott T <Scott.Fletcher@duke-energy.com>; harders@dnr.sc.gov <harders@dnr.sc.gov>; Erin.Settevendemio@hdrinc.com <Erin.Settevendemio@hdrinc.com>; cstarker@upstateforever.org <cstarker@upstateforever.org>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; danielt@dnr.sc.gov <danielt@dnr.sc.gov>; dwilde@keoweefolks.org <dwilde@keoweefolks.org>; woodw@dnr.sc.gov <woodw@dnr.sc.gov>; suewilliams130@gmail.com <suewilliams130@gmail.com>; simmonsw@dnr.sc.gov <simmonsw@dnr.sc.gov>; gcyantis2@yahoo.com <gcyantis2@yahoo.com>; Kevin Nebiolo <Kevin.Nebiolo@KleinschmidtGroup.com>; Jen Huff <jen.huff@hdrinc.com>; Andrew Gleason

<andrewandwilla@hotmail.com>; Glenn Hilliard <glenn@hilliardgrp.com>; phil.mitchell@gmail.com <phil.mitchell@gmail.com>
Cc: Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Angie.Scangas@hdrinc.com <angie.scangas@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>
Subject: RE: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda (COMMENTS DUE 4/26)

Dear Bad Creek Resource Committee members:

Just a reminder that comments are due on the CHEOPS Modeling Draft Report by next Friday, April 26.

Thanks,
John

From: Crutchfield Jr., John U
Sent: Wednesday, March 27, 2024 7:23 AM
To: PellettC@dnr.sc.gov; Alison.Jakupca@KleinschmidtGroup.com; BreedloveA@dnr.sc.gov; grossea@dnr.sc.gov; attawaya@dnr.sc.gov; bereskind@greenvillewater.com; wes.cooler@mac.com; RankinD@dnr.sc.gov; adoug41@att.net; mixong@dnr.sc.gov; jhains@g.clemson.edu; ehollis@upstateforever.org; jphillips@greenvillewater.com; kindelj@dnr.sc.gov; jtk7140@me.com; bradleyk@dnr.sc.gov; Kelly.Kirven@KleinschmidtGroup.com; forresterk@dnr.sc.gov; quattrol@dnr.sc.gov; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Kerry.McCarney-Castle@hdrinc.com; Abney, Michael A <Michael.Abney@duke-energy.com>; millere@dnr.sc.gov; lputnammitchell@gmail.com; amedeemd@dhec.sc.gov; kernm@dnr.sc.gov; Eric Mularski <Eric.Mularski@hdrinc.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; melanie_olds@fws.gov; cloningerp@dnr.sc.gov; morep@dnr.sc.gov; bill.ranson@retiree.furman.edu; SelfR@dnr.sc.gov; charris@scprt.com; Maggie.Salazar@hdrinc.com; Tessels@dnr.sc.gov; Fletcher, Scott T <Scott.Fletcher@duke-energy.com>; harders@dnr.sc.gov; Erin.Settevendemio@hdrinc.com; cstarker@upstateforever.org; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; danielt@dnr.sc.gov; dwilde@keoweefolks.org; woodw@dnr.sc.gov; suewilliams130@gmail.com; simmonsw@dnr.sc.gov; gcyantis2@yahoo.com; Kevin Nebiolo <Kevin.Nebiolo@KleinschmidtGroup.com>; Jen Huff <jen.huff@hdrinc.com>; Andrew Gleason <andrewandwilla@hotmail.com>; Glenn Hilliard <glenn@hilliardgrp.com>; phil.mitchell@gmail.com
Cc: Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Sarah Kulpa <Sarah.Kulpa@hdrinc.com>; Angie.Scangas@hdrinc.com; Ziegler, Ty <ty.ziegler@hdrinc.com>
Subject: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda

Dear Bad Creek Resource Committee members:

Duke Energy is pleased to distribute the draft Water Resources – Task 4 (i.e., CHEOPS Modeling) report for your review. This draft includes the results from CHEOPS modeling for the Baseline and Bad Creek II scenarios as well as populated Performance Measures sheets. The draft report is available on the SharePoint site using this link: Bad Creek Relicensing Project – Resource Committees - Draft CHEOPS report - All Documents (sharepoint.com).

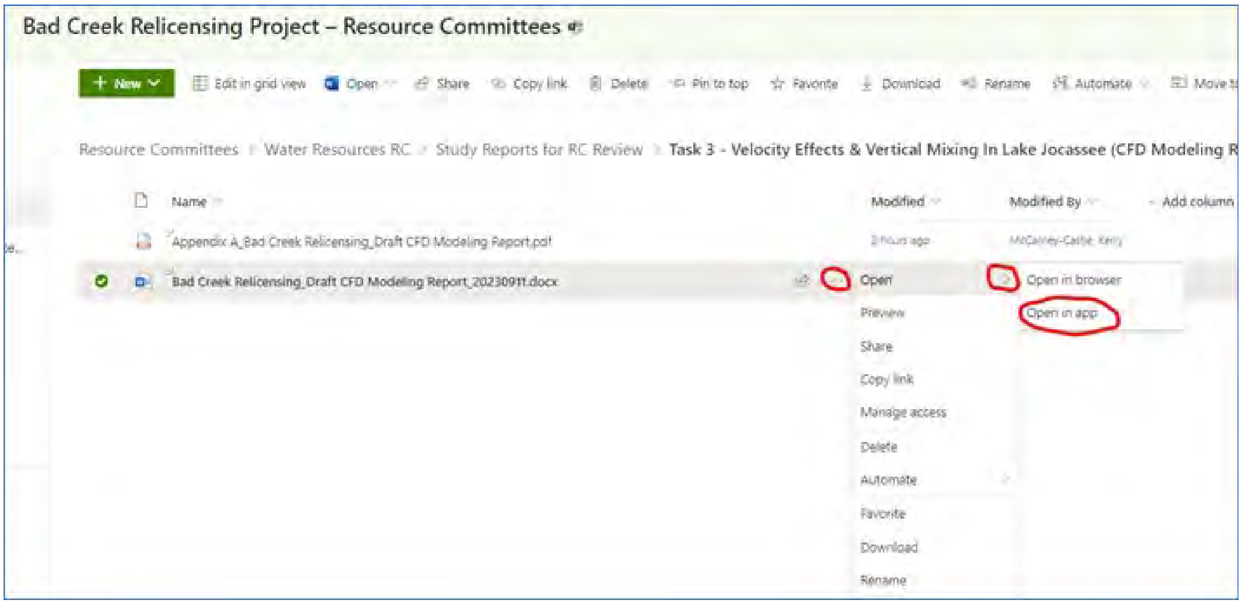
Please provide your comments within the draft report using Track Changes as explained further below within 30 days (**April 26, 2024).** When you have completed your review – even if you have no comments – I would appreciate an email stating that is the case.

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy is providing relicensing deliverables on the SharePoint site for relicensing participants to access, review, and comment on files. Please provide all comments in the SharePoint Word document using tracked changes. This will eliminate version control issues, enable relicensing participants to gain insight into one another's comments, and result in a consolidated document for comment response.

- We strongly recommend opening the document in Word; otherwise the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to [@McCarney-Castle, Kerry] for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**[Editing a Document in SharePoint]". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



We will be discussing the draft report and report findings during the April 4, 2024, Joint Resource Committee meeting. I have attached the meeting agenda for your reference.

If you have questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry; Stuart, Alan Witten
Subject:	Fwd: [EXTERNAL] Re: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda (COMMENTS DUE 4/26)
Date:	Saturday, April 20, 2024 7:26:23 AM
Attachments:	image001.png

From: Yantis Gerry <gcyantis2@yahoo.com>
Sent: Saturday, April 20, 2024 3:24 AM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Cc: Sue Williams <suewilliams130@gmail.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda (COMMENTS DUE 4/26)

John,
From an AQD perspective, we have no comments CHEOPS Modeling Draft Report.
Thank you,
Gerry
Advocates for Quality Development

On Friday, April 19, 2024, 1:52 PM, Crutchfield Jr., John U <John.Crutchfield@duke-energy.com> wrote:

Dear Bad Creek Resource Committee members:

Just a reminder that comments are due on the CHEOPS Modeling Draft Report by next Friday, April 26.

Thanks,
John

From: Crutchfield Jr., John U
Sent: Wednesday, March 27, 2024 7:23 AM
To: PellettC@dnr.sc.gov; Alison.Jakupca@KleinschmidtGroup.com; BreedloveA@dnr.sc.gov; grossea@dnr.sc.gov; attawaya@dnr.sc.gov; bereskind@greenvillewater.com; wes.cooler@mac.com; RankinD@dnr.sc.gov; adoug41@att.net; mixong@dnr.sc.gov; jhains@g.clemson.edu; ehollis@upstateforever.org; jphillips@greenvillewater.com; kindelj@dnr.sc.gov; jtk7140@me.com; bradleyk@dnr.sc.gov; Kelly.Kirven@KleinschmidtGroup.com; forresterk@dnr.sc.gov; quattrol@dnr.sc.gov; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Kerry.McCarney-Castle@hdrinc.com; Abney, Michael A <Michael.Abney@duke-energy.com>; millere@dnr.sc.gov; lputnammitchell@gmail.com; amedeemd@dhec.sc.gov; kernm@dnr.sc.gov; Eric Mularski <Eric.Mularski@hdrinc.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; melanie_olds@fws.gov; cloningerp@dnr.sc.gov; morep@dnr.sc.gov; bill.ranson@retiree.furman.edu; SelfR@dnr.sc.gov; charris@scprt.com; Maggie.Salazar@hdrinc.com; Tessels@dnr.sc.gov; Fletcher, Scott T

<Scott.Fletcher@duke-energy.com>; harders@dnr.sc.gov; Erin.Settevendemio@hdrinc.com; cstarker@upstateforever.org; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; danielt@dnr.sc.gov; dwilde@keoweefolks.org; woodw@dnr.sc.gov; suewilliams130@gmail.com; simmonsw@dnr.sc.gov; gcyantis2@yahoo.com; Kevin Nebiolo <Kevin.Nebiolo@KleinschmidtGroup.com>; Jen Huff <jen.huff@hdrinc.com>; Andrew Gleason <andrewandwilla@hotmail.com>; Glenn Hilliard <glenn@hilliardgrp.com>; phil.mitchell@gmail.com
Cc: Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Sarah Kulpa <Sarah.Kulpa@hdrinc.com>; Angie.Scangas@hdrinc.com; Ziegler, Ty <ty.ziegler@hdrinc.com>
Subject: Bad Creek Relicensing - CHEOPS Modeling Draft Report Ready for Review and April 4 Meeting Agenda

Dear Bad Creek Resource Committee members:

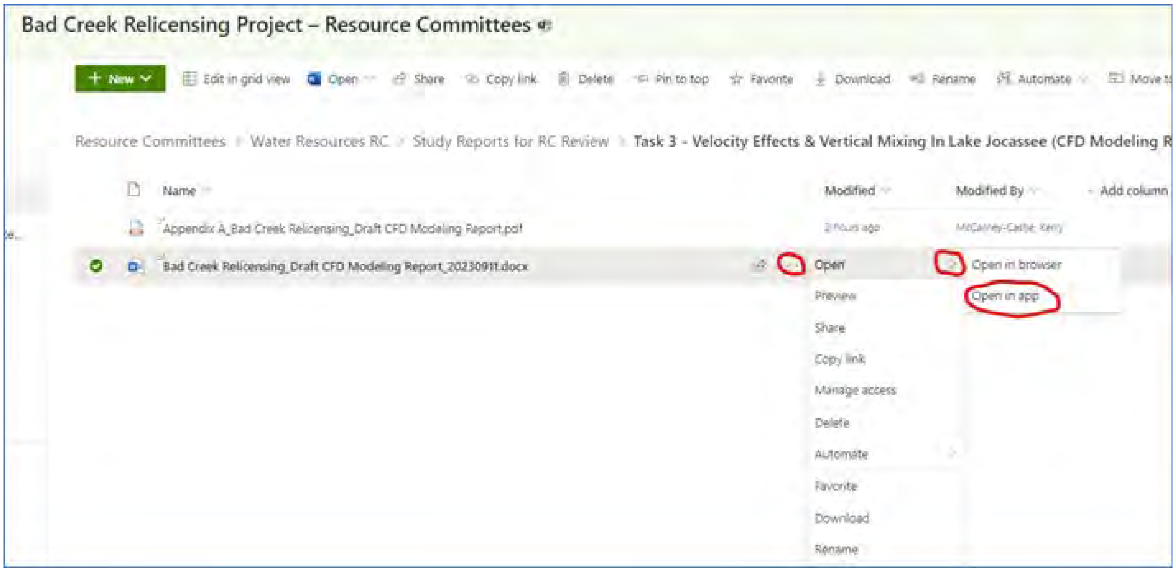
Duke Energy is pleased to distribute the draft Water Resources – Task 4 (i.e., CHEOPS Modeling) report for your review. This draft includes the results from CHEOPS modeling for the Baseline and Bad Creek II scenarios as well as populated Performance Measures sheets. The draft report is available on the SharePoint site using this link: Bad Creek Relicensing Project – Resource Committees - Draft CHEOPS report - All Documents (sharepoint.com).

Please provide your comments within the draft report using Track Changes as explained further below within 30 days (**April 26, 2024).** When you have completed your review – even if you have no comments – I would appreciate an email stating that is the case.

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy is providing relicensing deliverables on the SharePoint site for relicensing participants to access, review, and comment on files. Please provide all comments in the SharePoint Word document using tracked changes. This will eliminate version control issues, enable relicensing participants to gain insight into one another's comments, and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



We will be discussing the draft report and report findings during the April 4, 2024, Joint Resource Committee meeting. I have attached the meeting agenda for your reference.

If you have questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

Subject: FW: Bad Creek Relicensing - CHEOPS Modeling FINAL Report

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Tuesday, April 30, 2024 10:09 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Andrew Grosse <grossea@dnr.sc.gov>; Austen Attaway <attawaya@dnr.sc.gov>; bereskind <bereskind@greenvillewater.com>; Wes Cooler <wes.cooler@mac.com>; Dan Rankin <RankinD@dnr.sc.gov>; Andy Douglas <adoug41@att.net>; Greg Mixon <mixong@dnr.sc.gov>; jhains@g.clemson.edu; Erika Hollis <ehollis@upstateforever.org>; Jeff Phillips <jphillips@greenvillewater.com>; Jennifer Kindel <kindelj@dnr.sc.gov>; jtk7140@me.com; Keith A. Bradley <bradleyk@dnr.sc.gov>; Kelly Kirven <Kelly.Kirven@KleinschmidtGroup.com>; Ken Forrester <forresterk@dnr.sc.gov>; quattrol <quattrol@dnr.sc.gov>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; McCarney-Castle, Kerry <Kerry.McCarney-Castle@hdrinc.com>; Abney, Michael A <Michael.Abney@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; lputnammitchell <lputnammitchell@gmail.com>; Amedee, Morgan D. <amedeemd@dhec.sc.gov>; Morgan Kern <kernm@dnr.sc.gov>; Mularski, Eric <Eric.Mularski@HDRInc.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; Olds, Melanie J <melanie_olds@fws.gov>; Pat Cloninger <cloningerp@dnr.sc.gov>; More, Priyanka <morep@dnr.sc.gov>; Bill Ranson-Retired <bill.ranson@retiree.furman.edu>; SelfR <SelfR@dnr.sc.gov>; Charles (Rowdy) B Harris <charris@scprt.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>; Samantha Tessel <Tessels@dnr.sc.gov>; Fletcher, Scott T <Scott.Fletcher@duke-energy.com>; Scott Harder <harders@dnr.sc.gov>; Settevendemio, Erin <Erin.Settevendemio@hdrinc.com>; Chris Starker <cstarker@upstateforever.org>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Tom Daniel <danielt@dnr.sc.gov>; Dale Wilde <dwilde@keoweefolks.org>; William T. Wood <woodw@dnr.sc.gov>; suewilliams130@gmail.com; simmonsw@dnr.sc.gov; gcyantis2 <gcyantis2@yahoo.com>; Kevin Nebiolo <Kevin.Nebiolo@KleinschmidtGroup.com>; Huff, Jen <jen.huff@hdrinc.com>; Andrew Gleason <andrewandwilla@hotmail.com>; glenn@hilliardgrp.com; phil.mitchell@gmail.com
Cc: Lineberger, Jeff <Jeff.Lineberger@duke-energy.com>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Scangas, Angie <angie.scangas@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>
Subject: RE: Bad Creek Relicensing - CHEOPS Modeling FINAL Report

Dear Bad Creek Resource Committee members:

The CHEOPS modeling report has been finalized and can be accessed at the Bad Creek Relicensing SharePoint site:

20240326_Bad Creek_CHEOPS Final Report.pdf

Please let Alan or me know if you have any questions.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	Alex Pellett; Amy Breedlove; Dale Wilde; Dan Rankin; bereskind; Elizabeth Miller; Erika Hollis; gcyantis2; Jeff Phillips; Huff, Jen; McCarney-Castle, Kerry; quattrol; Olds, Melanie J; More, Priyanka; Amedee, Morgan D.; Raber, Maverick James; Ross Self; Scott Harder; Stuart, Alan Witten; William T. Wood; Abney, Michael A; Amy Breedlove; Dan Rankin; Elizabeth Miller; Erika Hollis; Settevendemio, Erin; gcyantis2; Huff, Jen; jhains@g.clemson.edu; quattrol; Olds, Melanie J; Amedee, Morgan D.; Morgan Kern; Ross Self; Stuart, Alan Witten; Wahl, Nick; William T. Wood; Alex Pellett; Alison Jakupca; Bruce, Ed; Dan Rankin; Dunn, Lynne; Elizabeth Miller; Greg Mixon; Huff, Jen; jhains@g.clemson.edu; Salazar, Maggie; Amedee, Morgan D.; Pat Cloninger; Charles (Rowdy) B Harris; Kulpa, Sarah; Stuart, Alan Witten; Terry Keene; Tom Daniel; Amy Breedlove; Andrew Gleason; Andy Douglas; Bill Ranson-Retired; Chris Starker; Dale Wilde; Dan Rankin; Elizabeth Miller; glenn@hilliardgrp.com; Huff, Jen; Kelly Kirven; Ken Forrester; quattrol; Salazar, Maggie; Amedee, Morgan D.; Pardue, Ethan; Pat Cloninger; Phil Mitchell; PShirley; Ross Self; Charles (Rowdy) B Harris; Stuart, Alan Witten; suewilliams130@gmail.com; William T. Wood; Willie Simmons
Cc:	Kulpa, Sarah; McCarney-Castle, Kerry; Ziegler, Ty; Scangas, Angie
Subject:	Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Date:	Wednesday, June 12, 2024 11:58:09 AM
Attachments:	image001.png image002.png
Importance:	High

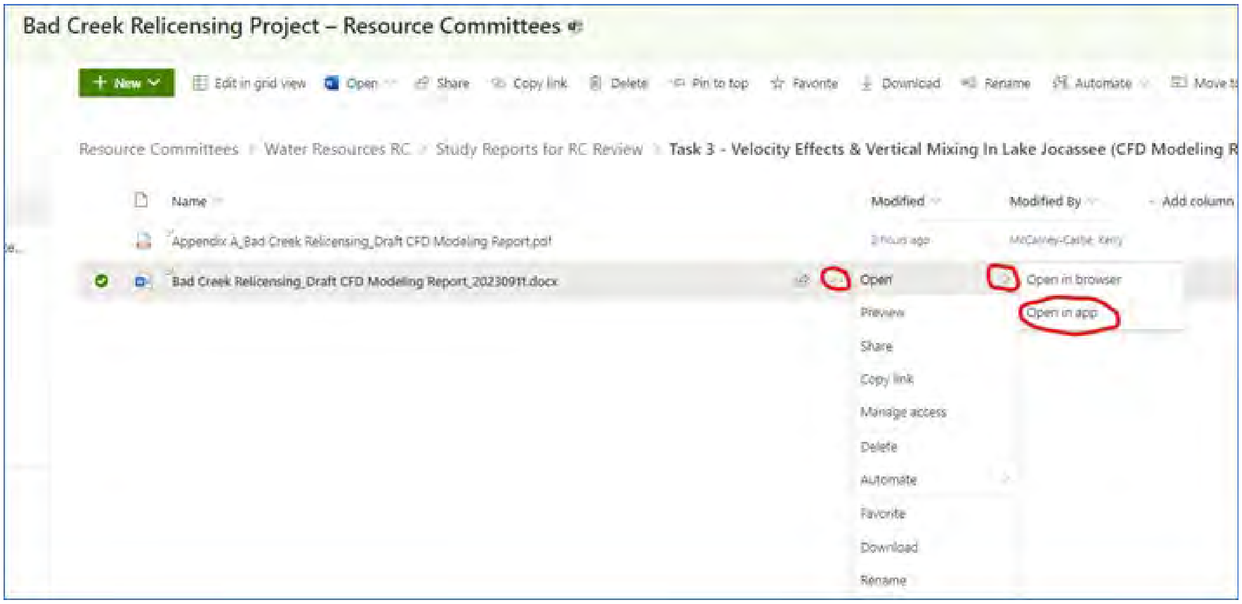
Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the **Bad Creek CFD Model Updated Pumping Rates Draft Addendum** for Resource Committee review. This draft report is the second addendum to the Task 3 final report (*Velocity Effects and Vertical Mixing in Lake Jocassee Duke to a Second Powerhouse*), which was filed with the Initial Study Report in January of this year. The purpose of the addendum is to provide results of additional CFD modeling performed to incorporate increased hydraulic pumping at Bad Creek II from a recently proposed technology modification (variable speed pump-turbines vs. single speed). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Addendum 2_Updated Pumping CFD Model Report. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **July 12**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment; therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



Also, please note this draft report addendum is being sent to the Water Resources, Aquatics, Operations, and Recreation & Visual Resource committees, and you may receive multiple emails if you are on several of these committees' distribution lists. I apologize in advance if you get multiple emails.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Date:	Wednesday, June 12, 2024 1:28:32 PM
Attachments:	image001.png image002.png

From: Andrew Gleason <andrewandwilla@hotmail.com>
Sent: Wednesday, June 12, 2024 1:25 PM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Cc: Bill Ranson-Retired <bill.ranson@retiree.furman.edu>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

I will not be making any comments on this report. Bill Ranson may, but I doubt it.

