Bad Creek Revised Study Plan Appendices

Part III

Appendix I

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APPENDIX I

SUPPLEMENTAL INFORMATION – GEOLOGY AND PROJECT FEASIBILITY

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

December 2022

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GEOLOGY AND PROJECT FEASIBILITY
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740
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ATTACHMENTS

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ACRONYMS AND ABBREVIATIONS

Bad Creek or Project	Bad Creek Pumped Storage Project
Bad Creek II Complex	Bad Creek II Power Complex
CFD	Computational Fluid Dynamics
cm	centimeter
CVSZ	Central Virginia Seismic Zone
Duke Energy or Licensee	Duke Energy Carolinas, LLC
ETSZ	East Tennessee Seismic Zone
FERC or Commission	Federal Energy Regulatory Commission
ft	feet/foot
km	kilometers
I/O structure	inlet/outlet structure
KT Project	Keowee-Toxaway Hydroelectric Project
Ma	million years ago
MASW	multichannel analysis of surface waves
msl	mean sea level
NEPA	National Environmental Policy Act
PM&E	Protection, Mitigation, and Enhancement
PAD	Pre-application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
SD2	Scoping Document 2
TGn	Toxaway Gneiss
TFF	Tallulah Falls Formation

1 Study Requests and Formal Comments

The Federal Energy Regulatory Commission's (FERC or the Commission) August 5, 2022 Scoping Document 2 (SD2) identified the following environmental resource issues to be analyzed in the National Environmental Policy Act (NEPA) document for the Bad Creek Pumped Storage Project (Project) relicensing related to geology and soil resources. These resource issues address the effects of continued Project operations under the Existing License as well as potential construction and operation of a second powerhouse during the New License term for the Bad Creek II Power Complex (Bad Creek II Bad Creek II Complex]):

- Effects of seismic activity in the Project area on construction of the Bad Creek II Complex, and vice versa.
- Effects of (expanded) Project operation on shoreline erosion along the lower reservoir (*will be analyzed for both cumulative and site-specific effects*)
- Effects of (expanded) Project construction on slope instability in the Project area.
- Effects of (expanded) Project construction and spoil disposal on soil erosion and sedimentation.

As stated in Section 1.3 of the Pre-application Document (PAD) (Duke Energy 2022) and reiterated in the Proposed Study Plan (PSP) submitted to the FERC on August 5, 2022, a full engineering feasibility study in support of the proposed Bad Creek II Complex was completed in Summer 2022, and some follow-on activities will continue into 2023. Relevant components of the feasibility study report are summarized herein to address specific environmental resource issues identified the Commission's Scoping Documents. Three individual volumes of the Bad Creek II Power Complex Feasibility Study (submitted to Duke Energy under Confidential Client Privilege on September 1, 2022; HDR 2022) along with select relevant appendices are included as Attachment 1 (Geology and Seismology Studies Report), Attachment 2 (Geotechnical Studies Report) and Attachment 3 (Lower Reservoir Computational Fluid Dynamics [CFD] Flow Modeling Report).

No formal study requests related to geology and soil resources were received during the scoping process and as stated in the PAD and PSP, Duke Energy does not propose to conduct a separate relicensing study focused on geology and soils. Stakeholder and FERC comments relevant to geology and soils were considered in the development of the PSP and this Revised Study Plan (RSP). All comments on the PAD and Scoping Document 1 relevant to geology and soils were included in Appendix A of the PSP and are included in this RSP in the formal correspondence documentation provided in Appendix B.

2 Goals and Objectives

While there are no anticipated additional adverse effects to geology and soils resources due to the continued operation of the Project, potential adverse effects resulting from the construction and operation of the Bad Creek II Complex should be evaluated. The goal of the Geology and Feasibility report is to summarize key methods and results from the feasibility study related to geology and seismology of the Project area as well as findings from the lower reservoir CFD modeling effort, which provides relevant information on shoreline erosion in Whitewater River cove. The full reports and select report appendices are included in Attachments 1, 2, and 3. The information in the following sections addresses the first three resource issues identified by FERC in SD2 listed above. The fourth item in the list of resource issues (i.e., effects of Project construction and spoil disposal on soil erosion and sedimentation) will be addressed through the Water Resources Study carried out for the relicensing as well as during environmental permitting efforts related to construction and spoil disposal.