Andrew Gleason
Foothills Trail Conservancy Chairman
864-546-1589
andrewandwilla@hotmail.com

Foothills Trail

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Wednesday, June 12, 2024 11:57 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; David Bereskin <bereskind@greenvillewater.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Gerry Yantis <gcyantis2@yahoo.com>; Jeffrey Phillips <jphillips@greenvillewater.com>; Jen Huff <jen.huff@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; More Priyanka <morep@dnr.sc.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Ross Self <SelfR@dnr.sc.gov>; Scott Harder <harders@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Abney, Michael A <Michael.Abney@duke-energy.com>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Erin Settevendemio <Erin.Settevendemio@hdrinc.com>; Gerry Yantis <gcyantis2@yahoo.com>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds

<melanie_olds@fws.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Morgan Kern <kernm@dnr.sc.gov>; Ross Self <SelfR@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Alex Pellett <PellettC@dnr.sc.gov>; Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>; Bruce, Ed <Ed.Bruce@duke-energy.com>; Dan Rankin <RankinD@dnr.sc.gov>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Greg Mixon <mixong@dnr.sc.gov>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pat Cloninger <cloningerp@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Terry Keene <jtk7140@me.com>; Tom Daniel <danielt@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Andrew Gleason <andrewandwilla@hotmail.com>; Andy Douglas <adoug41@att.net>; Bill Ranson <bill.ranson@retiree.furman.edu>; Chris Starker <cstarker@upstateforever.org>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Glenn Hilliard <glenn@hilliardgrp.com>; Jen Huff <jen.huff@hdrinc.com>; Kelly Kirven <Kelly.Kirven@KleinschmidtGroup.com>; Ken Forrester <forresterk@dnr.sc.gov>; Lynn Quattro <quattrol@dnr.sc.gov>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pardue, Ethan <Ethan.Pardue@duke-energy.com>; Pat Cloninger <cloningerp@dnr.sc.gov>; Phil Mitchell <phil.mitchell@gmail.com>; Phil Shirley <pshirley@oconeeco.com>; Ross Self <SelfR@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Sue Williams <suewilliams130@gmail.com>; William Wood <woodw@dnr.sc.gov>; Willie Simmons <simmonsw@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>; Angie.Scangas@hdrinc.com <angie.scangas@hdrinc.com>
Subject: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

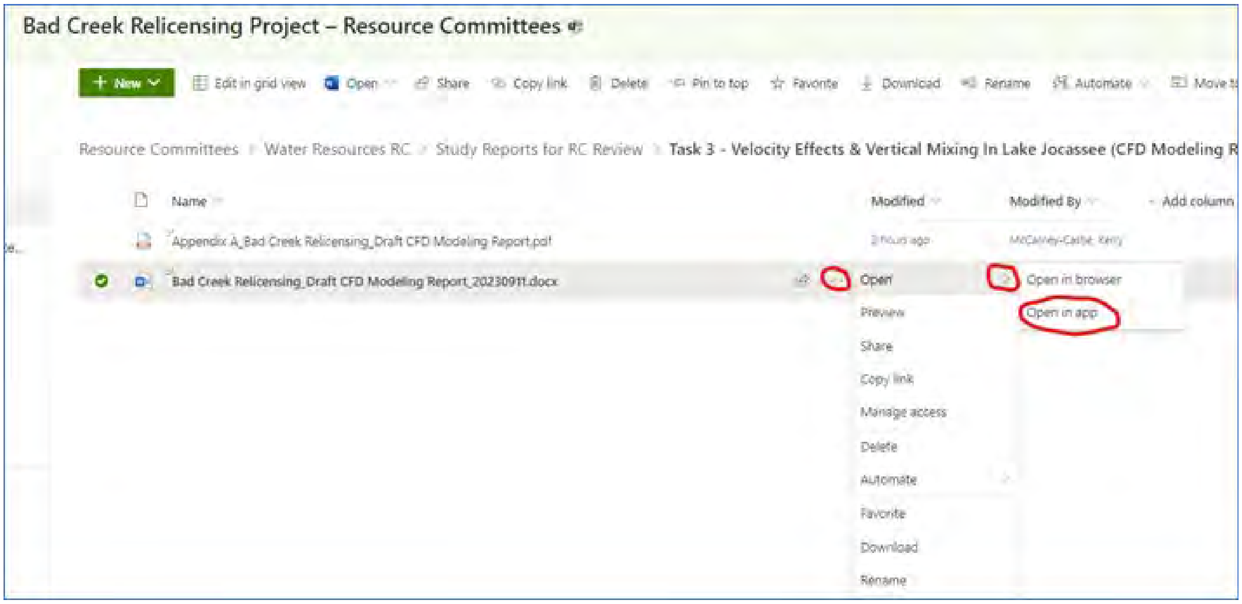
Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the **Bad Creek CFD Model Updated Pumping Rates Draft Addendum** for Resource Committee review. This draft report is the second addendum to the Task 3 final report (*Velocity Effects and Vertical Mixing in Lake Jocassee Duke to a Second Powerhouse*), which was filed with the Initial Study Report in January of this year. The purpose of the addendum is to provide results of additional CFD modeling performed to incorporate increased hydraulic pumping at Bad Creek II from a recently proposed technology modification (variable speed pump-turbines vs. single speed). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Addendum 2_Updated Pumping CFD Model Report. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **July 12**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment; therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!*])



Also, please note this draft report addendum is being sent to the Water Resources, Aquatics, Operations, and Recreation & Visual Resource committees, and you may receive multiple emails if you are on several of these committees' distribution lists. I apologize in advance if you get multiple emails.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Date:	Wednesday, June 12, 2024 12:51:28 PM

From: Sue Williams <suewilliams130@gmail.com>
Sent: Wednesday, June 12, 2024 12:50 PM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

I have reviewed the Addendum.

Sue Williams
Six Mile, SC

On Jun 12, 2024, at 11:58, Crutchfield Jr., John U <John.Crutchfield@duke-energy.com> wrote:

Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the **Bad Creek CFD Model Updated Pumping Rates Draft Addendum** for Resource Committee review. This draft report is the second addendum to the Task 3 final report (*Velocity Effects and Vertical Mixing in Lake Jocassee Duke to a Second Powerhouse*), which was filed with the Initial Study Report in January of this year. The purpose of the addendum is to provide results of additional CFD modeling performed to incorporate increased hydraulic pumping at Bad Creek II from a recently proposed technology modification (variable speed pump-turbines vs. single speed). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link:
<image001.png>
Addendum 2_Updated Pumping CFD Model Report. Duke Energy is requesting a 30-

day review period, therefore, please submit all comments by **July 12**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

1. As discussed in the kick-off meeting (July 2022), Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment; therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.

2. We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

    (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!*])

<image002.png>

Also, please note this draft report addendum is being sent to the Water Resources, Aquatics, Operations, and Recreation & Visual Resource committees, and you may receive multiple emails if you are on several of these committees' distribution lists. I apologize in advance if you get multiple emails.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] CFD Model Report
Date:	Tuesday, July 2, 2024 11:00:12 AM

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

FYI.

From: John Hains <jhains@g.clemson.edu>
Sent: Tuesday, July 2, 2024 10:59 AM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Cc: Dale Wilde <dwilde@keoweefolks.org>
Subject: [EXTERNAL] CFD Model Report

***** CAUTION! EXTERNAL SENDER *** STOP. ASSESS. VERIFY!!** Were you expecting this email? Are grammar and spelling correct? Does the content make sense? Can you verify the sender? If suspicious report it, then do not click links, open attachments or enter your ID or password.

Good Morning John,

I have finished my review of the report and as I think I mentioned to Alan at an earlier date, I believe the modeling for this is good and I have criticism neither of the way it was done, nor of the report and addendum.

However, when subsequent field studies have commenced in order to confirm the predictions of the model, I stand by my request to make before/after field data from Lake Jocassee available. It would also be useful in that analysis to revisit the before/after operational lake data for Bad Creek I...for the purpose of making a complete comparison between the proposed project and the way the lake responded to the original project.

I will be glad to discuss this further with you if that is needed.

Best,

John Hains

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Date:	Wednesday, July 3, 2024 5:05:16 PM
Attachments:	image001.png image002.png

From: Erika Hollis <ehollis@upstateforever.org>
Sent: Wednesday, July 3, 2024 4:12 PM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

John,

I have reviewed the Bad Creek CFD Model Update and have no comments.

Thank you,
Erika Hollis

Erika J. Hollis
Clean Water Director
Upstate Forever
507 Pettigru St
Greenville, SC 29601
(864) 250-0500 ext. 117
ehollis@upstateforever.org

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Date: Wednesday, June 12, 2024 at 11:58 AM
To: Alex Pellett <PellettC@dnr.sc.gov>, Amy Breedlove <BreedloveA@dnr.sc.gov>, dwilde@keoweefolks.org <dwilde@keoweefolks.org>, Dan Rankin <RankinD@dnr.sc.gov>, David Bereskin <bereskind@greenvillewater.com>, Elizabeth Miller <MillerE@dnr.sc.gov>, Erika Hollis <ehollis@upstateforever.org>, Gerry Yantis <gcyantis2@yahoo.com>, Jeffrey Phillips <jphillips@greenvillewater.com>, Jen Huff <jen.huff@hdrinc.com>, Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>, Lynn Quattro <quattrol@dnr.sc.gov>, Melanie Olds <melanie_olds@fws.gov>, More Priyanka <morep@dnr.sc.gov>, Morgan Amedee <amedeemd@dhec.sc.gov>, Raber, Maverick James <Maverick.Raber@duke-energy.com>, Ross Self <SelfR@dnr.sc.gov>, Scott Harder <harders@dnr.sc.gov>, alan.stuart@duke-energy.com <alan.stuart@duke-energy.com>, William Wood <woodw@dnr.sc.gov>, Abney, Michael A <Michael.Abney@duke-energy.com>, Amy Breedlove <BreedloveA@dnr.sc.gov>, Dan Rankin <RankinD@dnr.sc.gov>, Elizabeth Miller <MillerE@dnr.sc.gov>, Erika Hollis

<ehollis@upstateforever.org>, Erin Settevendemio <Erin.Settevendemio@hdrinc.com>, Gerry Yantis <gcyantis2@yahoo.com>, Jen Huff <jen.huff@hdrinc.com>, John Haines <jhains@g.clemson.edu>, Lynn Quattro <quattrol@dnr.sc.gov>, Melanie Olds <melanie_olds@fws.gov>, Morgan Amedee <amedeemd@dhec.sc.gov>, Morgan Kern <kernm@dnr.sc.gov>, Ross Self <SelfR@dnr.sc.gov>, alan.stuart@duke-energy.com <alan.stuart@duke-energy.com>, Wahl, Nick <Nick.Wahl@duke-energy.com>, William Wood <woodw@dnr.sc.gov>, Alex Pellett <PellettC@dnr.sc.gov>, Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>, Bruce, Ed <Ed.Bruce@duke-energy.com>, Dan Rankin <RankinD@dnr.sc.gov>, Dunn, Lynne <Lynne.Dunn@duke-energy.com>, Elizabeth Miller <MillerE@dnr.sc.gov>, Greg Mixon <mixong@dnr.sc.gov>, Jen Huff <jen.huff@hdrinc.com>, John Haines <jhains@g.clemson.edu>, Maggie Salazar <maggie.salazar@hdrinc.com>, Morgan Amedee <amedeemd@dhec.sc.gov>, Pat Cloninger <cloningerp@dnr.sc.gov>, Rowdy Harris <charris@scprt.com>, Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>, alan.stuart@duke-energy.com <alan.stuart@duke-energy.com>, Terry Keene <jtk7140@me.com>, Tom Daniel <danielt@dnr.sc.gov>, Amy Breedlove <BreedloveA@dnr.sc.gov>, Andrew Gleason <andrewandwilla@hotmail.com>, Andy Douglas <adoug41@att.net>, Bill Ranson <bill.ranson@retiree.furman.edu>, Chris Starker <cstarker@upstateforever.org>, dwilde@keoweefolks.org <dwilde@keoweefolks.org>, Dan Rankin <RankinD@dnr.sc.gov>, Elizabeth Miller <MillerE@dnr.sc.gov>, Glenn Hilliard <glenn@hilliardgrp.com>, Jen Huff <jen.huff@hdrinc.com>, Kelly Kirven <Kelly.Kirven@KleinschmidtGroup.com>, Ken Forrester <forresterk@dnr.sc.gov>, Lynn Quattro <quattrol@dnr.sc.gov>, Maggie Salazar <maggie.salazar@hdrinc.com>, Morgan Amedee <amedeemd@dhec.sc.gov>, Pardue, Ethan <Ethan.Pardue@duke-energy.com>, Pat Cloninger <cloningerp@dnr.sc.gov>, Phil Mitchell <phil.mitchell@gmail.com>, Phil Shirley <pshirley@oconeeco.com>, Ross Self <SelfR@dnr.sc.gov>, Rowdy Harris <charris@scprt.com>, alan.stuart@duke-energy.com <alan.stuart@duke-energy.com>, Sue Williams <suewilliams130@gmail.com>, William Wood <woodw@dnr.sc.gov>, Willie Simmons <simmonsw@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>, Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>, Ziegler, Ty <ty.ziegler@hdrinc.com>, Angie.Scangas@hdrinc.com <angie.scangas@hdrinc.com>
Subject: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the **Bad Creek CFD Model Updated Pumping Rates Draft Addendum** for Resource Committee review. This draft report is the second addendum to the Task 3 final report (*Velocity Effects and Vertical Mixing in Lake Jocassee Duke to a Second Powerhouse*), which was filed with the Initial Study Report in January of this year. The purpose of the addendum is to provide results of additional CFD modeling performed to incorporate increased hydraulic pumping at Bad Creek II from a recently proposed technology modification (variable speed pump-turbines vs. single speed). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Addendum 2_Updated Pumping CFD Model Report. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **July 12**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

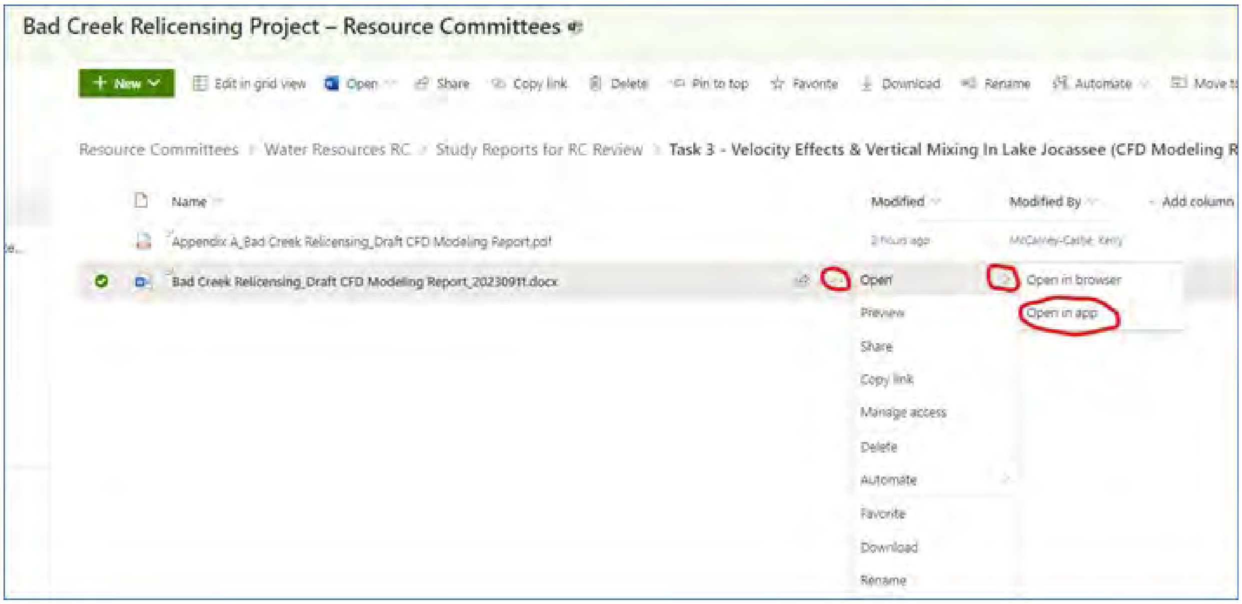
Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment;

therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.

- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



Also, please note this draft report addendum is being sent to the Water Resources, Aquatics, Operations, and Recreation & Visual Resource committees, and you may receive multiple emails if you are on several of these committees' distribution lists. I apologize in advance if you get multiple emails.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Date:	Monday, July 8, 2024 7:34:49 AM

From: Dale Wilde <dwilde@keoweefolks.org>
Sent: Monday, July 8, 2024 7:32 AM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

John,

To my knowledge, John Hains was going to submit his comments. To date he has had no negative comments regarding this model.

See you Thursday.

Ms. Dale Wilde
President, FOLKS
C: 207-604-6539
E: dwilde@keoweefolks.org

Friends of Lake Keowee Society is dedicated to the preservation and enhancement of Lake Keowee and its watershed through advocacy, conservation, and education.

> On Jul 8, 2024, at 6:54 AM, Crutchfield Jr., John U <John.Crutchfield@duke-energy.com> wrote:
>
> Dear Bad Creek Relicensing Resources Committees:
>
> Just a reminder that comments on the Bad Creek CFD Model Updated Pumping Rates

Draft Addendum are due by **July 12**.

Thanks, John

From: Crutchfield Jr., John U
Sent: Wednesday, June 12, 2024 11:58 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; David Bereskin <bereskind@greenvillewater.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Gerry Yantis <gcyantis2@yahoo.com>; Jeffrey Phillips <jphillips@greenvillewater.com>; Jen Huff <jen.huff@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; More Priyanka <morep@dnr.sc.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Ross Self <SelfR@dnr.sc.gov>; Scott Harder <harders@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Abney, Michael A <Michael.Abney@duke-energy.com>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Erin Settevendemio <Erin.Settevendemio@hdrinc.com>; Gerry Yantis <gcyantis2@yahoo.com>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Morgan Kern <kernm@dnr.sc.gov>; Ross Self <SelfR@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Alex Pellett <PellettC@dnr.sc.gov>; Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>; Bruce, Ed <Ed.Bruce@duke-energy.com>; Dan Rankin <RankinD@dnr.sc.gov>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Greg Mixon <mixong@dnr.sc.gov>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pat Cloninger <cloningerp@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Sarah Kulpa <Sarah.Kulpa@hdrinc.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Terry Keene <jtk7140@me.com>; Tom Daniel <danielt@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Andrew Gleason <andrewandwilla@hotmail.com>; Andy Douglas <adoug41@att.net>; Bill Ranson <bill.ranson@retiree.furman.edu>; Chris Starker <cstarker@upstateforever.org>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Glenn Hilliard <glenn@hilliardgrp.com>; Jen Huff <jen.huff@hdrinc.com>; Kelly Kirven <Kelly.Kirven@KleinschmidtGroup.com>; Ken Forrester <forresterk@dnr.sc.gov>; Lynn Quattro <quattrol@dnr.sc.gov>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pardue, Ethan <Ethan.Pardue@duke-energy.com>; Pat Cloninger <cloningerp@dnr.sc.gov>; Phil Mitchell <phil.mitchell@gmail.com>; Phil Shirley <pshirley@oconeeco.com>; Ross Self <SelfR@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Stuart, Alan Witten

<Alan.Stuart@duke-energy.com>; Sue Williams <suewilliams130@gmail.com>; William Wood <woodw@dnr.sc.gov>; Willie Simmons <simmonsw@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>; Angie.Scangas@hdrinc.com
Subject: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Importance: High

Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the **Bad Creek CFD Model Updated Pumping Rates Draft Addendum** for Resource Committee review. This draft report is the second addendum to the Task 3 final report (*Velocity Effects and Vertical Mixing in Lake Jocassee Duke to a Second Powerhouse*), which was filed with the Initial Study Report in January of this year. The purpose of the addendum is to provide results of additional CFD modeling performed to incorporate increased hydraulic pumping at Bad Creek II from a recently proposed technology modification (variable speed pump-turbines vs. single speed). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link:
<image001.png>
Addendum 2_Updated Pumping CFD Model Report. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **July 12**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

1. As discussed in the kick-off meeting (July 2022), Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment; therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
2. We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

   (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides* *an alternative way to open the document in Word – either technique works!])*

<image002.png>

Also, please note this draft report addendum is being sent to the Water Resources, Aquatics, Operations, and Recreation & Visual Resource committees, and you may receive multiple emails if you are on several of these committees' distribution lists. I apologize in advance if you get multiple emails.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Date:	Monday, July 8, 2024 7:48:25 AM
Attachments:	image001.png image002.png

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

From: Andrew Gleason <andrewandwilla@hotmail.com>
Sent: Monday, July 8, 2024 7:45 AM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Cc: Bill Ranson-Retired <bill.ranson@retiree.furman.edu>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

***** CAUTION! EXTERNAL SENDER *** STOP. ASSESS. VERIFY!!** Were you expecting this email? Are grammar and spelling correct? Does the content make sense? Can you verify the sender? If suspicious report it, then do not click links, open attachments or enter your ID or password.

I have reviewed and do not have any comments.