3 Geology and Geotechnical Studies

Extensive geologic and geotechnical field and laboratory investigations were carried out to support the feasibility design of the Bad Creek II Complex. As part of the overall feasibility study effort, HDR performed a geological/geotechnical field investigation with the following objectives:

1. To provide a well-structured study plan, utilizing the geologic mapping data and special geologic studies during the construction of the existing Project, additional geologic assessments conducted to date, topographic data, and preliminary layout studies to function as a bridge between the site feasibility study and potential future site studies.
2. To assess, to the extent possible, site geological/geotechnical conditions in support of site layouts, conceptual designs, basic construction methods, and construction materials. Results of the geological/geotechnical studies will be used to develop recommendations regarding project structures, locations, and layout; provide input for Project cost opinions and schedule; and plan future geological/geotechnical investigations for the Project.

The study involved 1) a review of existing geological information from the investigations for and during construction of the Bad Creek Project and 2) incorporation of geotechnical and geophysical data from HDR's geotechnical exploration program, which included geophysical field testing and drilling five exploration boreholes. The study included a field review of rock core from the five boreholes drilled for the feasibility study, review of seismic refraction and multichannel analysis of surface waves (MASW) lines and other geophysical data (downhole geophysical measurements), review of geotechnical testing data, and a field reconnaissance to assess geologic features and site conditions as related to the construction and operation of the proposed Bad Creek II Complex. Results from the geology and geotechnical studies are summarized in the sections that follow and details are provided in Attachment 1 (Geology and Seismology Studies Report) and Attachment 2 (Geotechnical Studies Report), along with site and regional geology, lithology, structural geology and shear zones, in-situ stress measurements, and regional and local seismology.

Geologic characteristics that could impact the proposed Project are identified and further evaluation of these characteristics will be performed during the next study phase if the Bad Creek II Complex is pursued.

3.1 Background

3.1.1 Regional Geology

The Project is located in the Blue Ridge physiographic province, a mountainous zone that extends northeast-southwest from southern Pennsylvania to central Alabama, varying in width from less than 15 miles to 70 miles maximum. It is characterized by rugged terrain with valleys ranging in elevation from 1,000 feet (ft) in the south to greater than 1,500 ft in the north. In North Carolina, massive and resistant gneissic and metasedimentary rocks underlie most of the province, with the valleys tending to follow weaker-rock outcrops (e.g., schist or minor carbonate rocks) and fractures or fault/shear zones. The underlying geologic structure has a strong influence on local topography.

The crystalline rocks of the southern Appalachians occur in northeast-trending parallel geologic terranes. The Bad Creek Project is within the Tugaloo terrane, which includes rocks of the eastern Blue Ridge northwest of the Brevard zone (Figure 3-1; Hatcher et al. 2007; Hatcher 2002). The Blue Ridge is a complex crystalline terrane consisting of Precambrian gneissic basement rocks structurally overlain by a vast thickness of metasedimentary and metavolcanic rocks of Precambrian to lower Paleozoic age (Hatcher 1978a, 1978b). The structure of the Blue Ridge is controlled by major thrust faults, associated complex polyphase folding, and subsequent brittle faulting (Hatcher 1978a; Clendenin and Garihan 2007a, 2007b). The principal rock unit of the western Tugaloo terrane (eastern Blue Ridge belt) is the Tallulah Falls Formation (TFF). The TFF generally consists of biotite gneiss (metagraywacke), pelitic schist, mafic volcanic rocks, and quartzite; in places the rocks of the TFF are migmatitic[1]. These rocks are intruded by Paleozoic granitoid rocks and overlie 1,150 to 1,200 million years ago (Ma) Precambrian Grenville basement rocks in the Toxaway Dome. Dominant metamorphic fabric and peak metamorphism in the eastern Blue Ridge is circa 450 Ma, based on metamorphic ages of detrital monazite and zircon grains from TFF rocks (Miller et al. 1997, 2000; Moecher et al. 2011; Cattanach et al. 2012).

The Toxaway Gneiss (TGn), part of the Precambrian Grenville basement of the eastern Blue Ridge, is exposed in the core of the Toxaway Dome. It is typically a medium- to coarse-grained banded biotite-plagioclase-microcline-quartz gneiss with some massive and augen varieties, which do not appear to be significantly different in chemical/mineralogical composition (Schaeffer 1987, 2016; Merschat et al. 2003). The TGn has an Rb/Sr whole-rock isochron age of 1203+54 Ma (Fullagar et al. 1979). A derived zircon age for the TGn is 1,150 Ma (Carrigan et al. 2003 in Hatcher et al. 2007). More detail is included in the complete Geology and Seismology Studies Report in Attachment 1.