Andrew Gleason
Foothills Trail Conservancy Chairman
864-546-1589
andrewandwilla@hotmail.com

Foothills Trail

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Monday, July 8, 2024 6:53 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; David Bereskin <bereskind@greenvillewater.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Gerry Yantis <gcyantis2@yahoo.com>; Jeffrey Phillips <jphillips@greenvillewater.com>; Jen Huff <jen.huff@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; More Priyanka <morep@dnr.sc.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Ross Self <SelfR@dnr.sc.gov>; Scott Harder <harders@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Abney, Michael A <Michael.Abney@duke-energy.com>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Erin Settevendemio <Erin.Settevendemio@hdrinc.com>; Gerry Yantis <gcyantis2@yahoo.com>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds

<melanie_olds@fws.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Morgan Kern <kernm@dnr.sc.gov>; Ross Self <SelfR@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Alex Pellett <PellettC@dnr.sc.gov>; Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>; Bruce, Ed <Ed.Bruce@duke-energy.com>; Dan Rankin <RankinD@dnr.sc.gov>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Greg Mixon <mixong@dnr.sc.gov>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pat Cloninger <cloningerp@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Terry Keene <jtk7140@me.com>; Tom Daniel <danielt@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Andrew Gleason <andrewandwilla@hotmail.com>; Andy Douglas <adoug41@att.net>; Bill Ranson <bill.ranson@retiree.furman.edu>; Chris Starker <cstarker@upstateforever.org>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Glenn Hilliard <glenn@hilliardgrp.com>; Jen Huff <jen.huff@hdrinc.com>; Kelly Kirven <Kelly.Kirven@KleinschmidtGroup.com>; Ken Forrester <forresterk@dnr.sc.gov>; Lynn Quattro <quattrol@dnr.sc.gov>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pardue, Ethan <Ethan.Pardue@duke-energy.com>; Pat Cloninger <cloningerp@dnr.sc.gov>; Phil Mitchell <phil.mitchell@gmail.com>; Phil Shirley <pshirley@oconeeco.com>; Ross Self <SelfR@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Sue Williams <suewilliams130@gmail.com>; William Wood <woodw@dnr.sc.gov>; Willie Simmons <simmonsw@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>; Angie.Scangas@hdrinc.com <angie.scangas@hdrinc.com>
Subject: RE: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

Dear Bad Creek Relicensing Resources Committees:

Just a reminder that comments on the Bad Creek CFD Model Updated Pumping Rates Draft Addendum are due by **July 12**.

Thanks, John

From: Crutchfield Jr., John U
Sent: Wednesday, June 12, 2024 11:58 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; David Bereskin <bereskind@greenvillewater.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Gerry Yantis <gcyantis2@yahoo.com>; Jeffrey Phillips <jphillips@greenvillewater.com>; Jen Huff <jen.huff@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; More Priyanka <morep@dnr.sc.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Ross Self <SelfR@dnr.sc.gov>; Scott Harder <harders@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Abney, Michael A <Michael.Abney@duke-energy.com>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Erin Settevendemio <Erin.Settevendemio@hdrinc.com>; Gerry Yantis <gcyantis2@yahoo.com>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Morgan Kern <kernm@dnr.sc.gov>; Ross Self <SelfR@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Alex Pellett <PellettC@dnr.sc.gov>; Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>; Bruce, Ed <Ed.Bruce@duke-energy.com>; Dan Rankin <RankinD@dnr.sc.gov>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Greg Mixon <mixong@dnr.sc.gov>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Maggie

Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pat Cloninger <cloningerp@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Sarah Kulpa <Sarah.Kulpa@hdrinc.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Terry Keene <jtk7140@me.com>; Tom Daniel <danielt@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Andrew Gleason <andrewandwilla@hotmail.com>; Andy Douglas <adoug41@att.net>; Bill Ranson <bill.ranson@retiree.furman.edu>; Chris Starker <cstarker@upstateforever.org>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Glenn Hilliard <glenn@hilliardgrp.com>; Jen Huff <jen.huff@hdrinc.com>; Kelly Kirven <Kelly.Kirven@KleinschmidtGroup.com>; Ken Forrester <forresterk@dnr.sc.gov>; Lynn Quattro <quattrol@dnr.sc.gov>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pardue, Ethan <Ethan.Pardue@duke-energy.com>; Pat Cloninger <cloningerp@dnr.sc.gov>; Phil Mitchell <phil.mitchell@gmail.com>; Phil Shirley <pshirley@oconeeco.com>; Ross Self <SelfR@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Sue Williams <suewilliams130@gmail.com>; William Wood <woodw@dnr.sc.gov>; Willie Simmons <simmonsw@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>; Angie.Scangas@hdrinc.com
Subject: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Importance: High

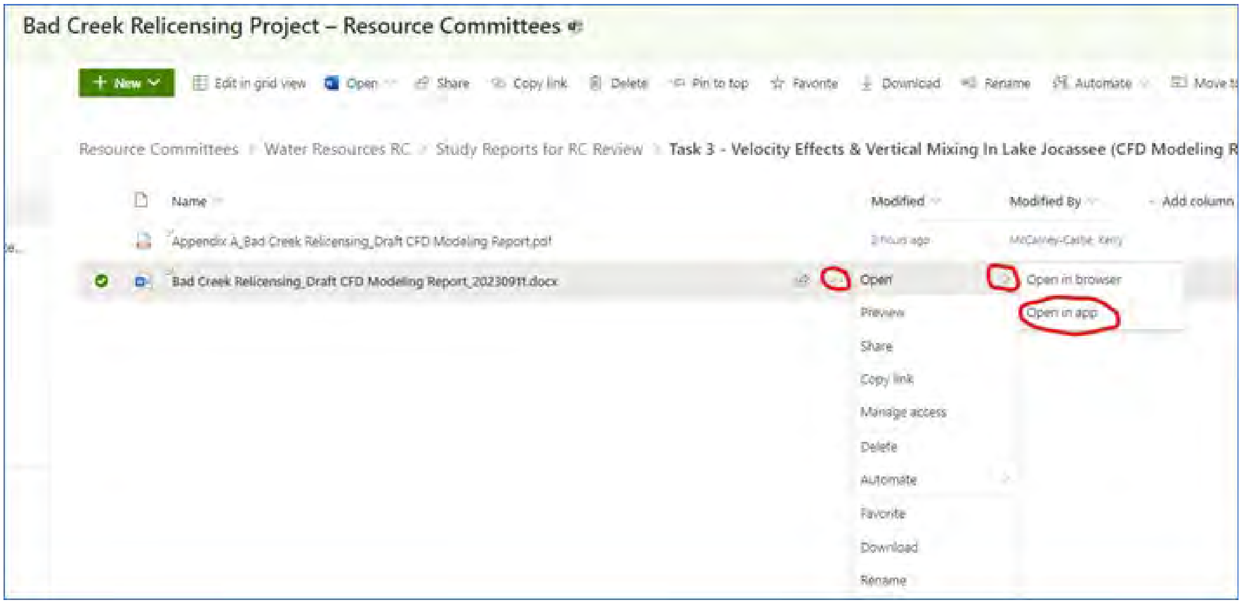
Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the **Bad Creek CFD Model Updated Pumping Rates Draft Addendum** for Resource Committee review. This draft report is the second addendum to the Task 3 final report (*Velocity Effects and Vertical Mixing in Lake Jocassee Duke to a Second Powerhouse*), which was filed with the Initial Study Report in January of this year. The purpose of the addendum is to provide results of additional CFD modeling performed to incorporate increased hydraulic pumping at Bad Creek II from a recently proposed technology modification (variable speed pump-turbines vs. single speed). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Addendum 2_Updated Pumping CFD Model Report. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **July 12**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment; therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



Also, please note this draft report addendum is being sent to the Water Resources, Aquatics, Operations, and Recreation & Visual Resource committees, and you may receive multiple emails if you are on several of these committees' distribution lists. I apologize in advance if you get multiple emails.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Date:	Tuesday, July 9, 2024 6:50:04 AM
Attachments:	image001.png image002.png

From: Bill Ranson-Retired <bill.ranson@retiree.furman.edu>
Sent: Tuesday, July 9, 2024 6:24 AM
To: Andrew Gleason <andrewandwilla@hotmail.com>; Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

No comments from me.
Bill Ranson

From: Andrew Gleason <andrewandwilla@hotmail.com>
Date: Wednesday, June 12, 2024 at 1:24 PM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Cc: Bill Ranson-Retired <bill.ranson@retiree.furman.edu>
Subject: Re: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

I will not be making any comments on this report. Bill Ranson may, but I doubt it.

Andrew Gleason
Foothills Trail Conservancy Chairman
864-546-1589
andrewandwilla@hotmail.com

Foothills Trail

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Wednesday, June 12, 2024 11:57 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dale Wilde

<dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; David Bereskin <bereskind@greenvillewater.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Gerry Yantis <gcyantis2@yahoo.com>; Jeffrey Phillips <jphillips@greenvillewater.com>; Jen Huff <jen.huff@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; More Priyanka <morep@dnr.sc.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Ross Self <SelfR@dnr.sc.gov>; Scott Harder <harders@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Abney, Michael A <Michael.Abney@duke-energy.com>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Erin Settevendemio <Erin.Settevendemio@hdrinc.com>; Gerry Yantis <gcyantis2@yahoo.com>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Morgan Kern <kernm@dnr.sc.gov>; Ross Self <SelfR@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Alex Pellett <PellettC@dnr.sc.gov>; Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>; Bruce, Ed <Ed.Bruce@duke-energy.com>; Dan Rankin <RankinD@dnr.sc.gov>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Greg Mixon <mixong@dnr.sc.gov>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pat Cloninger <cloningerp@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Terry Keene <jtk7140@me.com>; Tom Daniel <danielt@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Andrew Gleason <andrewandwilla@hotmail.com>; Andy Douglas <adoug41@att.net>; Bill Ranson <bill.ranson@retiree.furman.edu>; Chris Starker <cstarker@upstateforever.org>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Glenn Hilliard <glenn@hilliardgrp.com>; Jen Huff <jen.huff@hdrinc.com>; Kelly Kirven <Kelly.Kirven@KleinschmidtGroup.com>; Ken Forrester <forresterk@dnr.sc.gov>; Lynn Quattro <quattrol@dnr.sc.gov>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pardue, Ethan <Ethan.Pardue@duke-energy.com>; Pat Cloninger <cloningerp@dnr.sc.gov>; Phil Mitchell <phil.mitchell@gmail.com>; Phil Shirley <pshirley@oconeeco.com>; Ross Self <SelfR@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Sue Williams <suewilliams130@gmail.com>; William Wood <woodw@dnr.sc.gov>; Willie Simmons <simmonsw@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>; Angie.Scangas@hdrinc.com <angie.scangas@hdrinc.com>
Subject: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the **Bad Creek CFD Model Updated Pumping Rates Draft Addendum** for Resource Committee review. This draft report is the second addendum to the Task 3 final report (*Velocity Effects and Vertical Mixing in Lake Jocassee Duke to a Second Powerhouse*), which was filed with the Initial Study Report in January of this year. The purpose of the addendum is to provide results of additional CFD modeling performed to incorporate increased hydraulic pumping at Bad Creek II from a recently proposed technology modification (variable speed pump-turbines vs. single speed). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Addendum 2_Updated Pumping CFD Model Report. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **July 12**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

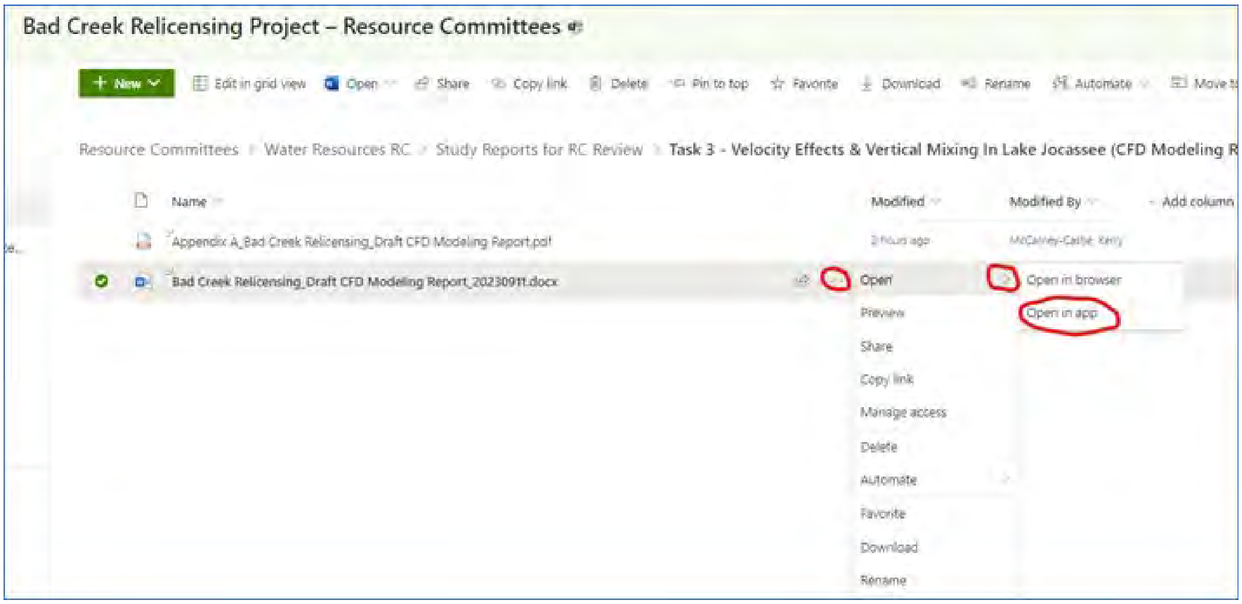
Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment;

therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.

- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to [@McCarney-Castle, Kerry](#) for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**[Editing a Document in SharePoint](#)". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



Also, please note this draft report addendum is being sent to the Water Resources, Aquatics, Operations, and Recreation & Visual Resource committees, and you may receive multiple emails if you are on several of these committees' distribution lists. I apologize in advance if you get multiple emails.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)
Date:	Tuesday, July 9, 2024 11:53:06 AM
Attachments:	image001.png image002.png Outlook-lr0l3pdt.png Outlook-goyfw22v.png

---

From: Olds, Melanie J <melanie_olds@fws.gov>
Sent: Tuesday, July 9, 2024 11:34 AM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Subject: Re: [EXTERNAL] Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

John,

Due to workload and not having expertise in this type of model the Service will not be reviewing and will defer to other Resource Committee's members for their expertise and comments.

Melanie

Melanie Olds

Fish & Wildlife Biologist

Regulatory Team Lead/FERC Coordinator

U.S. Fish and Wildlife Service

South Carolina Ecological Services Field Office

176 Croghan Spur Road, Suite 200

Charleston, SC 29407

Phone: (843) 534-0403

From: Morgan D. Amedee
To: Stuart, Alan Witten; Charles W. Hightower
Cc: Crutchfield Jr., John U; Kulpa, Sarah; McCarney-Castle, Kerry; Ziegler, Ty; Mularski, Eric; William R. "Rusty" Wenerick
Subject: Re: [EXTERNAL] Re: Thursday"s meeting agenda
Date: Tuesday, August 6, 2024 2:40:41 PM
Attachments: image001.png
Outlook-lripksit.png

Hi Alan,

Thank you for the update.

Kind regards,

Morgan Amedee
Project Manager
Water Quality Certification and Wetlands Section
Water Quality Division
O: (803) 898-4179
Morgan.Amedee@des.sc.gov
DES.SC.gov

SC DEPARTMENT of ENVIRONMENTAL SERVICES

Please note my new email address, with the SC Department of Environmental Services (SCDES), which launched as a new state agency on July 1, 2024. While my old DHEC email will direct to me for a while, please update your address book with my new SCDES contact information.

From: Stuart, Alan Witten <Alan.Stuart@duke-energy.com>
Sent: Tuesday, August 6, 2024 1:42 PM
To: Morgan D. Amedee <Morgan.Amedee@des.sc.gov>; Charles W. Hightower <Charles.Hightower@des.sc.gov>
Cc: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; McCarney-Castle, Kerry <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Mularski, Eric -HDRInc <Eric.Mularski@HDRInc.com>; William R. "Rusty" Wenerick <Rusty.Wenerick@des.sc.gov>
Subject: RE: [EXTERNAL] Re: Thursday's meeting agenda

unexpected email. ***

Good afternoon Morgan,

After reviewing the short-term forecast and potential effects Hurricane Debby may have on the SC Midlands, we have decided to convene Thursday's meeting virtually. We believe this is the best approach to keeping people safe.

I will update the Microsoft Teams meeting notice to include a MS Teams option for the Virtual meeting. I will also add Rusty to the distribution list.

We believe we can still have a productive meeting going the Virtual route and appreciate everyone's flexibility.

Please keep an eye out for the updated Outlook notice.

Questions, please let me know. Otherwise, talk to you on Thursday !

Thanks !
Alan

From: Morgan D. Amedee <Morgan.Amedee@des.sc.gov>
Sent: Monday, August 5, 2024 1:18 PM
To: Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Charles W. Hightower <Charles.Hightower@des.sc.gov>
Cc: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; McCarney-Castle, Kerry <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Mularski, Eric -HDRInc <Eric.Mularski@HDRInc.com>; William R. "Rusty" Wenerick <Rusty.Wenerick@des.sc.gov>
Subject: [EXTERNAL] Re: Thursday's meeting agenda

Hi Alan,

Thank you for sending the proposed meeting agenda.

Chuck will be unable to attend the meeting this Thursday. However, my colleague Rusty Wenerick, who is cc'd on this email, will be joining us.

Even if our offices are closed, we are still required to work remotely. In this case, a virtual meeting would be the best option.

Kind regards,

Morgan Amedee
Project Manager
Water Quality Certification and Wetlands Section
Water Quality Division
O: (803) 898-4179
Morgan.Amedee@des.sc.gov
DES.SC.gov

SC DEPARTMENT of ENVIRONMENTAL SERVICES

Please note my new email address, with the SC Department of Environmental Services (SCDES), which launched as a new state agency on July 1, 2024. While my old DHEC email will direct to me for a while, please update your address book with my new SCDES contact information.

From: Stuart, Alan Witten <Alan.Stuart@duke-energy.com>
Sent: Monday, August 5, 2024 12:15 PM
To: Morgan D. Amedee <Morgan.Amedee@des.sc.gov>; Charles W. Hightower <Charles.Hightower@des.sc.gov>
Cc: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; McCarney-Castle, Kerry <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Mularski, Eric -HDRInc <Eric.Mularski@HDRInc.com>
Subject: Thursday's meeting agenda

Good morning Morgan/Chuck,

Below is our proposed meeting Agenda with items we'd like to on Thursday. At this point, we are still planning to meet in-person at HDR's office in Columbia. However, recognizing the fact that Hurricane Debby may throw us a curve ball. Worst case if we need to regroup, we will conduct a Virtual meeting if conditions get really bad in the Columbia area. Hopefully, things won't get really bad but we'll make a decision by mid-day Wednesday on how best to proceed to ensure everyone's safety

One question, if Governor McMaster shuts down state government offices in the Columbia area on Wednesday into Thursday, I assume we will be forced to postpone the meeting since you folks technically won't be working. This a fair statement ?

Thanks !
Alan

Welcome and Meeting Purpose
Safety Moment
Introductions
Project Overview (Existing and Proposed Projects)
Relicensing / 401 WQC Schedule and Studies
Agency Coordination and CWA 404/401 WQC Process
Bad Creek II Proposed Water Quality Monitoring Plan
Future Meetings / Information Needs
Next Steps and Action Items
Closing

Alan Stuart
Senior Project Manager, Regulated & Renewable Energy
Duke Energy
525 S.Tryon St., DEP – 35B | Charlotte, NC 28202
Office 980-373-2079 |Cell 803-640-8765

Bad Creek II Power Complex Project

Water Quality Permitting Discussion

DUKE ENERGY®

BUILDING A SMARTER ENERGY FUTURE®

AUGUST 8, 2024

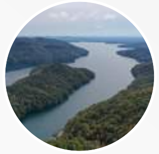
Meeting Agenda

- Welcome and Meeting Purpose
- Safety Moment
- Introductions
- Project Overview (Existing and Proposed Projects)
- Relicensing / 401 WQC Schedule and Studies
- Agency Coordination and CWA 404/401 WQC Process
- Bad Creek II Proposed Water Quality Monitoring Plan
- Future Meetings / Information Needs
- Next Steps and Action Items
- Closing

Safety Moment – Back to School Safety

Source: https://www.safety.af.mil/News/Article-Display/Article/2320756/school-is-back-safety-tips/