3.1.2 Site Geology

The Project is located immediately northwest of the Brevard zone in the Tugaloo terrane within the Toxaway Dome (Figure 3-1) and most of the site is underlain by TGn (see Figure 9 in Attachment 1). All tunnels, shafts, and the powerhouse cavern for the existing Project were excavated in TGn and based on geologic information available, the underground structures for the proposed Bad Creek II will be excavated in the same rock (Figure 3-2). The Main Dam and East Dike are founded on TGn; the West Dam and a portion of the reservoir are underlain by a sequence of schistose rocks belonging to the TFF. The TFF rocks are predominantly the garnet-aluminous schist member; however, in places portions of the upper graywacke-schist member is present. This belt of TFF rocks is isolated from similar rocks on northwest and southeast of the Toxaway Dome by the refolding of earlier folds (Hatcher 1978a; Schaeffer 1987, 2016).

Layers of biotite-hornblende schist (sills or dikes, possibly feeders for the mafic volcanic rocks of the TFF) are present with thicknesses up to 20 ft. Their orientation is parallel to the dominant foliation/banding in the TGn. At least two generations of quartz-feldspar-mica pegmatites occur within the TGn. They are distinguished by the fact that the later generation is undeformed except by fracturing, whereas the earlier generation is folded. Most of the early pegmatites parallel the dominant foliation, the

[1] Migmatite – Rock consisting of alternating layers or lenses of granitic material in gneisses and schists; related to partial melting of the rock during deformation and metamorphism and then re-crystallization of the melt during the waning stages of metamorphism.

later generation cuts across foliation. Small cross-cutting quartz veins are also present. For more details on the TFF in the site vicinity, see Attachment 1.