Bad Creek II Power Complex Project - Introductions



Lead Technical Manager

- John Crutchfield – Duke Energy

Project Manager

- Alan Stuart – Duke Energy

Clean Water Act Permitting Lead

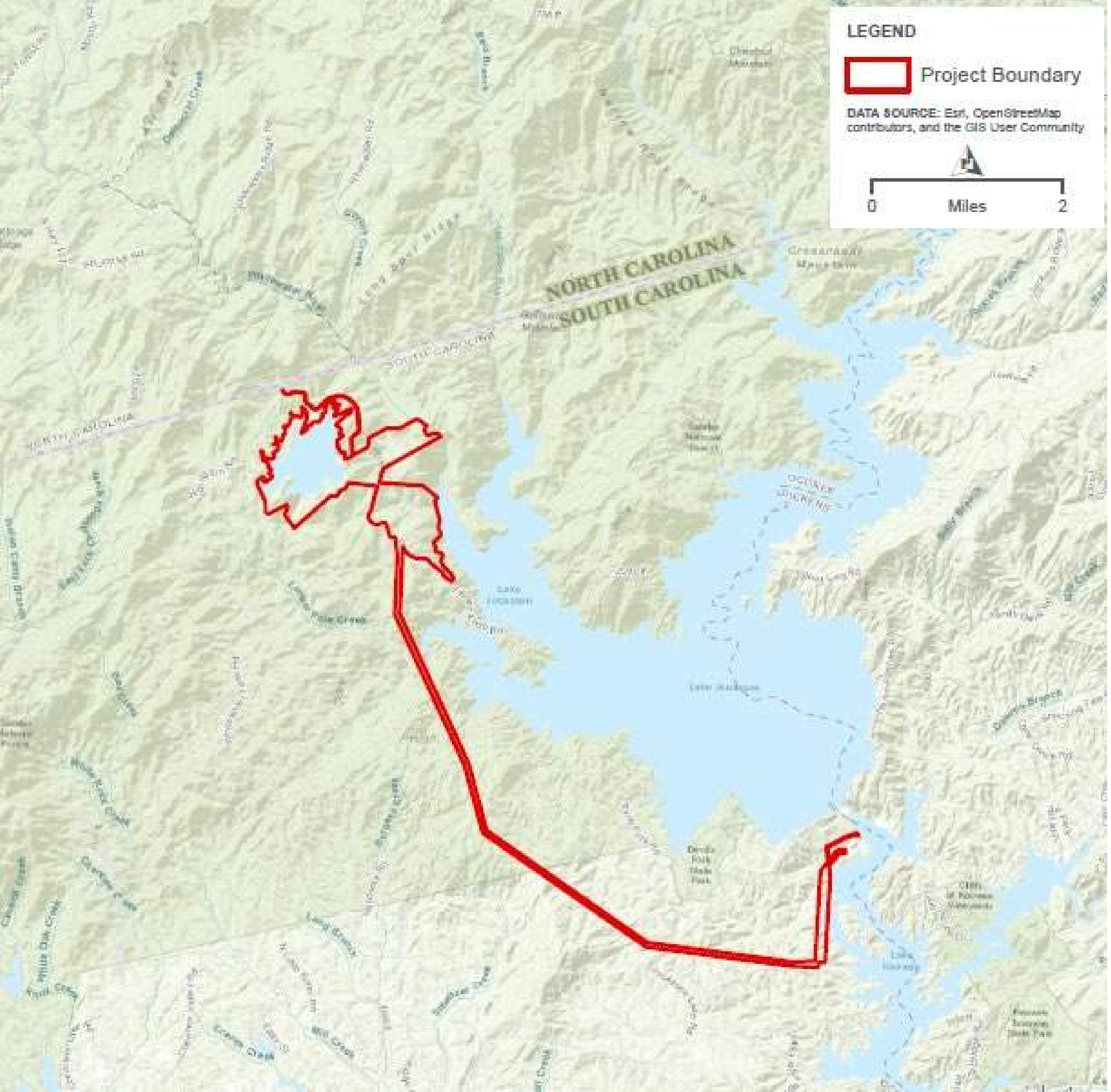
- Eric Mularski - HDR

FERC Relicensing Consultant Lead

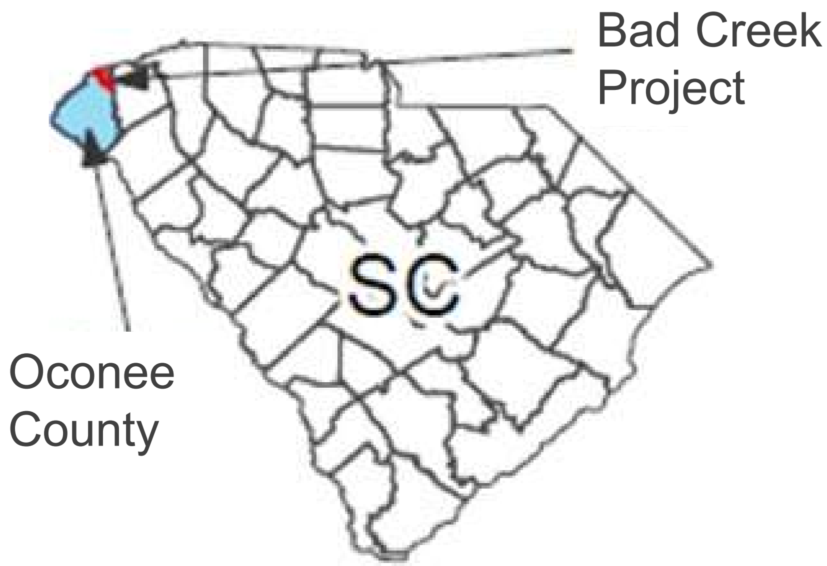
- Sarah Kulpa - HDR

Project Overview

- Existing Bad Creek Pumped Storage Station

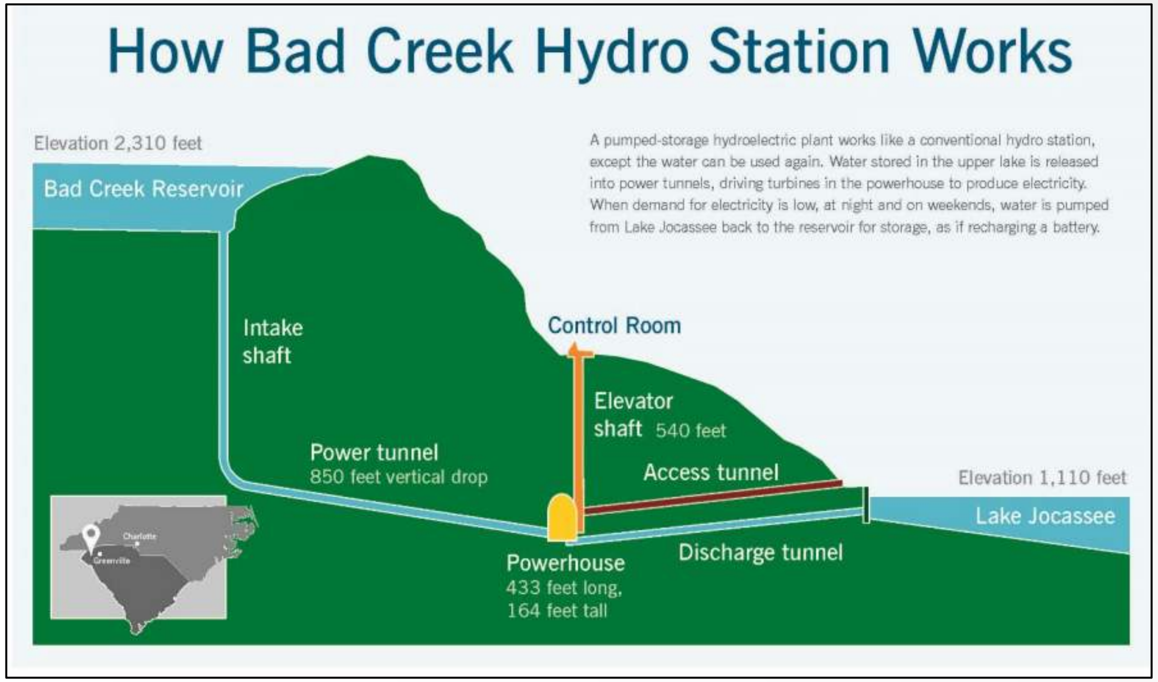


Site Location and Existing FERC Project Boundary



Bad Creek Pumped Storage Station Background

- The Bad Creek Pumped Storage Project (FERC No. 2740) uses the Bad Creek Upper Reservoir as the upper pool and Lake Jocassee as the lower pool. Lake Jocasee is licensed as part of the Keowee-Toxaway Hydroelectric Project.
- Construction was completed in 1991. The existing Bad Creek license expires <u>July 31, 2027</u>. Project currently undergoing relicensing.



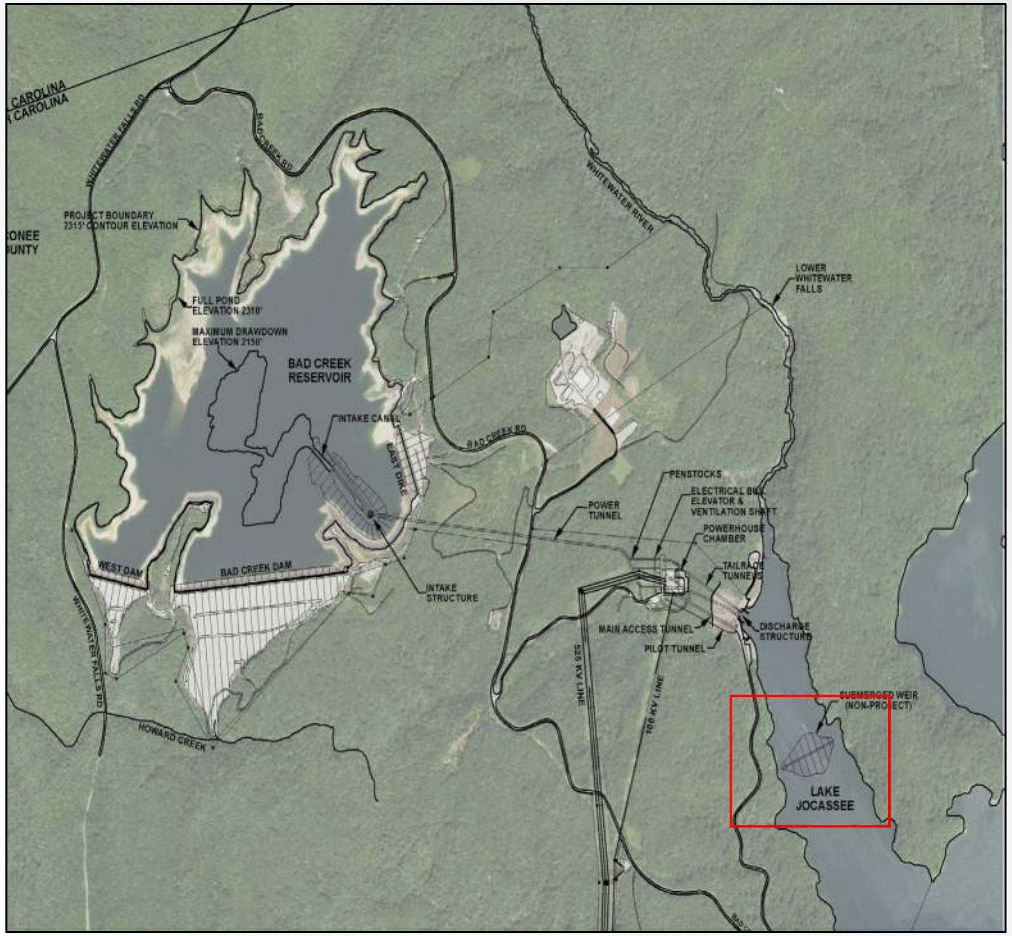
- Operations consist of pumping water from Lake Jocassee up to the Bad Creek Reservoir, providing a means of storing energy from surplus generation during over-supply or low demand periods, and provides power back to the grid when energy demand is higher by releasing water back to Lake Jocassee.
- There is no public access to the upper reservoir due to large fluctuations in water levels.

Bad Creek Pumped Storage Station Background

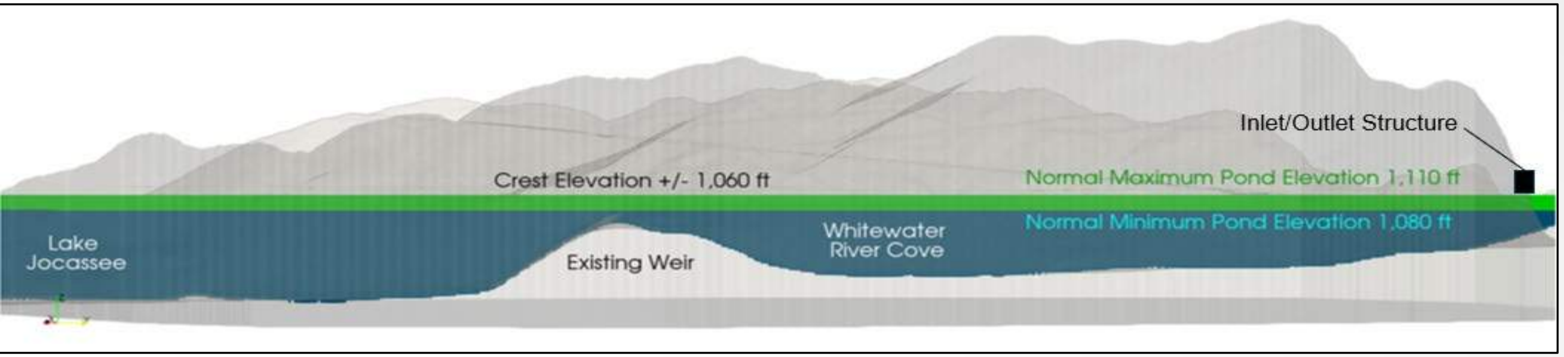
- The powerhouse is a three-level structure located in a mined rock cavern 600 ft underground. Bad Creek has 4 pump-turbine units with an Authorized Installed Capacity of 1,400 MW.

- Project inlet/outlet structure is located in the Whitewater River Cove of Lake Jocassee; at full pond, water surface is 40 feet above intake.

Existing Submerged Weir



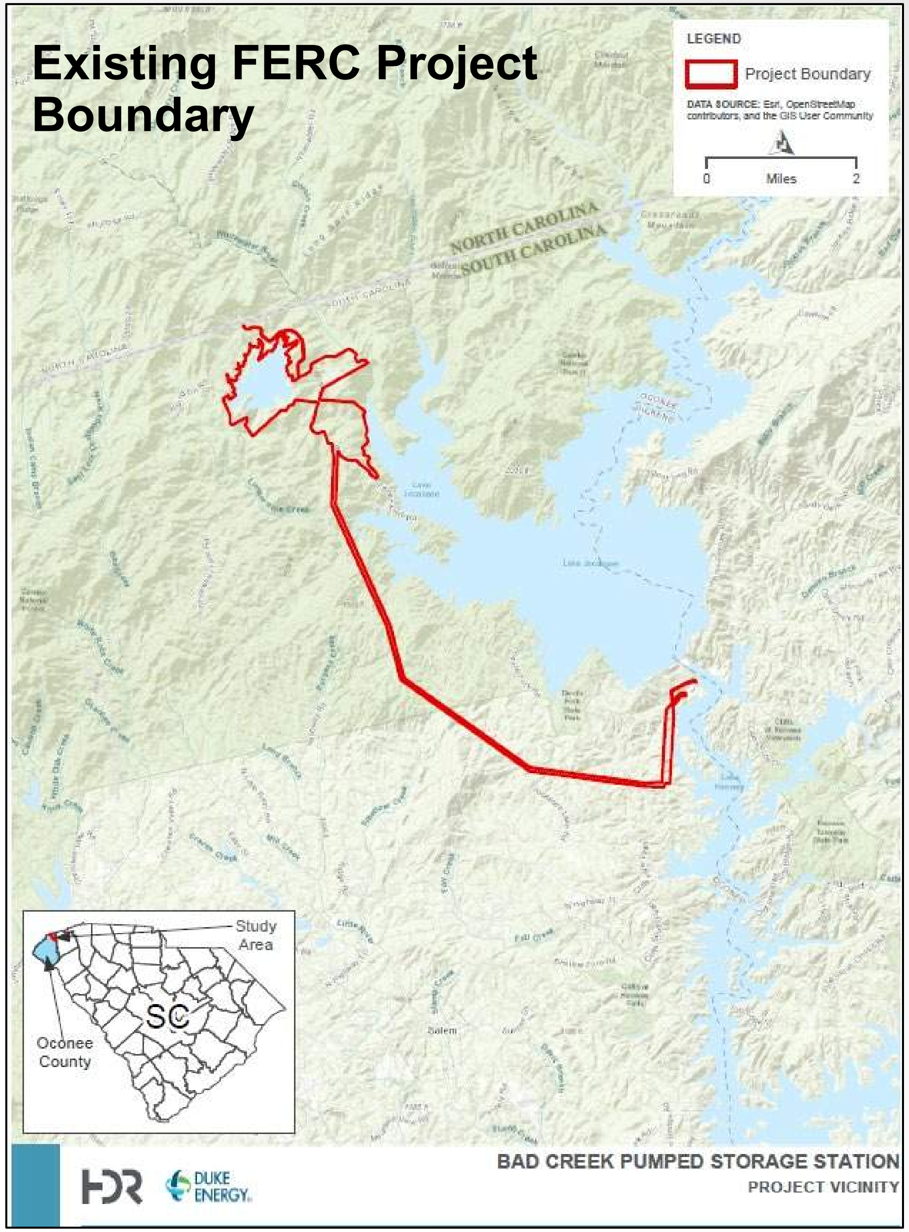
- Built out of half a million cubic yards of rock excavated during original underground excavation.
- Located approx. 1,800 feet downstream of the existing Inlet/Outlet structure.
- The weir reduces vertical mixing of warmer water from the discharge with the cooler water in the lake (downstream of the weir) for protection of fish habitat.
- The weir also dissipates the energy from the discharged water.
- Duke Energy proposes to expand the weir in the downstream direction with excavated rock from the proposed powerhouse.



Project Overview

- Proposed Bad Creek II Power Complex

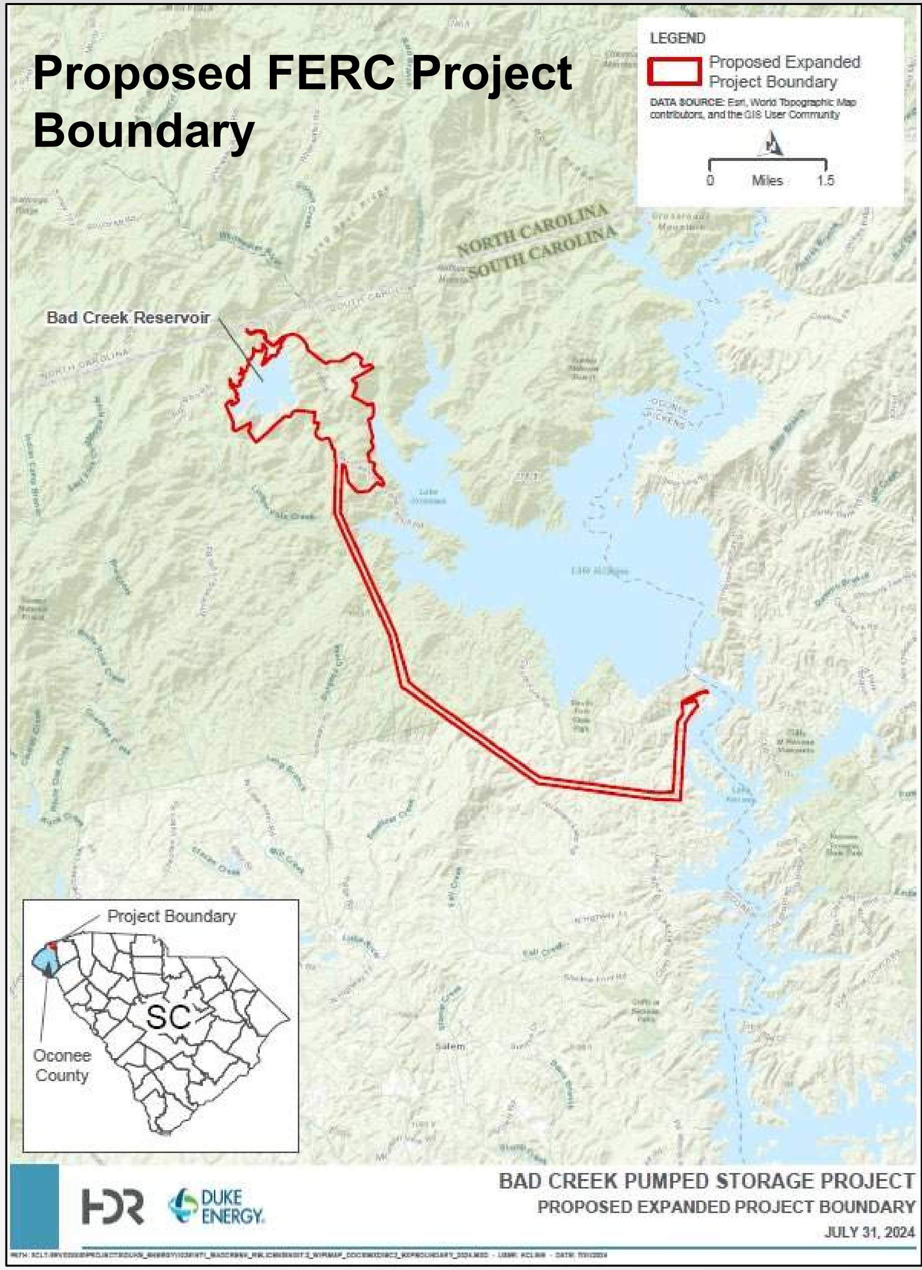
Proposed Expanded Project Boundary



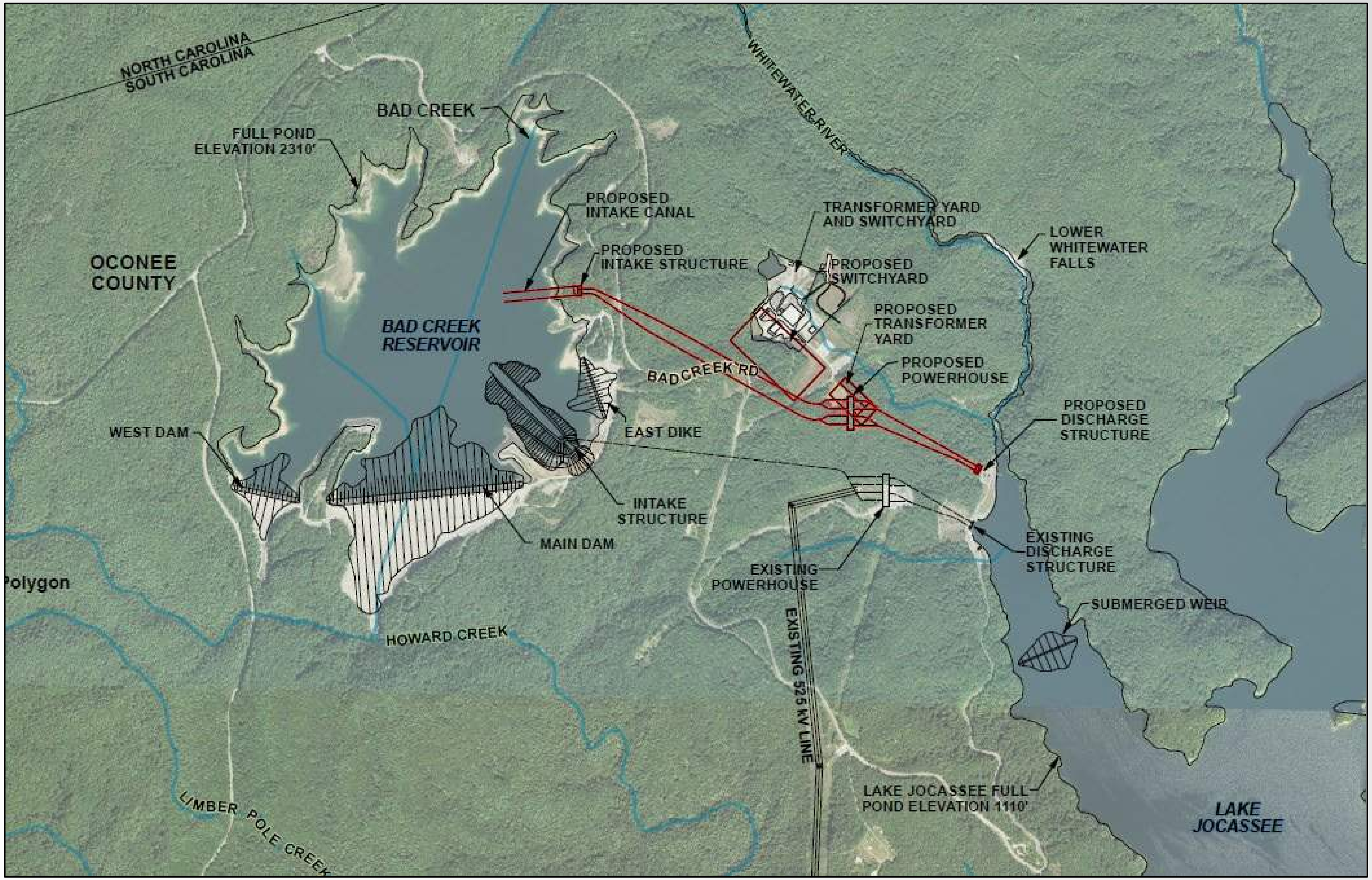
- Project boundary expanded to include areas potentially impacted from spoil placement and other activities associated with construction

- **Original:** 1,280 acres
- **Proposed:** 1,733 acres

(Increase of ~453 acres)



Proposed Bad Creek II Power Complex – Facilities Layout

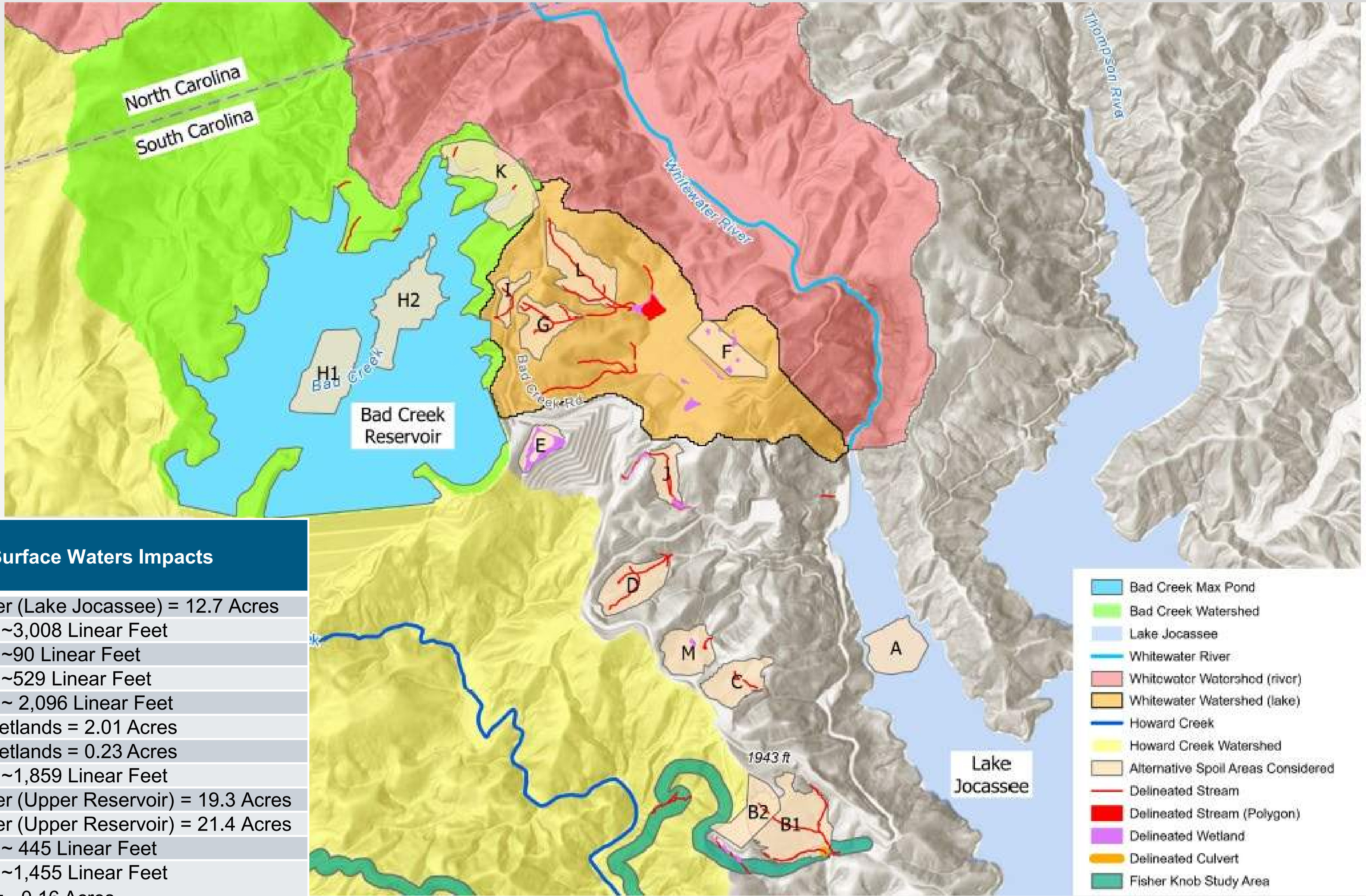


Proposed Bad Creek II Power Complex

View of proposed inlet/outlet structure from Whitewater River Cove

- Approximately **4.4 million cubic yards of excavated material** for Bad Creek II construction will need to be deposited at upland spoil locations and/or along the existing submerged weir in Lake Jocassee.

- Preferred potential areas for spoil placement are **currently under evaluation**.



	Volume (Million Cubic Yards)	Limits of Disturbance (Acres)	Surface Waters Impacts
A	1.3	12.7	Open Water (Lake Jocassee) = 12.7 Acres
B1	1.7	26.3	Streams = ~3,008 Linear Feet
B2			Streams = ~90 Linear Feet
C	0.6	11.1	Streams = ~529 Linear Feet
D	1.3	12.5	Streams = ~ 2,096 Linear Feet
E	0.16	6.2	Isolated Wetlands = 2.01 Acres
F	0.39	10.7	Isolated Wetlands = 0.23 Acres
G	1.1	10.5	Streams = ~1,859 Linear Feet
H1	1.5	19.3	Open Water (Upper Reservoir) = 19.3 Acres
H2	0.79	21.4	Open Water (Upper Reservoir) = 21.4 Acres
I	0.057	3.6	Streams = ~ 445 Linear Feet
J	0.44	6.9	Streams = ~1,455 Linear Feet Wetlands = ~0.16 Acres
K	1.0	21.9	Streams = ~211 Linear Feet Wetlands = ~0.04 Acres
L	1.1	16.6	Streams = ~2,519 Linear Feet
M	0.8	10.5	Streams = ~125 Linear Feet Open Water = ~0.08 Acres Wetlands = ~0.15 Acres

Relicensing/401 WQC Schedule and Studies

Bad Creek Pumped Storage Project – FERC Relicensing Milestones

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
Issue Scoping Document 2 (SD2) (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	Sept 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
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
ISR Meeting (18 CFR §5.15(c)(2))	Licensee Stakeholders	Within 15 days following filing of ISR	Jan 17, 2024
File ISR Meeting Summary (18 CFR §5.15(c)(3))	Licensee	Within 15 days following ISR Meeting	Feb 1, 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 1, 2024

Bad Creek Pumped Storage Project – FERC Relicensing Milestones (cont.)

Activity	Responsible Parties	Timeframe	Estimated Filing Date or Deadline
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 1, 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 1, 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
Deadline to File 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
Comments on 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

Bad Creek Pumped Storage Project – Relicensing Studies Overview

- Duke Energy proposed **<u>six resource studies;</u>** most studies are complete or will be completed 2024.

1. Water Resources Study Tasks
- Existing Water Quality Data Summary
- Water Quality Monitoring in Whitewater River Arm
- Velocity Effects and Vertical Mixing in Lake Jocassee
- Water Exchange Rates and Reservoir Levels
- **<u>Water Quality Monitoring Plan Development</u>**

2. Aquatic Resources Study Tasks
- Entrainment Desktop
- Effects of Bad Creek II on Aquatic Habitat
- Impacts to Surface Waters and Associated Aquatic Fauna

3. Recreational Resources Study Tasks
- Recreation Use and Needs
- Foothills Trail Conditions Assessment
- Whitewater River Cove Existing Recreational Use
- Whitewater River Cove Recreational Public Safety Evaluation

4. Visual Resources Study Tasks
- Existing Scenery
- Visible Project Features and Key Viewpoints
- Visualizations and Renderings
- Lighting Evaluation

5. Cultural Resources Study Tasks
- Consultation on Area of Potential Effects
- Archeological and Historic Structures Survey

6. Environmental Justice
- Demographics evaluation (minority, low-income, non-English speaking, sensitive receptors) based on 2020 Census Bureau data

- **Other studies conducted in support of Bad Creek II:**
  - Geology and Geotechnical Studies
  - Transmission Siting Study
  - Natural Resources Field Surveys and Assessments
  - Bat Survey
  - Small Whorled Pogonia Survey
  - Herptile Survey

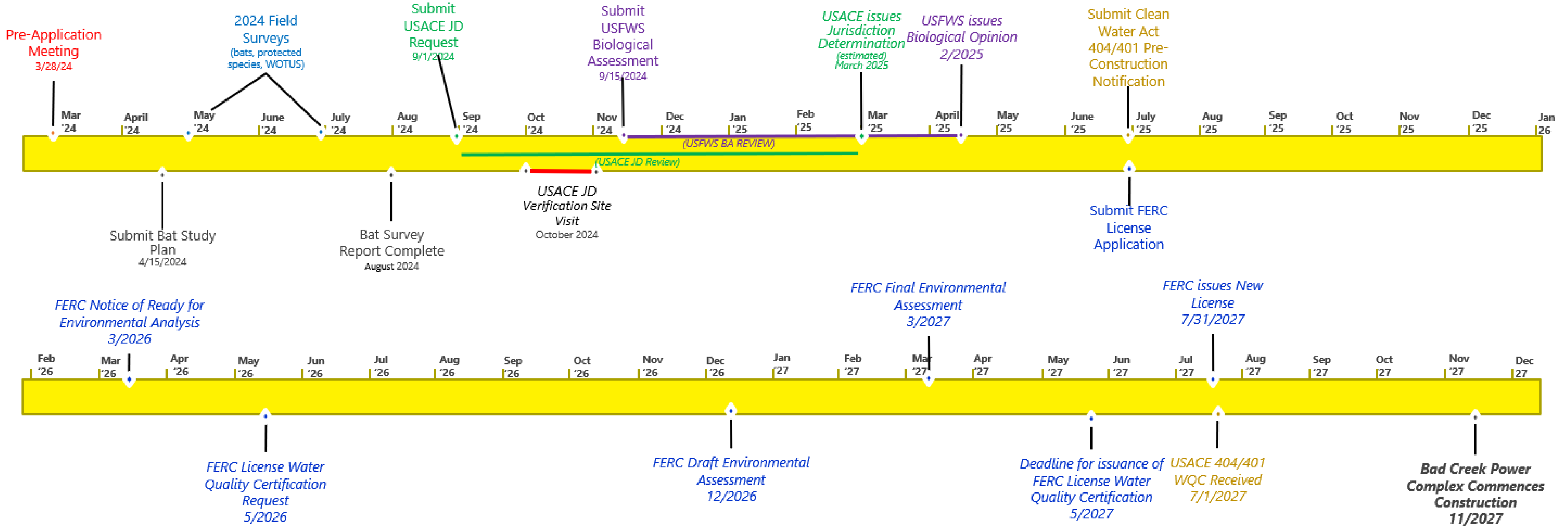
Agency Coordination and CWA 404 / 401 WQC Process

USACE 404 Pre-Application Meeting

- In parallel with FERC licensing, Duke Energy is consulting with the U.S. Army Corps of Engineers (USACE) and resource agencies in support of development of application for Section 404 permitting under the Clean Water Act.
- USACE Clean Water Act 404 Pre-Application Meeting was held on March 28, 2024 - USACE, SHPO, USFWS, and SCDNR participated.
- Follow-up discussion with USACE for additional guidance on April 11, 2024.
- WOTUS surveys are ongoing, working toward Jurisdictional Determination (JD) this fall.
- USACE has indicated interest in leveraging FERC NEPA/relicensing process in their record of decision.

Permitting and Regulatory Agency Coordination Schedule

Bad Creek 404/401 Permitting & FERC Relicensing
August 2024



Italicized dates are estimated dates for regulatory actions or contingent on regulatory actions.

401 WQC Process and Agency Coordination Schedule

- **Duke Energy would like to solicit SCDES guidance and feedback regarding the following:**
  - Water Quality Certifications required for the FERC license (construction and operation of Bad Creek II, as well as continued operation of Bad Creek I) and the 404 permit (construction of Bad Creek II).
  - Any modifications to WQC application requirements resulting from agency restructuring?
    - https://scdhec.gov/bow/water-quality-certification-program-section-401-overview
  - Schedule shown on the previous slide depicts two regulatory processes in parallel and desired timing relative to license issuance.
    - Deadlines for SCDES under both FERC and USACE processes?
    - Current concerns (or foreseeable concerns) regarding process or schedule?

Proposed Water Quality Monitoring Plan

Proposed Water Quality Monitoring Plan (WQMP)

As part of the Water Resources relicensing study, Duke Energy proposed to develop a WQMP as a protection, mitigation, and enhancement (PM&E) measure for the Bad Creek II Power Complex construction and operation.

The Plan will be developed in collaboration with regulatory agencies (SCDES), resource agencies (SCDNR), and other relicensing stakeholder groups.

At this time, Duke Energy would like to **solicit SCDES feedback on key components of the Plan** prior to submitting a draft for stakeholder review.

The Plan describes two different monitoring strategies to assess Project waters depending on location (i.e., Lake Jocassee vs. upland areas).

Part I: Lake Jocassee

Part I – Lake Jocassee

SC Water Quality Standards – Surface 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 milligrams per liter (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	Freshwater 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.

** Lake Jocassee is classified as Trout Waters (TPGT)*

Part I – Lake Jocassee

Potential Impacts

- Similar to 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 I/O structure and expansion of the existing submerged weir by placement of rock materials excavated during tunneling activities.

- Temporarily elevated turbidity levels in Lake Jocassee due to surface runoff also have the potential to occur during high precipitation events impacting construction areas.

- No long-term degradation of water quality is expected to result from construction and operation of the Bad Creek II Complex (*supported by historical water quality data*).

Part I - Lake Jocassee

- **Monitoring Location / Compliance Point**
  - Station 563.0 (see map)

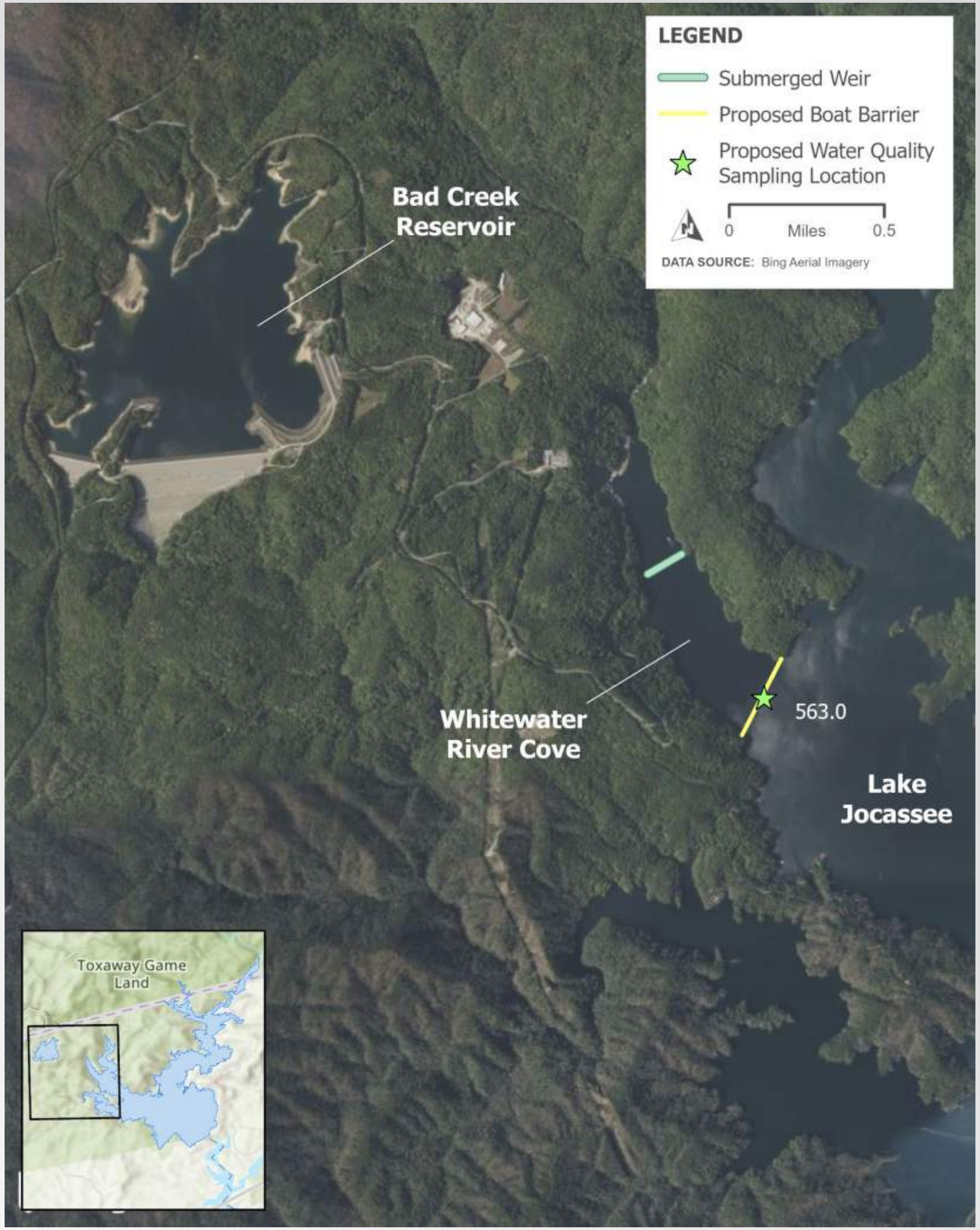
- **Methods**

- Multi-parameter sonde attached to high-visibility buoy near proposed boat barrier. [*Boat barrier will restrict access to WWRC during construction.*]

- Will record daily turbidity, DO, temp, pH, and conductivity at surface (0.3m). Data will be reviewed weekly during construction and bi-weekly during post-construction.

- If no telemetry capability, Duke Energy will retrieve data manually via boat weekly during construction, bi-weekly during post-construction.

- While all WQ parameters will be recorded, turbidity (NTU) will be used as the compliance parameter to inform construction activities.



Part I – Lake Jocassee

Turbidity Excursions

- A turbidity excursion is defined as any surface reading above the State water quality standard (i.e., compliance threshold).

- **SCDES Surface Water Quality Assessment Methodology for Turbidity**
  - If criteria are exceeded in more than 25 percent of the samples (over entire dataset), the criterion is not supported and constitutes a violation of water quality. If the criterion is exceeded in more than 10 but less than 25 percent of samples, sites are evaluated on a case-by-case basis to determine if local conditions indicate classified uses are impaired. (https://scdhec.gov/sites/default/files/media/document/Surface%20Water%20Quality.pdf)

- Duke Energy proposes a similar approach for turbidity criteria as follows:
  - If daily readings exceed the turbidity compliance threshold **in more than 10 percent but less than 25 percent over a rolling 30-day period**, Duke Energy will investigate to determine if excursions are the result of active construction activities (e.g., lower I/O and cofferdam construction, weir expansion) or rainfall events.
  - If elevated turbidity values are determined to be the result of a rainfall event (i.e., overland flow and runoff), data characterizing the rain event (timing and amount of precipitation) will be documented by accessing and recording data from the nearest weather station. Corresponding turbidity data will also be documented.
  - If turbidity excursions are not clearly linked to a rainfall event and daily readings exceed the turbidity compliance threshold (more than 10 percent of the time over a rolling 30-day period), Duke Energy will consult with SCDES. [Similarly, if excursions exceed 25 percent of the samples over a 30-day period and are not linked to rainfall events, SCDES will be alerted.]

Part I – Lake Jocassee

Request for Temporary Variance (Turbidity)

- Duke Energy seeks feedback from SCDES regarding applicability of using freshwater lakes turbidity standard during Bad Creek II construction (as opposed to trout waters turbidity standard).

- Variance is described in https://scdhec.gov/sites/default/files/Library/Regulations/R.61-68.pdf as "*a short-term exemption from meeting certain otherwise applicable water quality standards*". Prior to removing any uses or granting a variance, notice and an opportunity for a public hearing shall be provided.

- SCDES may then grant a variance provided the following apply:

  - ✓ a. The variance is granted to an individual discharger for a specific pollutant(s) or parameter(s) and does not otherwise modify water quality standards; and

  - ✓ b. The variance identifies and justifies the criterion that shall apply during the existence of the variance; and

  - ✓ c. The variance is established as close to the underlying criterion as is possible and, upon expiration of the variance, the underlying criterion shall become the effective water quality standard for the waterbody; and

  - ✓ d. The variance is reviewed every three (3) years, at a minimum, and extended only where the conditions for granting the variance still apply; and

  - ✓ e. The variance does not exempt the discharger from compliance with any applicable technology or other water quality-based permit effluent limitations; and

  - ✓ f. The variance does not affect permit effluent limitations for other dischargers.

Part II: Upland Areas and Streams

Part II - Upland Areas and Streams

Potential Temporary Impacts

- Construction activities could potentially lead to temporary impacts to water quality due to increased turbidity, therefore Duke Energy will install temporary BMPs (e.g., sediment basins, silt fences, waddles, etc.) proposed under the SCDES Construction General Permit to mitigate risk to streams impacted by spoil placement.
  - *BMPs will be regularly inspected and maintained to control runoff from affected areas into surface waters. BMP inspections and the ESC Plan will be developed and implemented through the NPDES construction permitting process.*

- Upland placement of spoil materials will result in potential impacts to surface waters (i.e., waters of the U.S.); therefore, an individual permit from the USACE will be required as well as a water quality certification from SCDES under the authorities of Sections 404 and 401 of the CWA.