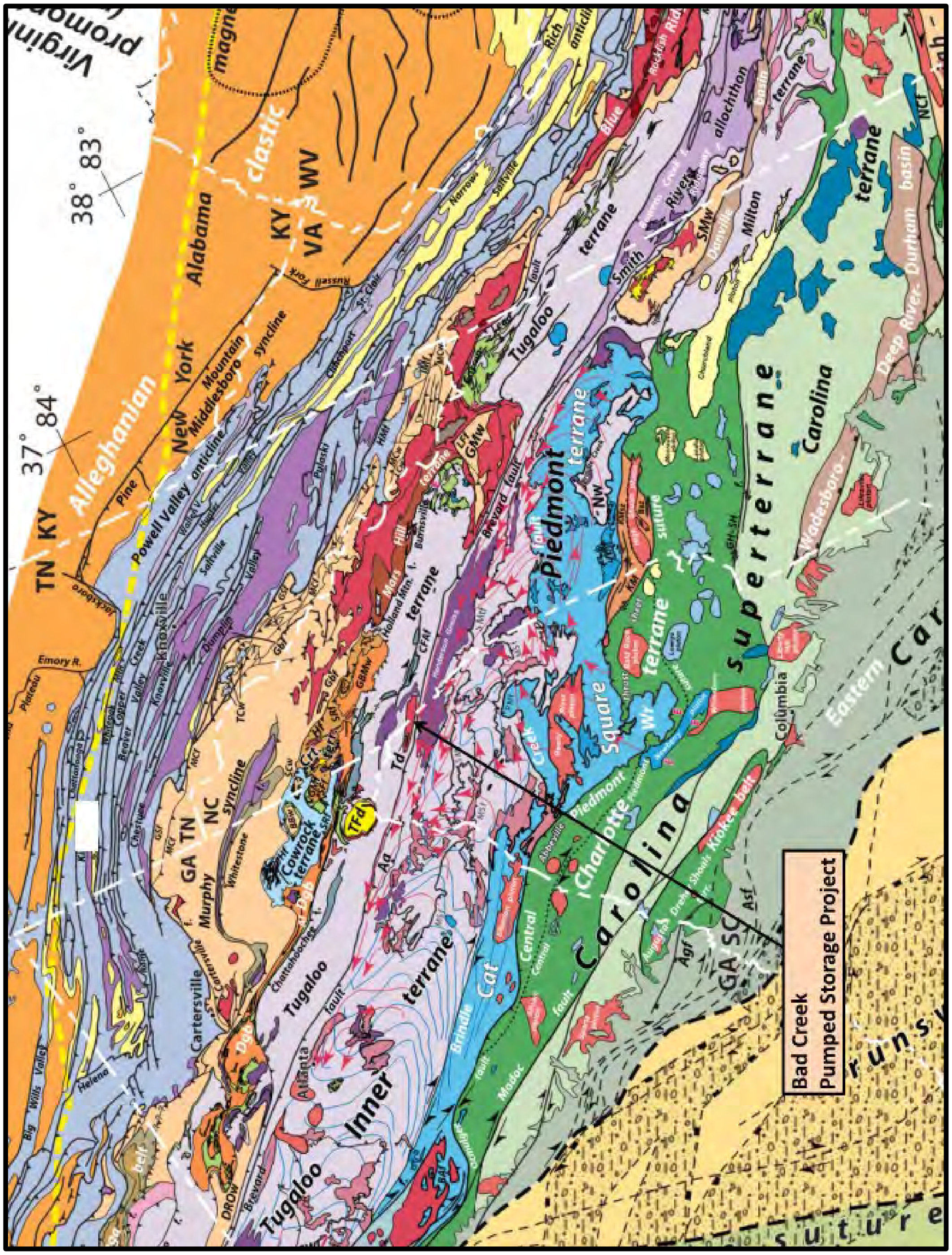


Figure 3-1. Tectonic Map of the Southern and Central Appalachians and Location of the Bad Creek Pumped Storage Project (from Hatcher et al. 2007) (Td = Toxaway Gneiss)