Howard Creek

Part II - Upland Areas and Streams

- In addition to routine BMP inspections downstream of potential spoil areas, Duke Energy proposes to conduct pre-construction and post-construction **stream habitat quality assessment surveys** in perennial streams associated with drainage from spoil areas.

- Pre-construction habitat assessments will be compared with post-construction to document construction-related impacts, determine when these areas have recovered to pre-construction conditions, and to help plan for site restoration / stabilization.

  - Monitoring locations consist of accessible downstream reaches where the cumulative effect of construction activities can be observed.

  - Locations would be used to document stream conditions and function where water has flowed from the construction area, through a BMP, and into WOTUS.

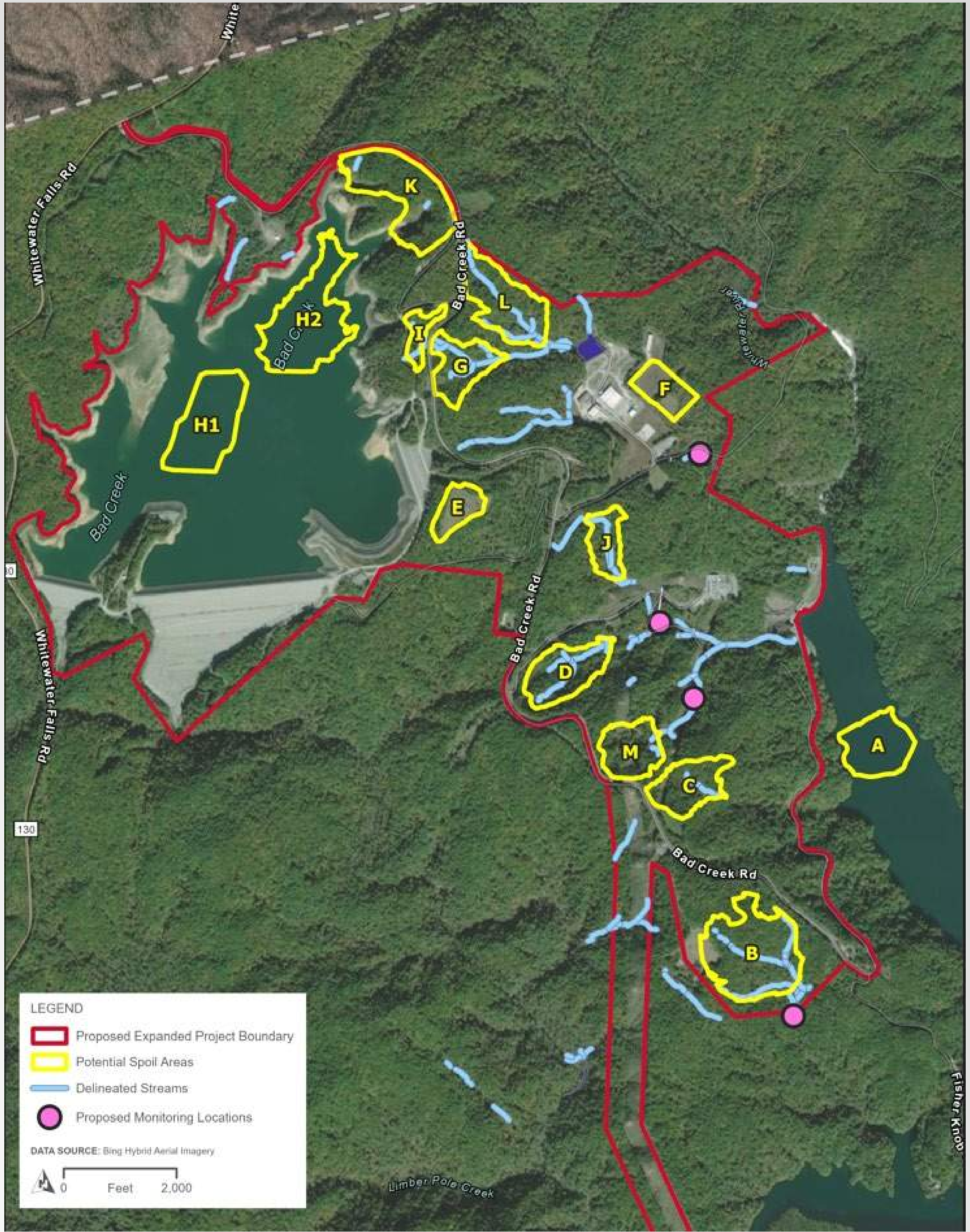
Part II - Upland Areas and Streams

Stream Habitat Quality Assessment Surveys

- Duke Energy proposes one survey prior to construction and surveys at 1-year, 3-years, and 5-years following commencement of Bad Creek II operations.

- The following methods will be used for surveys:
    - USEPA Rapid Bioassessment Protocol Habitat Assessments (High Gradient Streams)
    - NC Stream Assessment Methodology
    - SC Stream Quantification Tool
    - Macroinvertebrate sampling (SCDHEC 2017)

- Duke Energy is considering construction of a temporary access road to residents of Fisher Knob community. If this road is pursued, stream surveys will also be performed on portions of perennial streams crossed by the access road.



Future Information Needs / Discussions

Questions and Action Items

From:	Morgan D. Amedee
To:	Stuart, Alan Witten
Cc:	Crutchfield Jr., John U; Kulpa, Sarah; McCarney-Castle, Kerry; Ziegler, Ty; Salazar, Maggie
Subject:	Edits to Draft Meeting Summary
Date:	Friday, August 23, 2024 3:38:27 PM
Attachments:	Outlook-m5syzfwr.png WQ Permitting Discussion Aug 8 2024 Meeting Summary Draft for SCDES Review (1).docx

Some people who received this message don't often get email from morgan.amedee@des.sc.gov. Learn why this is important

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Good afternoon,

Please find attached the draft meeting summary. Rusty has made a few comments and edits to the draft.

Additionally, I wanted to let you know that I am working on getting answers to the questions that came up during our recent meeting.

Kind regards,

Morgan Amedee
Project Manager
Water Quality Certification and Wetlands Section
Water Quality Division
O: (803) 898-4179
Morgan.Amedee@des.sc.gov
DES.SC.gov

SC DEPARTMENT of ENVIRONMENTAL SERVICES

Please note my new email address, with the SC Department of Environmental Services (SCDES), which launched as a new state agency on July 1, 2024. While my old DHEC email will direct to me for a while, please update your address book with my new SCDES contact information.

Meeting Summary

Project:	Bad Creek Pumped Storage Station / Bad Creek II Power Complex
Subject:	Water Quality Permitting Discussion – Meeting Summary
Date:	Thursday, August 08, 2024
Location:	Virtual / Teams

Attendees:

Morgan Amedee (SCDES)
Rusty Wenerick (SCDES)
Alan Stuart (Duke Energy)
John Crutchfield (Duke Energy)
Sarah Kulpa (HDR)
Ty Ziegler (HDR)
Eric Mularski (HDR)
Kerry McCarney-Castle (HDR)

Introduction and Meeting Purpose

Alan Stuart (Duke Energy) opened the meeting, shared the meeting agenda, facilitated introductions, and provided a safety moment on back-to-school driving safety. The purpose of today's meeting is to begin discussions with the South Carolina Department of Environmental Services (SCDES) regarding the Clean Water Act (CWA) 401 Water Quality Certification (WQC) process as it relates to the Bad Creek Pumped Storage Project (FERC No. 2740) FERC relicensing and associated U.S. Army Corps (USACE) CWA 404 permitting process. A. Stuart indicated Duke Energy met with representatives from the USACE and SCDES (and others) earlier this year (March 2024) for the Pre-Application Meeting to discuss permitting strategy from the CWA 404 perspective and today's meeting is to discuss specifically permitting strategy as it relates to the CWA 401 WQC and how this aligns with the FERC and USACE CWA 404 processes. Duke Energy hopes to solicit feedback from SCDES on these topics as well as the proposed Water Quality Monitoring Plan (WQMP) for Bad Creek II.

Discussion

Project Description and On-site Waters

The existing Project (FERC No. 2740) located in Oconee County, South Carolina, uses the Bad Creek Reservoir as the upper pool and Lake Jocassee as the lower pool. Lake Jocassee is licensed as part of the Keowee-Toxaway Hydroelectric Project. The existing license for the Project expires July 31, 2027; the final license application for Bad Creek will be filed in 2025.

A. Stuart provided an overview of the existing (Bad Creek Pumped Storage Project) and proposed (Bad Creek II Power Complex) facilities and described Bad Creek operations, the underground powerhouse, the function of the submerged weir in the Whitewater River cove of Lake Jocassee downstream of the inlet/outlet structure (i.e., to dissipate energy and reduce vertical mixing downstream in the lake), and other project facilities.

- Rusty Wenerick asked about Bad Creek Reservoir storage, how deep the reservoir is, and what the two outlined portions were depicted on the aerial image within Bad Creek Reservoir (Slide #9). A. Stuart responded the two outlined areas in the reservoir are the original quarry areas; Sarah Kulpa added they are referred to as dead storage, meaning water isn't used for generation or pumping (but it is critical to maintain a certain amount of water for operations/priming pumps). A. Stuart pulled up Google Earth on the screen – in 2018 maintenance was done to support an outage so the upper reservoir was drained to service the water control structures into the turbine units. Maximum elevation of the upper reservoir is 2310 feet and max drawdown is 2150 feet, so the usable storage is 160 feet.

Action Item: HDR to determine maximum depth of dead storage at the bottom of Bad Creek Reservoir and share with SCDES.[1]

A. Stuart presented proposed modifications to the FERC project boundary to accommodate the new facility and onsite storage of excavated material (spoil) from the new powerhouse tunnel and other facilities, followed by a slide of the Bad Creek II Power Complex facilities layout. He indicated major differences between the existing and proposed project include (1) two main conveyance tunnels to isolate the units (i.e., individual pump turbines could be taken offline for maintenance); and (2) the inlet/outlet (I/O) structure would be upgraded based on lessons learned from the original project. Additionally, Bad Creek II will have variable speed pump-turbine units to provide operational flexibility and help maintain stability to the electrical grid as opposed to fix-speed units at the existing Project. An aerial photo of the lower I/O structure in the Whitewater River cove of Lake Jocassee was presented (note the excavation will not extend all the way back to the black line shown on the photo, but there will be some excavation into the bank [Slide #13]) as well as a rendering of the proposed I/O structure adjacent the existing I/O structure, showing the portal and gantry crane.

A. Stuart stated approximately 4.4 million cubic yards of excavated material for Bad Creek II construction will need to be deposited at upland spoil locations and/or along the existing submerged weir in Lake Jocassee and showed a map of potential spoil areas. Duke Energy is proposing that all areas be permitted for CWA 404 impacts, however, not all spoil areas will be needed/used. Impacts to streams associated within spoil areas will be avoided to the extent possible. Several alternatives are being explored (i.e., Spoil Area K) to reduce potential impacts to other more sensitive areas. Eric Mularski noted surface water impacts shown in the table (Slide #14) are preliminary; wetlands and waterbody field delineations are complete within the proposed spoil area alternatives and Duke Energy is currently preparing a Jurisdictional

[1] There is approximately 150 feet of dead pool storage in Bad Creek reservoir, as the reservoir bottom elevation is 2000 feet.

Determination (JD) package for the USACE to verify surface water boundaries subject to CWA Section 404 regulation (e.g. waters of the U.S.). Some surface waters may not be regulated by the USACE (e.g., isolated wetlands); Duke Energy hopes to schedule the field visit with USACE for jurisdictional determination for WOTUS this fall.

- R. Wenerick asked if Duke Energy has considered South Carolina designated surface water classifications for streams on-site. E. Mularski responded Classified Waters per Regulation 61-69 (*S.C. Code Sections 48-1-10 et seq.)* have been mapped for on-site waters and that Duke Energy has carried out several surveys on existing waters (i.e., USEPA Rapid Bioassessment Protocol [RBP], North Carolina Stream Assessment Methodology) with potential impacts. Flow regimes were determined for each water assessed (i.e., ephemeral, intermittent, perennial, etc.) utilizing the North Carolina Division of Water Resource's Identification Methods for the Origins of Intermittent and Perennial Streams as a stream duration assessments methodology (SDAM). WOTUS surveys for the entire Bad Creek expanded FERC Boundary are nearly complete. A. Stuart mentioned Howard Creek and Limber Pole Creek are perennial trout waters but the majority of mapped waters on-site are not perennial streams (many are seeps, ephemeral, etc.). R. Wenerick added small headwater streams would take on the classification of the waterbody to which they are tributaries to, and for Outstanding Resources Waters (ORW), spoils would be prohibited. E. Mularski noted the only currently verified ORW near the site is the Whitewater River, which is not impacted by the project or proposed construction. Most tributaries associated with the site flow into Lake Jocassee, which is classified as trout put grow take (TPGT), so these tributaries would be classified trout waters. (*Also see Additional Discussion on Page 7*)

Relicensing Studies

The Integrated Licensing Process (ILP) schedule was presented to the group with completed and upcoming relicensing milestones. A. Stuart noted the Bad Creek relicensing settlement agreement process has been initiated; this process will include input from stakeholders to define mitigation measures for the Project and proposed Bad Creek II Complex.

A. Stuart handed the presentation over to T. Ziegler to summarize the FERC-approved studies for the relicensing, which have been developed in consultation with various stakeholders, including SCDES. There are six relicensing studies, and relevant to the discussion today is the Water Resources Study. There are five tasks under the Water Resources Study; Task 5 is development of the future WQMP.

- R. Wenerick asked if there is available water quality data in Bad Creek Reservoir. T. Ziegler stated water fluctuations in the Bad Creek Reservoir make it unfeasible and unsafe for water quality sampling. The reservoir is not open to the public and noted that water in the Whitewater River cove is representative of water in Bad Creek Reservoir (directly exchanged via water conveyance tunnel).
- R. Wenerick asked if there are any water quality issues or problems in Lake Jocassee. T. Ziegler responded noting water quality data going back to 1975 indicate Lake Jocassee is supportive of all uses. Recent water quality monitoring for the relicensing in

Whitewater River cove (2023 and 2024) also support water quality (tempearture and DO) standards.

- A. Stuart stated Morgan Amedee already has access to all existing reports developed thus far for the Project and offered to add R. Wenerick to the Bad Creek relicensing SharePoint site or the public relicensing website if he would like to review the study reports developed over the last two years.

Action Item: Provide Rusty Wenerick with link to study reports.[2]

- R. Wenerick asked about on-site tributaries and water quality of portions of streams impounded by the Bad Creek Reservoir that drain to Lake Jocassee. T. Ziegler noted Bad Creek has been impounded and previous information related to Howard Creek is included in the Task 1 report of the Water Resources study, but water quality standards are supported in Howard Creek based on previously collected data.
- R. Wenerick asked about the existing 401 WQC for the original project construction. S. Kulpa noted there were no special conditions in the original certification.[3]

USACE / FERC/ SCDES Permitting Coordination

A. Stuart continued with the presentation and shared the permitting and regulatory agency coordination schedule (attached to this meeting summary). In parallel with FERC licensing, Duke Energy is consulting with the USACE and resource agencies in support of development of application for CWA Section 404 permit. Duke Energy would like to solicit SCDES guidance regarding the WQC required for the FERC license (construction and operation of Bad Creek II, as well as continued operation of Bad Creek I) and the WQC required for the CWA 404 Individual Permit (construction of Bad Creek II) and whether one or two certifications should be considered and/or required. R. Wenerick noted this would need to be discussed with input from SCDES Management.

Action Item: SCDES to discuss permitting strategy with SCDES Management regarding certification(s) for FERC relicensing and USACE permit.

A. Stuart inquired, given the FERC schedule and the 404 schedule, when might SCDES be able to provide that information to Duke Energy (i.e., two applications vs. one application) so Duke Energy can be in position to respond to whatever direction SCDES would like to proceed.

- Bad Creek II construction will be covered under an Individual Permit. Given the timeline and the 60-day deadline to request the 401 for the relicensing, it is preferable a joint public notice is made before the SCDES 401 request for the 404 permit; USACE would determine when that timeline starts. (Both have a one-year federal clock.) Some of the issues within the scope of the 404 might be different than the FERC relicensing scope; S. Kulpa acknowledged the overlap – considering the FERC process as an umbrella.

---

[2] Link has been provided in transmittal email.
[3] The SC State Budget and Control Board issued the original authorization for discharge of fill material in conjunction with the Bad Creek Pumped Storage Project in the waters of Lake Jocassee on November 18, 1980.

The FERC License Order is what authorizes the construction of Bad Creek II and associated activities *as well as* continued operation of Bad Creek I. The 404 permit would be focused on construction activities that will (potentially) affect WOTUS. Therefore, what the USACE authorizes can be considered a subset of what FERC authorizes, and the USACE will likely lean heavily on FERC's environmental assessment. If there are two authorizations, they need to be compatible / similar.

- A. Stuart noted if everything is tied into a single 401 WQC, it would be grounded with FERC licensing and construction of the new facility; therefore, there may be value in obtaining independent 401 certifications for each process (i.e., FERC and 404), acknowledging there would be quite a bit of overlap between the two.
- R. Wenerick noted 401 certification for relicensing would need to happen before submittal of application for the 404 permit, but then stated he had misunderstood the slide as showing two parallel timelines, when the second (bottom) timeline was simply a continuation of the first (top) timeline. S. Kulpa indicated Duke Energy plans to file the application for individual permit in parallel with the license application. So the pre-filing meetings could be done as needed to launch the USACE process as FERC launches their process in parallel. Both applications would be filed in July 2025.
- R. Wenerick asked if SCDES could obtain the schedule presented on Slide #21; A. Stuart responded Duke Energy will provide slides and the meeting summary. (A copy of the schedule is also attached to this meeting summary).

A. Stuart acknowledged a lot of information has been presented and that SCDES would need to have internal discussions before getting feedback to Duke Energy. S. Kulpa asked if there is any other information that would be helpful to SCDES to facilitate their review and discussion. R. Wenerick responded he believes they have everything they need to discuss with SCDES Management. M. Amedee agreed. A. Stuart noted Duke Energy would be happy to walk through the presentation again with SCDES Management if that would be helpful.

Water Quality Monitoring Plan

Lake Jocassee (Whitewater River Cove Turbidity Compliance)

T. Ziegler resumed covering the slides and gave an overview of the WQMP and indicated Duke Energy would like to solicit feedback from SCDES on a few key components of the WQMP prior to distributing the draft plan to other relicensing stakeholders.

T. Ziegler provided a slide showing SC Water Quality Standards for surface waters, highlighting criteria turbidity (25 NTU for freshwater lakes; 10 NTU for trout waters), and introduced Duke Energy's proposed monitoring strategy for turbidity compliance in the Whitewater River cove during construction. Based on SCDES assessment methodology, Duke Energy proposes to use similar thresholds and guardrails for turbidity excursions (if >10% but less than 25% of readings exceed state criteria threshold for ambient waters, and excursions are not linked to rain events, Duke Energy would consult with SCDES).

- T. Ziegler asked SCDES if Duke Energy's understanding of the criteria is in alignment with SCDES methods and if Duke Energy's interpretation and proposed application of the monitoring strategy is appropriate for compliance. R. Wenerick responded he believed the criteria mentioned above originates from the SCDES 303(d) listing methodology, which is used to make determinations on impaired waters.
- T. Ziegler thanked SCDES for any feedback and input, acknowledging Duke Energy does not want to roll the WQMP out to a wider audience/stakeholder group without SCDES input. R. Wenerick agreed and responded SCDES will get back to Duke Energy.
- T. Ziegler added that not only is Duke Energy seeking feedback on turbidity compliance guardrails, but also the period of time proposed (excursions considered over rolling 30 days). SCDES surface water assessment methods typically provide for the entire dataset (i.e., years). Therefore, Duke Energy believes 30 days provides for a more conservative window of interpretation but would welcome SCDES input regarding this. R. Wenerick agreed that SCDES would provide feedback.

Action Item: SCDES to discuss internally with SCDES Management monitoring approach for turbidity methods and compliance in the Whitewater River cove during construction of Bad Creek II.

T. Ziegler advanced to the next slide, introducing Duke Energy's proposed request for a temporary variance for turbidity (during construction only) from 10 NTU (trout waters) to 25 NTU (freshwater lake). R. Wenerick noted SCDES would be able to give feedback on this proposed temporary variance.

Action Item: SCDES to discuss with internal management proposed request for temporary variance for surface turbidity during Bad Creek II construction.

T. Ziegler summarized the two main points we are seeking SCDES input on - A. Stuart agreed:

- Turbidity thresholds from compliance perspective and guardrails (i.e., number of turbidity excursions greater than 10% and less than 25% over rolling 30-day period, not tied to a rain event, would trigger consultation with SCDES)
- Temporary variance on turbidity during Bad Creek II construction

Upland Areas and Streams (BMPs and Stream Surveys)

T. Ziegler led discussion on potential impacts to upland water - construction activities could potentially lead to temporary impacts to water quality due to increased turbidity, therefore Duke Energy will install temporary BMPs (e.g., sediment basins, silt fences, waddles, etc.) proposed under the SCDES Construction General Permit to mitigate risk to streams impacted by spoil placement.

In addition to routine BMP inspections downstream of potential spoil areas, Duke Energy proposes to conduct pre-construction and post-construction stream habitat quality assessment surveys in perennial streams associated with drainage from spoil areas. E. Mularski provided an overview of stream surveys that were performed in 2023 in support of the relicensing and 404 permitting.

- R. Wenerick asked if biological assessments had been done (and are planned), noting biological information would likely give the best information, and asked who did the macroinvertebrate sampling thus far. E. Mularski responded he has led the recent efforts, adding he has 17 years of macroinvertebrate sampling experience (though a certified laboratory was used for taxonomy identification). R. Wenerick asked if only perennial would be considered in the proposed monitoring. Eric noted they used the NC SDAM methodology to identify ephemeral, intermittent, and perennial flow regime break points. A. Stuart confirmed that proposed monitoring points would be on perennial streams and E. Mularski agreed. T. Ziegler reiterated the sampling points would be situated downstream of the planned BMPs to capture cumulative effects of construction activities.
- T. Ziegler also mentioned the proposed temporary access road (Fisher Knob road) extending from Hwy 130 to the Fisher Knob community south of the project site. A. Stuart pointed to proposed location of Fisher Knob Road and added the road would be constructed on an old logging road (not new clearance). E. Mularski stated streams along the proposed access road have also been field delineated and several habitat assessment surveys have been performed. A. Stuart asked (regarding the temporary access road – Fisher Knob) for confirmation that temporary bridges along the proposed road would be below the ordinary high water mark (OHWM), the lateral extents protected under the Clean Water Act, and would not need to be permitted. E. Mularski responded concerning permitting, there could be temporary impacts associated with the road construction but there is no anticipated permanent fill below the OHWM or in wetlands. E. Mularski noted Duke Energy/HDR has performed RBP, SCDNR Stream Quantification Tool methods, and biological (fish/macroinvertebrate) sampling and these assessments will be included in the proposed surveys.

T. Ziegler recapped methods for upland streams for habitat surveys pre and post construction:

- Duke Energy proposes one survey prior to construction and surveys at 1-year, 3-years, and 5-years following commencement of Bad Creek II operations.
- The following methods will be used for surveys:
    - USEPA Rapid Bioassessment Protocol Habitat Assessments (High Gradient Streams)
    - NC Stream Assessment Methodology
    - SC Stream Quantification Tool
    - Macroinvertebrate sampling

Additional Discussion

A. Stuart asked if there are any immediate thoughts or feedback on the methods presented. R. Wenerick reiterated State classifications of on-site streams are important to consider, indicating the Whitewater River is ORW from the state line to Lake Jocassee and it appeared Bad Creek is listed as ORW as well. E. Mularski stated that Bad Creek and other unnamed tributary are illustrated as “provisional” water classifications on SCDES SC Watershed Atlas GIS layer and requested clarification on the unnamed stream piped under the existing facility (circled in yellow on Figure 1) provisionally called “ORW”. Duke Energy would like clarification on whether it is actually classified as ORW, since it has been impacted due to original reservoir construction. E. Mularski noted Spoils Area L and B would be affected by the unnamed tributary in question. R. Wenerick noted the provisional data hasn’t been QC’d so SCDES typically would refer to the SC 61-69 regulations; since the tributary is not named, he is not sure whether or not it should still be considered ORW. E. Mularski stated he could not locate the stream in the regulations, and requested guidance from SCDES on how to handle provisional ORWs, particularly the stream piped under the maintenance facility and Lower Whitewater Falls trailhead public parking lot. This stream is also crossed in several places by Musterground Road (see Figure 1).

Figure 1. Aerial photo of Bad Creek waters with unnamed tributary to Whitewater River circled in yellow

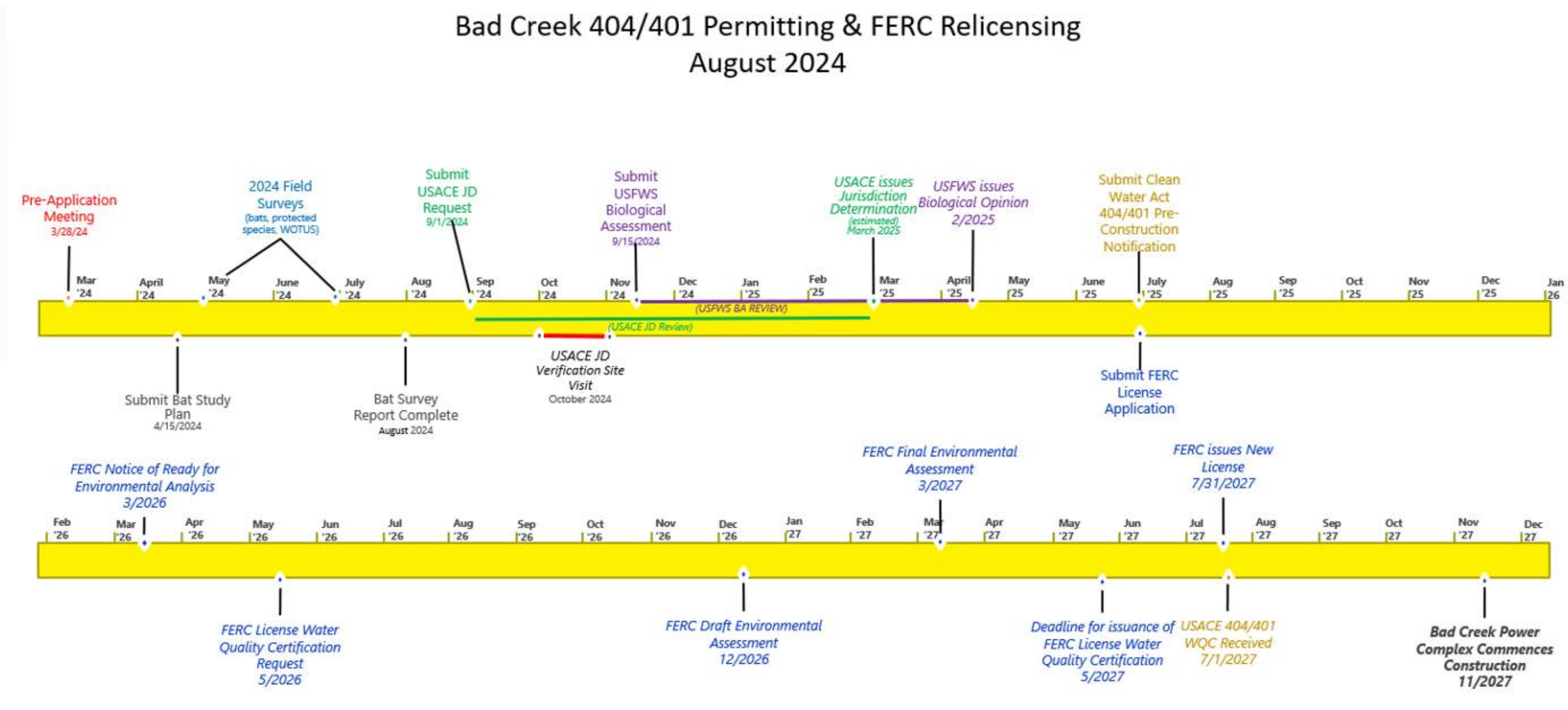
A. Stuart asked for clarification that spoil can be placed near waters classified as ORW but not within ORW waters (R. Wenerick agreed) and asked if Bad Creek is still considered ORW since it has been impounded, as that would have implications for Duke Energy placing fill in the reservoir. R. Wenerick said the reservoir is classified as Freshwater.

Action item: SCDES to provide clarification on unnamed tributary piped under the existing Bad Creek project draining to Lake Jocassee (if it is considered ORW and should be treated as such).

R. Wenerick asked who is Duke Energy’s Point of Contact (POC) at the USACE – E. Mularski said discussions have involved Brice McKoy, Laura Boos, and Chip Ridgway, and Chip Ridgway is the main POC.

Duke Energy is targeting submittal of the draft WQMP to SCDES (R. Wenerick and M. Amedee) by the end of next week (8/16/2024)[4] so SCDES feedback and comments can be incorporated (and possible follow-up meetings can be scheduled) prior to submitting a revised draft to the larger relicensing stakeholder group. A. Stuart then summarized action items from today's meeting, thanked the SCDES for their time and their forthcoming feedback, and closed the meeting.

[4] Duke Energy and HDR are still finalizing the draft WQMP, so this schedule is being shifted by approximately 1 week.



Italicized dates are estimated dates for regulatory actions or contingent on regulatory actions.

From:	Morgan D. Amedee
To:	Stuart, Alan Witten
Cc:	Crutchfield Jr., John U; Kulpa, Sarah; McCarney-Castle, Kerry; Ziegler, Ty; Salazar, Maggie
Subject:	Re: [EXTERNAL] Re: UPDATED RE: Draft Meeting Summary For the Bad Creek 401 WQC Discussion and Draft WQMP
Date:	Monday, September 23, 2024 3:25:59 PM
Attachments:	image001.png Outlook-rs0onjzn.png 20240823_Bad Creek Water Quality Monitoring Plan_Draft_SCDES Review.docx

Hi Alan,

I've reviewed the draft WQMP and have added one suggestion in the document. Please see the attached file for my feedback.

Let me know if you have any questions.

Kind regards,

Morgan Amedee
Project Manager
Water Quality Certification and Wetlands Section
Water Quality Division
O: (803) 898-4179
Morgan.Amedee@des.sc.gov
DES.SC.gov

SC DEPARTMENT of ENVIRONMENTAL SERVICES

Please note my new email address, with the SC Department of Environmental Services (SCDES), which launched as a new state agency on July 1, 2024. While my old DHEC email will direct to me for a while, please update your address book with my new SCDES contact information.

From: Stuart, Alan Witten <Alan.Stuart@duke-energy.com>
Sent: Saturday, August 24, 2024 10:19 AM
To: Morgan D. Amedee <Morgan.Amedee@des.sc.gov>; William R. "Rusty" Wenerick <Rusty.Wenerick@des.sc.gov>
Cc: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; McCarney-Castle, Kerry <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>

Subject: RE: [EXTERNAL] Re: UPDATED RE: Draft Meeting Summary For the Bad Creek 401 WQC Discussion and Draft WQMP

*** Caution. This is an EXTERNAL email. DO NOT open attachments or click links from unknown senders or unexpected email. ***

Thank you, Morgan

From: Morgan D. Amedee <Morgan.Amedee@des.sc.gov>
Sent: Friday, August 23, 2024 3:11 PM
To: Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William R. "Rusty" Wenerick <Rusty.Wenerick@des.sc.gov>
Cc: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; McCarney-Castle, Kerry <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>
Subject: [EXTERNAL] Re: UPDATED RE: Draft Meeting Summary For the Bad Creek 401 WQC Discussion and Draft WQMP

***** CAUTION! EXTERNAL SENDER *** STOP. ASSESS. VERIFY!!** Were you expecting this email? Are grammar and spelling correct? Does the content make sense? Can you verify the sender? If suspicious report it, then do not click links, open attachments or enter your ID or password.

Hi Alan,

The draft WQMP has been received. I will review and provide any input by the September 23 deadline.

Kind regards,

Morgan Amedee
Project Manager
Water Quality Certification and Wetlands Section
Water Quality Division
O: (803) 898-4179
Morgan.Amedee@des.sc.gov
DES.SC.gov

SC DEPARTMENT of ENVIRONMENTAL SERVICES

Please note my new email address, with the SC Department of Environmental Services (SCDES), which launched as a new state agency on July 1, 2024. While my old DHEC email will direct to me for a while, please update your address book with my new SCDES contact information.

From: Stuart, Alan Witten <Alan.Stuart@duke-energy.com>
Sent: Friday, August 23, 2024 12:35 PM
To: Morgan D. Amedee <Morgan.Amedee@des.sc.gov>; William R. "Rusty" Wenerick

<Rusty.Wenerick@des.sc.gov>
Cc: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; McCarney-Castle, Kerry <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>
Subject: UPDATED RE: Draft Meeting Summary For the Bad Creek 401 WQC Discussion and Draft WQMP

Good afternoon Morgan/Rusty,

As noted below, please find for your review and comment the Water Quality Monitoring Plan supporting potential construction of a second powerhouse at the Bad Creek Project. We welcome your input and, if possible, please provide that to us by September 23 as this will help keeps us on the FERC relicensing schedule.

If you have questions, please let us know.

Thank you and have a great weekend !
Alan

Alan Stuart
Senior Project Manager, Regulated & Renewable Energy
Duke Energy
525 S.Tryon St., DEP – 35B | Charlotte, NC 28202
Office 980-373-2079 |Cell 803-640-8765

From: Stuart, Alan Witten
Sent: Friday, August 16, 2024 3:54 PM
To: Morgan D. Amedee <Morgan.Amedee@des.sc.gov>; William R. "Rusty" Wenerick <Rusty.Wenerick@des.sc.gov>
Cc: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; McCarney-Castle, Kerry <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Salazar, Maggie <Maggie.Salazar@hdrinc.com>
Subject: Draft Meeting Summary For the Bad Creek 401 WQC Discussion

Dear Morgan and Rusty,

Thank you for taking time to meet with us last week regarding CWA 401 Water Quality Certification for the ongoing Bad Creek Pumped Storage Project relicensing as well as the proposed construction of Bad Creek II. Attached is the (draft) meeting summary for your review and comment – we've provided it as a Word document to facilitate your review and a pdf. Additionally, we have attached a pdf of the presentation from last week's meeting. Duke Energy is finishing up the draft Water Quality Monitoring Plan and will submit for your review next Friday (8/23). We would appreciate any review comments you may have on the meeting summary and Water Quality Monitoring Plan by September 23. We welcome your expertise and guidance regarding water quality permitting for the Bad Creek Project and look forward to continued discussions.

Thanks again,
Alan

Alan Stuart
Senior Project Manager, Regulated & Renewable Energy
Duke Energy
525 S.Tryon St., DEP – 35B | Charlotte, NC 28202
Office 980-373-2079 |Cell 803-640-8765

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Wednesday, June 12, 2024 11:57 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; David Bereskin <bereskind@greenvillewater.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Gerry Yantis <gcyantis2@yahoo.com>; Jeffrey Phillips <jphillips@greenvillewater.com>; Jen Huff <jen.huff@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; quattrol@dnr.sc.gov <quattrol@dnr.sc.gov>; Olds, Melanie J <melanie_olds@fws.gov>; More Priyanka <morep@dnr.sc.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; SelfR@dnr.sc.gov <SelfR@dnr.sc.gov>; Scott Harder <harders@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Abney, Michael A <michael.abney@duke-energy.com>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Erin Settevendemio <Erin.Settevendemio@hdrinc.com>; Gerry Yantis <gcyantis2@yahoo.com>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; quattrol@dnr.sc.gov <quattrol@dnr.sc.gov>; Olds, Melanie J <melanie_olds@fws.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Morgan Kern <kernm@dnr.sc.gov>; SelfR@dnr.sc.gov <SelfR@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Wahl, Nick <Nick.Wahl@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Alex Pellett <PellettC@dnr.sc.gov>; Alison Jakupca <Alison.Jakupca@KleinschmidtGroup.com>; Bruce, Ed <Ed.Bruce@duke-energy.com>; Dan Rankin <RankinD@dnr.sc.gov>; Dunn, Lynne <Lynne.Dunn@duke-energy.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Greg Mixon <mixong@dnr.sc.gov>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pat Cloninger <cloningerp@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Terry Keene <jtk7140@me.com>; Tom Daniel <danielt@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Andrew Gleason <andrewandwilla@hotmail.com>; Andy Douglas <adoug41@att.net>; Bill Ranson <bill.ranson@retiree.furman.edu>; Chris Starker <cstarker@upstateforever.org>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; Elizabeth Miller <MillerE@dnr.sc.gov>; Glenn Hilliard <glenn@hilliardgrp.com>; Jen Huff <jen.huff@hdrinc.com>; Kelly Kirven <Kelly.Kirven@KleinschmidtGroup.com>; Ken Forrester <forresterk@dnr.sc.gov>; quattrol@dnr.sc.gov <quattrol@dnr.sc.gov>; Maggie Salazar <maggie.salazar@hdrinc.com>; Morgan Amedee <amedeemd@dhec.sc.gov>; Pardue, Ethan <Ethan.Pardue@duke-energy.com>; Pat Cloninger <cloningerp@dnr.sc.gov>; Phil Mitchell <phil.mitchell@gmail.com>; Phil Shirley <pshirley@oconeeco.com>; SelfR@dnr.sc.gov <SelfR@dnr.sc.gov>; Rowdy Harris <charris@scprt.com>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Sue Williams <suewilliams130@gmail.com>; William Wood <woodw@dnr.sc.gov>; Willie Simmons <simmonsw@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>; Angie.Scangas@hdrinc.com <angie.scangas@hdrinc.com>
Subject: [EXTERNAL] Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Draft Addendum (REVIEW REQUESTED)

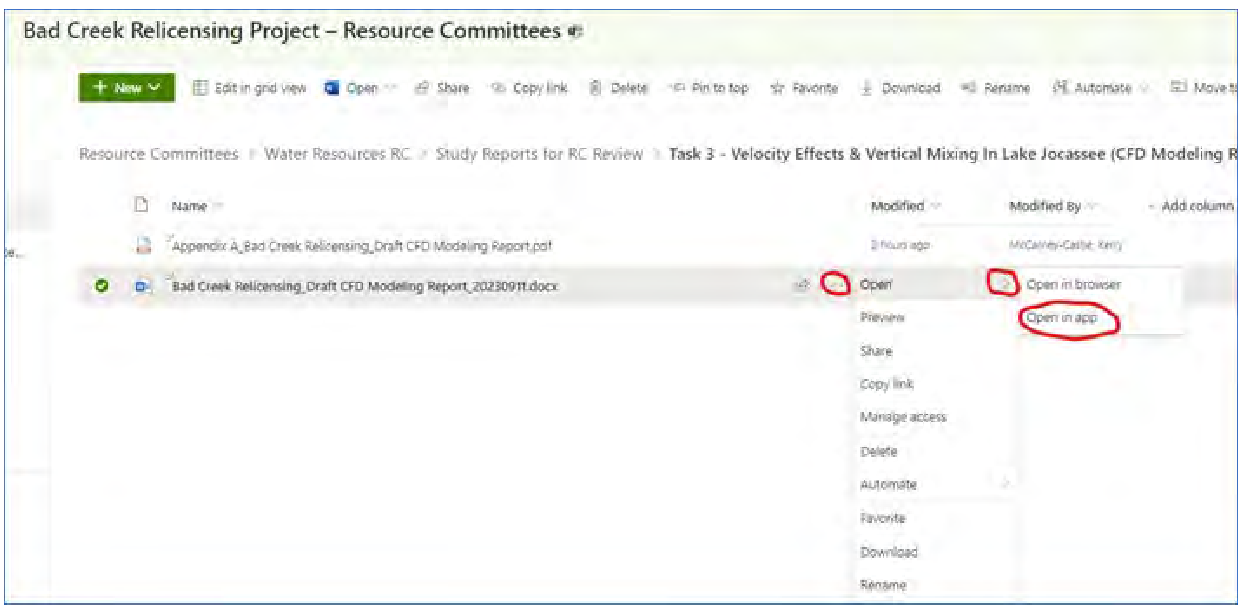
Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the **Bad Creek CFD Model Updated Pumping Rates Draft Addendum** for Resource Committee review. This draft report is the second addendum to the Task 3 final report (*Velocity Effects and Vertical Mixing in Lake Jocassee Duke to a Second Powerhouse*), which was filed with the Initial Study Report in January of this year. The purpose of the addendum is to provide results of additional CFD modeling performed to incorporate increased hydraulic pumping at Bad Creek II from a recently proposed technology modification (variable speed pump-turbines vs. single speed). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Addendum 2_Updated Pumping CFD Model Report. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **July 12**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

- As discussed in the kick-off meeting (July 2022), Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment; therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



Also, please note this draft report addendum is being sent to the Water Resources, Aquatics, Operations, and Recreation & Visual Resource committees, and you may receive multiple emails if you are on several of these committees' distribution lists. I apologize in advance if you get multiple emails.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	Alex Pellett; Amy Breedlove; Dale Wilde; Dan Rankin; bereskind; Elizabeth Miller; Erika Hollis; gcyantis2; Jeff Phillips; Huff, Jen; McCarney-Castle, Kerry; quattrol; Olds, Melanie J; More, Priyanka; Amedee, Morgan D.; Raber, Maverick James; Ross Self; Scott Harder; Stuart, Alan Witten; William T. Wood; Abney, Michael A; Amy Breedlove; Dan Rankin; Elizabeth Miller; Erika Hollis; Settevendemio, Erin; gcyantis2; Huff, Jen; jhains@g.clemson.edu; quattrol; Olds, Melanie J; Amedee, Morgan D.; Morgan Kern; Ross Self; Stuart, Alan Witten; Wahl, Nick; William T. Wood; Alex Pellett; Alison Jakupca; Bruce, Ed; Dan Rankin; Dunn, Lynne; Elizabeth Miller; Greg Mixon; Huff, Jen; jhains@g.clemson.edu; Salazar, Maggie; Amedee, Morgan D.; Pat Cloninger; Charles (Rowdy) B Harris; Kulpa, Sarah; Stuart, Alan Witten; Terry Keene; Tom Daniel; Amy Breedlove; Andrew Gleason; Andy Douglas; Bill Ranson-Retired; Chris Starker; Dale Wilde; Dan Rankin; Elizabeth Miller; glenn@hilliardgrp.com; Huff, Jen; Kelly Kirven; Ken Forrester; quattrol; Salazar, Maggie; Amedee, Morgan D.; Pardue, Ethan; Pat Cloninger; Phil Mitchell; PShirley; Ross Self; Charles (Rowdy) B Harris; Stuart, Alan Witten; suewilliams130@gmail.com; William T. Wood; Willie Simmons
Cc:	Kulpa, Sarah; McCarney-Castle, Kerry; Ziegler, Ty; Scangas, Angie
Subject:	RE: Bad Creek Relicensing - Bad Creek CFD Model Updated Pumping Rates Addendum (FINAL)
Date:	Tuesday, September 10, 2024 1:57:54 PM
Attachments:	image001.png
Importance:	High

Dear Bad Creek Relicensing Resources Committees:

Duke Energy is pleased to distribute the final **Bad Creek CFD Model Updated Pumping Rates Addendum** for your reference. This report will be included with the Updated Study Report as an addendum to the Task 3 report (i.e., Velocity Effects and Vertical Mixing in Lake Jocassee Due to a Second Powerhouse Report), which was finalized last year and filed with the Initial Study Report. The addendum will also be filed with FERC as an attachment to the sixth Quarterly Progress Report.