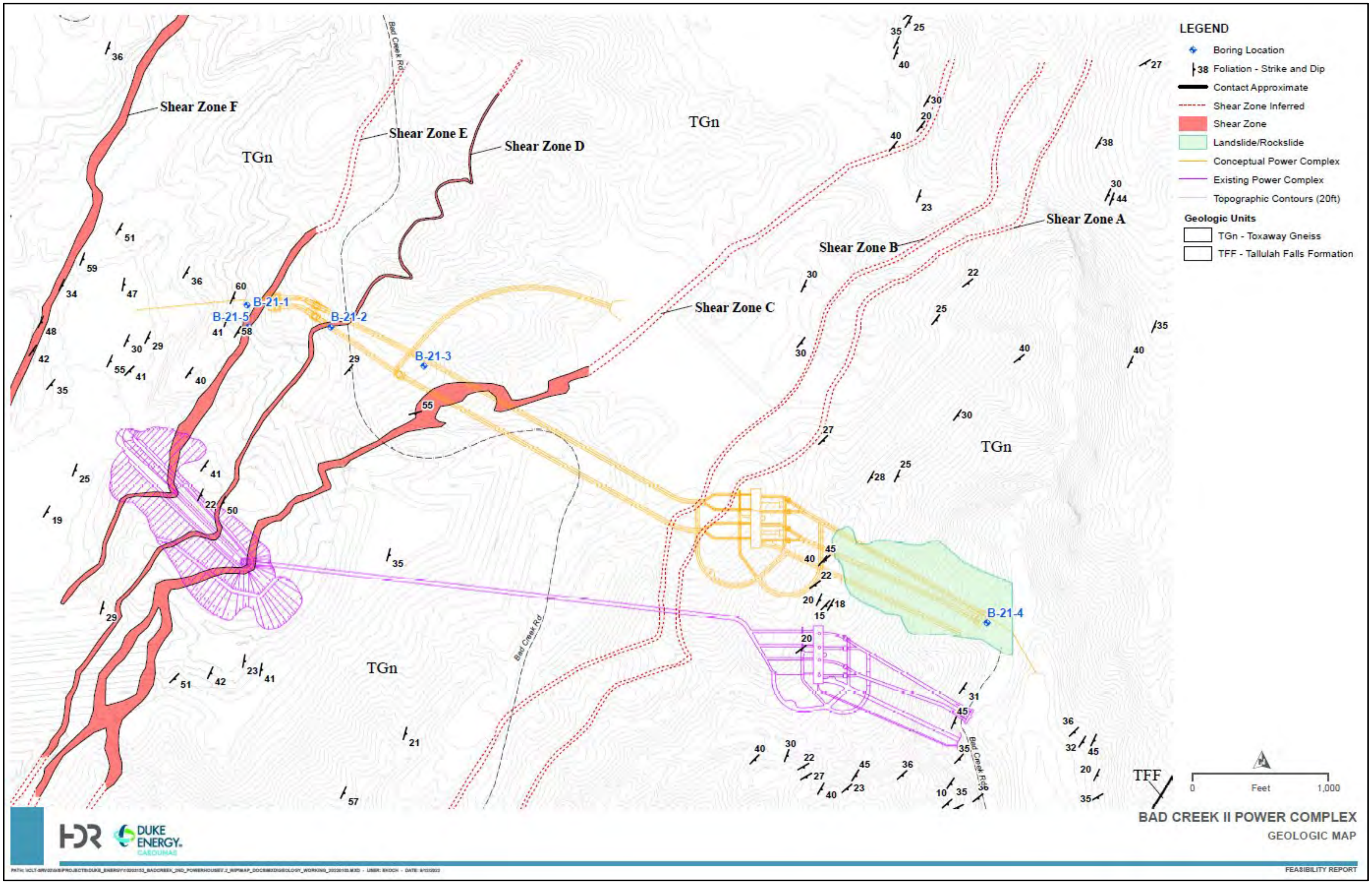


Figure 3-2. Geologic Map of Bad Creek Pumped Storage Project and Proposed Project

3.2 Previous Geologic Mapping

During the original design studies for the Project (pre-1985), the subsurface exploration program had the following primary objectives related to the underground excavations and structures: 1) examine the rock characteristics and geologic structure of the proposed powerhouse location, 2) determine the most feasible powerhouse orientation and location with respect to the geologic structure and in-situ stresses, 3) provide the data and experience necessary to facilitate an efficient design of the underground portions of the project, and 4) serve as a model for the instrumentation and monitoring to be incorporated into the permanent underground structures.

Along with a pilot tunnel excavation and testing from October 1976 through September 1977, the geologic program conducted during construction of the Project (from 1985 to 1991) provided geologic information for construction and design. Components of the original geologic study included observation, measurement, sampling, photographs, mapping, and evaluation of the exposed rock and foundation surfaces. The geologic conditions encountered in the underground works were documented by geologic mapping of at least one rib of all tunnels; the walls of the two vertical shafts; and the walls, crown, and floor of the powerhouse cavern at a scale of 1 inch = 6.56 ft. The aboveground structures including dam foundations, intake excavation, and discharge excavation were mapped at a scale of 1 inch = 20 ft. The upper reservoir area was mapped at a scale of 1 inch = 200 ft after all excavation and borrow work was completed. The mapping was the primary input into construction and design considerations as work progressed and was supplemented by additional studies as needed. The geologic work during construction, including additional studies beyond the geologic mapping (for documentation), are described and discussed in Duke Power Company (1991) and Schaeffer (2016 [included as Attachment 1, Appendix B]). Note that an alternate interpretation of the geology along Lake Jocassee at the inlet/outlet (I/O) structure area is presented by Clendenin and Garihan (2007a); details are included in the full report in Attachment 1.

3.2.1 Lithology

Detailed geologic mapping of the Bad Creek Project underground excavations resulted in a detailed subdivision of rock types within the TGn. The following units were recognized and mapped during the original construction:

- Granitic Gneiss, medium light gray to light gray, medium- to coarse-grained gneiss consisting of alternating layers of light-colored quartz-feldspar bands and darker biotite-quartz-feldspar bands, well-foliated;
- Banded Augen Granitic Gneiss, medium light gray to light gray, medium- to coarse-grained gneiss consisting of a foliated (banded) quartz-feldspar-biotite gneiss containing feldspar augen up to 1 centimeter (cm) long;

- Augen Granitic Gneiss, medium light gray, coarse-grained gneiss consisting of a coherent, massive, poorly foliated feldspar-quartz-biotite gneiss with feldspar and locally hornblende augen up to 3 cm long;
- Biotite Schist, medium dark gray to dark gray, coarse-grained biotite-hornblende schist;
- Biotite Gneiss, medium dark gray to dark gray, medium- to coarse-grained biotite-hornblende gneiss;
- Biotite Augen Gneiss, medium gray to medium dark gray, medium- to coarse-grained, foliated biotite-feldspar-quartz gneiss with feldspar augen up to 1 cm long, biotite content generally greater than 30 percent;
- Quartz-Feldspar Gneiss, very light gray to white, very coarse-grained, distinctly foliated quartz-feldspar gneiss with minor biotite (less than 10 percent);
- Very Coarse-Grained Granitic Gneiss, light gray, very coarse-grained, distinctly foliated quartz-feldspar-biotite gneiss, biotite content greater than 10 percent;
- Weathered Sheared Rock, moderate to moderately severe weathering, light gray to yellowish gray to greenish gray, original rock type granitic or augen granitic gneiss; and
- Hard Sheared Rock, medium light gray to light gray, medium- to coarse-grained rock, original rock type granitic or augen granitic gneiss.