You can access the final addendum at the link given below:

Addendum 2_Updated Pumping CFD Model Report

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	Alex Pellett; Amy Breedlove; Dale Wilde; Dan Rankin; bereskind; Elizabeth Miller; Erika Hollis; gcyantis2; Jeff Phillips; McCarney-Castle, Kerry; quattrol; Olds, Melanie J; More, Priyanka; Amedee, Morgan D.; Raber, Maverick James; Ross Self; Scott Harder; Stuart, Alan Witten; William T. Wood; Abney, Michael A; Settevendemio, Erin; Huff, Jen; jhains@g.clemson.edu; Wahl, Nick; Ericah Beason
Cc:	Kulpa, Sarah; Ziegler, Ty; Salazar, Maggie
Subject:	Bad Creek Relicensing - Bad Creek II Power Complex Draft Water Quality Monitoring Plan (READY FOR REVIEW)
Date:	Friday, October 4, 2024 10:49:39 AM
Attachments:	image001.png image002.png

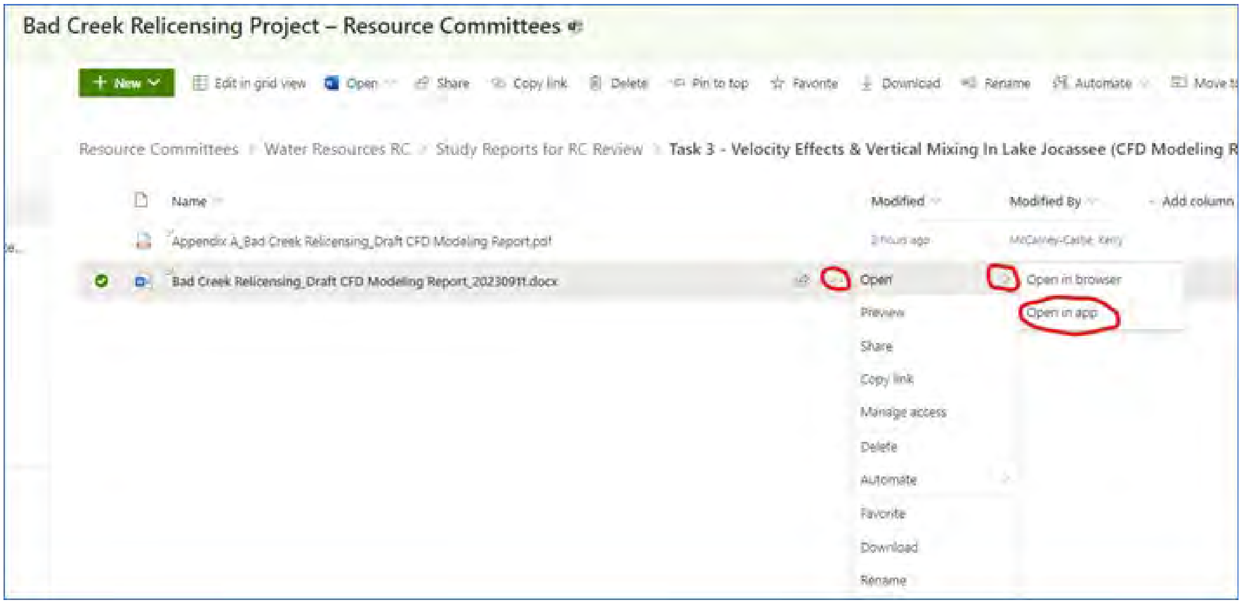
Dear Bad Creek Relicensing Aquatic and Water Resources Committees:

Duke Energy is pleased to distribute the Bad Creek II Power Complex **Water Quality Monitoring Plan** draft report for Resource Committee review (Water Resources Study, Task 5). This draft has been developed in consultation with and reviewed by the South Carolina Department of Environmental Services (SCDES). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Task 5 - Water Quality Monitoring Plan. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **November 4th**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

- We request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called "Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!*])



If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	Alex Pellett; Amy Breedlove; Dale Wilde; Dan Rankin; bereskind; Elizabeth Miller; Erika Hollis; Gerry Yantis; Jeff Phillips; Huff, Jen; McCarney-Castle, Kerry; quattrol; Olds, Melanie J; More, Priyanka; Amedee, Morgan D.; Raber, Maverick James; Ross Self; Scott Harder; Stuart, Alan Witten; William T. Wood; Morgan D. Amedee
Cc:	Kulpa, Sarah; Ziegler, Ty; Salazar, Maggie
Subject:	Bad Creek Relicensing Water Resources Task 2-Water Quality Monitoring in Whitewater River Arm Draft Report (READY FOR REVIEW)
Date:	Friday, October 25, 2024 10:21:42 AM
Attachments:	image001.png image002.png
Importance:	High

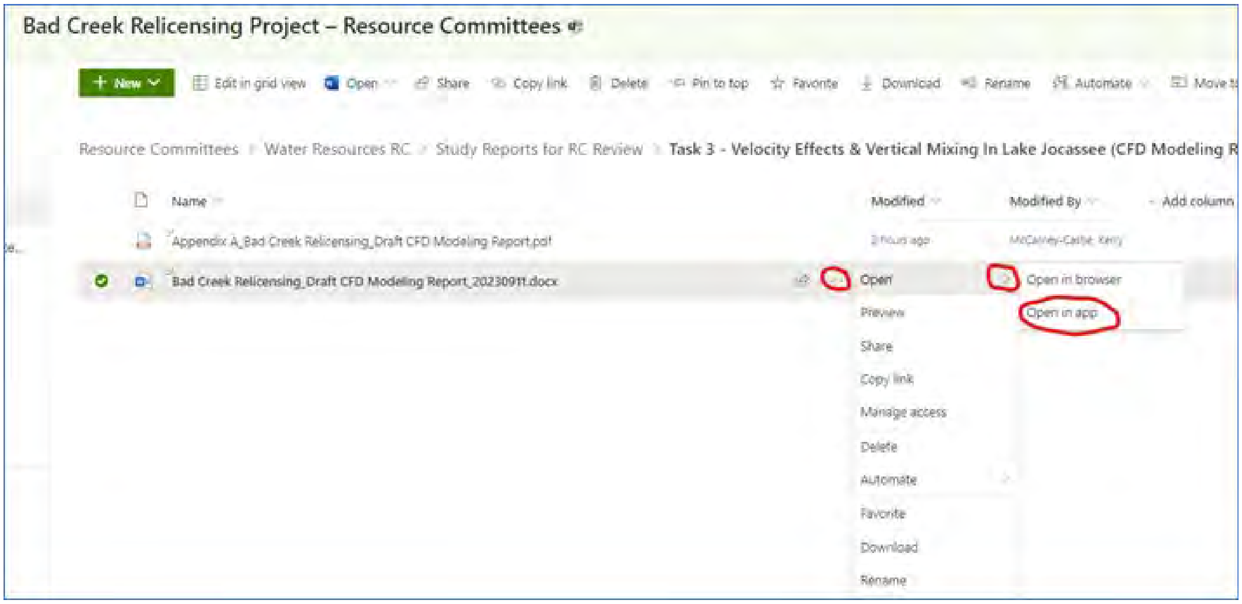
Dear Bad Creek Relicensing Water Resources Committee:

Duke Energy is pleased to distribute the *Water Quality Monitoring in Whitewater River Arm* draft report for Resource Committee review. This draft report satisfies Task 2 of the Bad Creek Relicensing Water Resources Study and presents results of continuous and bi-weekly water quality monitoring at three locations in the Whitewater River arm over two study seasons (June-Sept 2023 & 2024) to provide additional information on the function of the submerged weir and vertical mixing as well as baseline conditions under recently upgraded Project operations. The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Task 2 - Water Quality Monitoring in Whitewater River Arm. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **November 25th**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

- Duke Energy would like to make relicensing deliverables available on a shared platform (i.e., SharePoint) so all stakeholders can access, review, and comment; therefore, we request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

  (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **"**Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!])*



If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From: [Crutchfield Jr., John U](#)
To: [McCarney-Castle, Kerry](#)
Subject: FW: [EXTERNAL] Bad Creek Relicensing - Bad Creek II Power Complex Draft Water Quality Monitoring Plan (READY FOR REVIEW)
Date: Friday, November 1, 2024 10:12:25 AM
Attachments: image001.png
image002.png
Outlook-fel5dksf.png
Outlook-isc3qdvu.png

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

From: Olds, Melanie J <melanie_olds@fws.gov>
Sent: Friday, November 1, 2024 10:08 AM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Subject: Re: [EXTERNAL] Bad Creek Relicensing - Bad Creek II Power Complex Draft Water Quality Monitoring Plan (READY FOR REVIEW)

***** CAUTION! EXTERNAL SENDER *** STOP. ASSESS. VERIFY!!** Were you expecting this email? Are grammar and spelling correct? Does the content make sense? Can you verify the sender? If suspicious report it, then do not click links, open attachments or enter your ID or password.

John,

The Service has completed review and has no comments.

Melanie

Melanie Olds

Fish & Wildlife Biologist

Regulatory Team Lead/FERC Coordinator

U.S. Fish and Wildlife Service

South Carolina Ecological Services Field Office

176 Croghan Spur Road, Suite 200

Charleston, SC 29407

Phone: (843) 534-0403

From: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Sent: Friday, October 4, 2024 10:49 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; David Bereskin <bereskind@greenvillewater.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Gerry Yantis <gcyantis2@yahoo.com>; Jeffrey Phillips <jphillips@greenvillewater.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; quattrol@dnr.sc.gov <quattrol@dnr.sc.gov>; Olds, Melanie J <melanie_olds@fws.gov>; More Priyanka <morep@dnr.sc.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; SelfR@dnr.sc.gov <SelfR@dnr.sc.gov>; Scott Harder <harders@dnr.sc.gov>; Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Abney, Michael A <Michael.Abney@duke-energy.com>; Erin Settevendemio <Erin.Settevendemio@hdrinc.com>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Wahl, Nick <Nick.Wahl@duke-energy.com>; Ericah Beason <BeasonE@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>; Maggie Salazar <maggie.salazar@hdrinc.com>
Subject: [EXTERNAL] Bad Creek Relicensing - Bad Creek II Power Complex Draft Water Quality Monitoring Plan (READY FOR REVIEW)

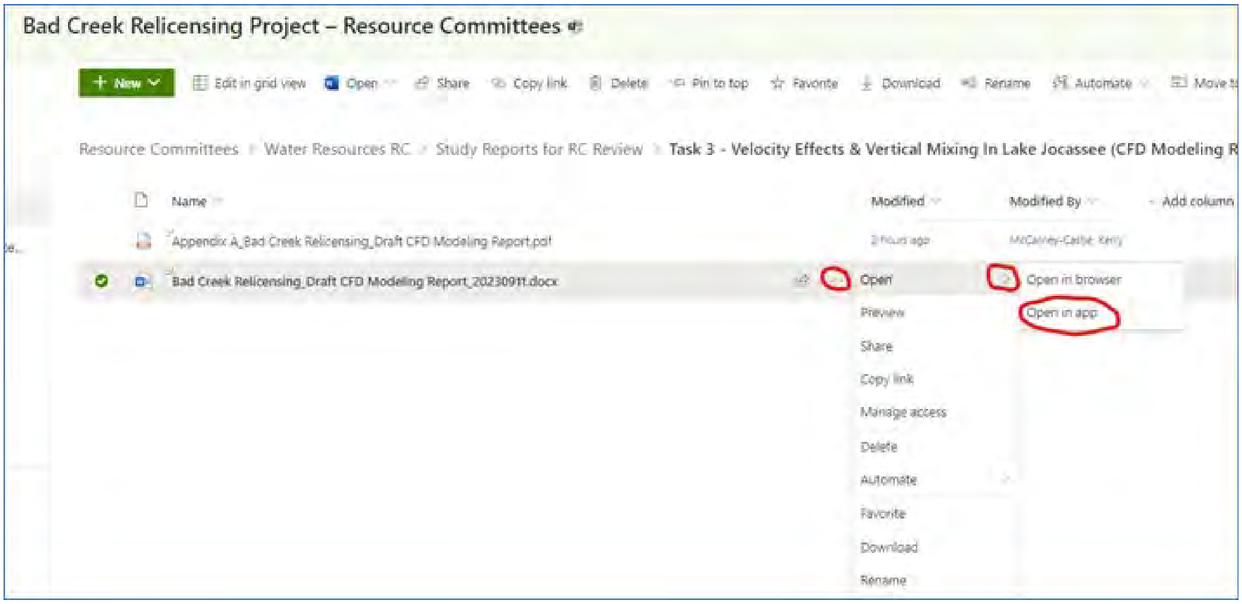
Dear Bad Creek Relicensing Aquatic and Water Resources Committees:

Duke Energy is pleased to distribute the Bad Creek II Power Complex **Water Quality Monitoring Plan** draft report for Resource Committee review (Water Resources Study, Task 5). This draft has been developed in consultation with and reviewed by the South Carolina Department of Environmental Services (SCDES). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Task 5 - Water Quality Monitoring Plan. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **November 4th**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

- We request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
- We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

(Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called **“**[Editing a Document in SharePoint](#)”. This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!]*)



If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	McCarney-Castle, Kerry
Subject:	FW: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek II Power Complex Draft Water Quality Monitoring Plan (READY FOR REVIEW)
Date:	Monday, November 4, 2024 8:27:29 AM
Attachments:	image001.png image002.png

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

From: Dale Wilde <dwilde@keoweefolks.org>
Sent: Monday, November 4, 2024 8:23 AM
To: Crutchfield Jr., John U <John.Crutchfield@duke-energy.com>
Cc: Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; Kelly Schaeffer <Kelly.Schaeffer@kleinschmidtgroup.com>
Subject: [EXTERNAL] Re: Bad Creek Relicensing - Bad Creek II Power Complex Draft Water Quality Monitoring Plan (READY FOR REVIEW)

***** CAUTION! EXTERNAL SENDER *** STOP. ASSESS. VERIFY!!** Were you expecting this email? Are grammar and spelling correct? Does the content make sense? Can you verify the sender? If suspicious report it, then do not click links, open attachments or enter your ID or password.

I have spoken with John Hains, and neither of us have any further comments on this QMP.

Ms. Dale Wilde
President, FOLKS
C: 207-604-6539
E: dwilde@keoweefolks.org

Friends of Lake Keowee Society is dedicated to the preservation and enhancement of Lake Keowee and its watershed through advocacy, conservation, and education.

On Oct 28, 2024, at 6:58 AM, Crutchfield Jr., John U <John.Crutchfield@duke-energy.com> wrote:

Dear Bad Creek Relicensing Aquatic and Water Resources Committees:

Just a reminder the Bad Creek II Power Complex Water Quality Monitoring Plan draft report is due by November 4th.

Regards, John

From: Crutchfield Jr., John U
Sent: Friday, October 4, 2024 10:49 AM
To: Alex Pellett <PellettC@dnr.sc.gov>; Amy Breedlove <BreedloveA@dnr.sc.gov>; Dale Wilde <dwilde@keoweefolks.org>; Dan Rankin <RankinD@dnr.sc.gov>; David Bereskin <bereskind@greenvillewater.com>; Elizabeth Miller <MillerE@dnr.sc.gov>; Erika Hollis <ehollis@upstateforever.org>; Gerry Yantis <gcyantis2@yahoo.com>; Jeffrey Phillips <jphillips@greenvillewater.com>; Kerry McCarney-Castle <Kerry.McCarney-Castle@hdrinc.com>; Lynn Quattro <quattrol@dnr.sc.gov>; Melanie Olds <melanie_olds@fws.gov>; More Priyanka <morep@dnr.sc.gov>; Morgan Amedee <amedeemd@dhec.sc.gov>; Raber, Maverick James <Maverick.Raber@duke-energy.com>; Ross Self <SelfR@dnr.sc.gov>; Scott Harder <harders@dnr.sc.gov>;

Stuart, Alan Witten <Alan.Stuart@duke-energy.com>; William Wood <woodw@dnr.sc.gov>; Abney, Michael A <Michael.Abney@duke-energy.com>; Erin Settevendemio <Erin.Settevendemio@hdrinc.com>; Jen Huff <jen.huff@hdrinc.com>; John Haines <jhains@g.clemson.edu>; Wahl, Nick <Nick.Wahl@duke-energy.com>; Ericah Beason <BeasonE@dnr.sc.gov>
Cc: Kulpa, Sarah -hdrinc <Sarah.Kulpa@hdrinc.com>; Ziegler, Ty <ty.ziegler@hdrinc.com>; Maggie Salazar <maggie.salazar@hdrinc.com>
Subject: Bad Creek Relicensing - Bad Creek II Power Complex Draft Water Quality Monitoring Plan (READY FOR REVIEW)

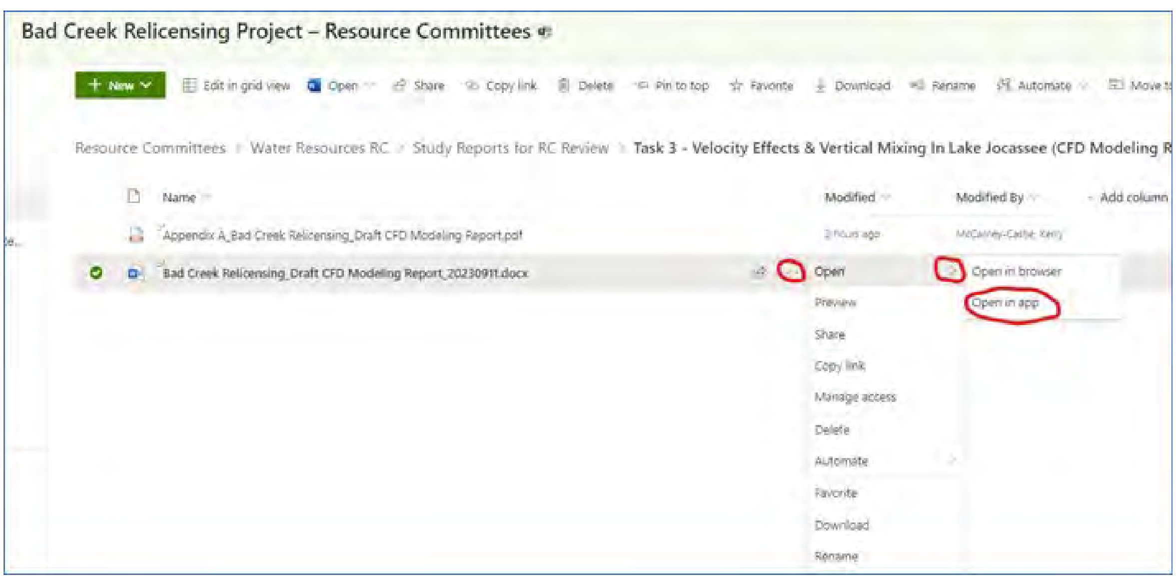
Dear Bad Creek Relicensing Aquatic and Water Resources Committees:

Duke Energy is pleased to distribute the Bad Creek II Power Complex **Water Quality Monitoring Plan** draft report for Resource Committee review (Water Resources Study, Task 5). This draft has been developed in consultation with and reviewed by the South Carolina Department of Environmental Services (SCDES). The deliverable is available on the Bad Creek Relicensing SharePoint site at the following link: Task 5 - Water Quality Monitoring Plan. Duke Energy is requesting a 30-day review period, therefore, please submit all comments by **November 4th**. A confirmation email is kindly requested upon review completion (email me at John.Crutchfield@duke-energy.com).

Important – Please Read!

1. We request all comments be made in the SharePoint Word document using tracked changes. This will eliminate version control issues and result in a consolidated document for comment response.
2. We strongly recommend opening the document in Word; otherwise, the formatting will look distorted. The simplest way to do this is to click on the three dots to the right of the document (example shown below), choose "Open", then choose "Open in app". This will open the document in Word, and you'll have the functionality you are accustomed to. Your changes will be saved automatically as you review. Please feel free to reach out to @McCarney-Castle, Kerry for SharePoint assistance.

   (Note: If you are new to SharePoint, a very brief tutorial with screenshots is available on the home page of the Resource Committees tab called "Editing a Document in SharePoint". This is the same tutorial that was presented during the kick-off meeting. [*The tutorial provides an alternative way to open the document in Word – either technique works!*])



If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	Alex Pellett; Amy Breedlove; Dale Wilde; Dan Rankin; bereskind; Elizabeth Miller; Erika Hollis; Gerry Yantis; Jeff Phillips; McCarney-Castle, Kerry; quattrol; Olds, Melanie J; More, Priyanka; Amedee, Morgan D.; Raber, Maverick James; Ross Self; Scott Harder; Stuart, Alan Witten; William T. Wood; Abney, Michael A; Settevendemio, Erin; Huff, Jen; jhains@g.clemson.edu; Wahl, Nick; Ericah Beason; Morgan D. Amedee
Cc:	Kulpa, Sarah; Ziegler, Ty; Salazar, Maggie
Subject:	RE: Bad Creek Relicensing - Bad Creek II Power Complex Water Quality Monitoring Plan Draft Report (FINAL DRAFT)
Date:	Tuesday, November 12, 2024 6:20:49 AM
Attachments:	image001.png
Importance:	High

Dear Bad Creek Relicensing Aquatic and Water Resources Committees:

The finalized Bad Creek II Power Complex Water Quality Monitoring Plan draft report has been uploaded to the Resource Committee SharePoint link: Final Report.

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095

From:	Crutchfield Jr., John U
To:	Alex Pellett; Amy Breedlove; Dale Wilde; Dan Rankin; bereskind; Elizabeth Miller; Erika Hollis; Gerry Yantis; Jeff Phillips; Huff, Jen; McCarney-Castle, Kerry; quattrol; Olds, Melanie J; More, Priyanka; Amedee, Morgan D.; Raber, Maverick James; Ross Self; Scott Harder; Stuart, Alan Witten; William T. Wood; Morgan D. Amedee; Abney, Michael A
Cc:	Kulpa, Sarah; Ziegler, Ty; Salazar, Maggie
Subject:	RE: Bad Creek Relicensing Water Resources Task 2-Water Quality Monitoring in Whitewater River Arm Draft Report (FINAL REPORT)
Date:	Sunday, December 1, 2024 6:28:47 PM
Attachments:	image001.png
Importance:	High

Dear Bad Creek Relicensing Water Resources Committee:

Duke Energy is pleased to distribute the Water Quality Monitoring in Whitewater River Arm final report. This report satisfies Task 2 of the Bad Creek Relicensing Water Resources Study and is accessible from the folder linked below. As always, Duke Energy appreciates your participation in the Bad Creek Relicensing.

Final Report

If you have any questions, please contact Alan Stuart or me.

Regards,

John Crutchfield
Project Manager II
Water Strategy, Hydro Licensing & Lake Services
Regulated & Renewable Energy
Duke Energy
525 South Tryon Street, DEP-35B | Charlotte, NC 28202
Office 980-373-2288| Cell 919-757-1095