3.2.2 Structural Geology

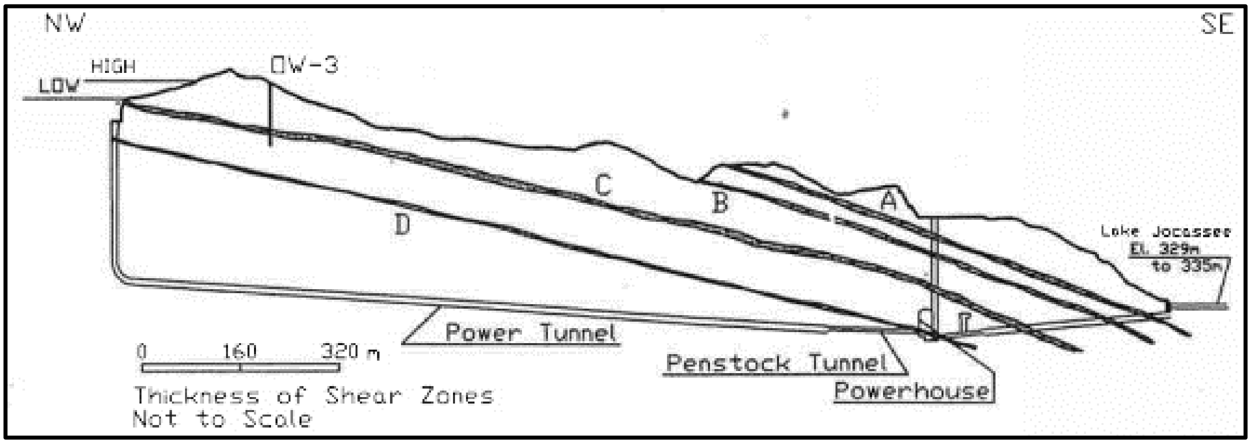
The foliation in the TGn and TFF rocks is defined by the parallel orientation of platy minerals and by compositional layering. The average orientation of foliation in the Bad Creek reservoir area is N37E; 38SE and varies from N35-50E; 28-41SE in the underground works. Minor folds are present; some lie within foliation whereas others fold the dominant foliation. The earliest set of folds are isolated “z-”, “s-”, and crescent-shaped fragments, which are axial planar to the dominant foliation. The presence of these isolated fold fragments indicates that transposition of an older foliation has occurred. The second set of folds are isoclinal to open with variable development of a secondary foliation. In areas where this folding is isoclinal, an axial planar foliation (defined by secondary biotite) is present. Later open folding was recognized in several tunnels of the existing Project.

Shear zones with thicknesses up to 200 ft occur throughout the TGn and generally parallel the dominant foliation. Four major shear zones are present in the reservoir and dam areas (Shear Zones C, D, E, and F on Figure 3-2) and two additional major shear zones (Shear Zones A and B on Figure 3-2) were mapped in the underground tunnels (Figure 3-3; projections to the ground surface are shown on Figure 3-2).

Shear Zone A is in the vertical access shaft and in the excavation along Lake Jocassee for the I/O structure. Shear Zone B is present in the vertical access shaft, the main access, Tailrace 1 and 2, and Tailrace 3 and 4 tunnels. Shear Zone C is present in the main access, penstock bypass, tailrace bypass, draft tube gate, Tailrace 1 and 2, and Tailrace 3 and 4 tunnels and the vertical access shaft. Shear Zone D is present in the manifold, Penstock 1, Penstock 2, Penstock 3, and Draft Tube 1 tunnels and in the west, north, and east wall and along the floor of the powerhouse cavern. The zones consist of hard sheared rock with layers of weathered sheared rock present. The zones are mineralized with chlorite, epidote, calcite, and quartz in various combinations. Along some of the shear planes, breccia is present with thicknesses of less than 1 inch to approximately 12 inches. The breccia consists of granitic gneiss, coarse quartz/feldspar (pegmatites), and vein quartz fragments in a matrix of fine-grained chlorite and epidote. Several of the shear zones have associated weathered zones up to 12 inches thick. Within the weathered zone there is up to 2 inches of gouge-breccia composed of granitic gneiss, coarse quartz/feldspar, and vein quartz fragments in a clay matrix. The hard sheared rock exhibits tight, complex isoclinal folding with sheared out limbs and a secondary axial planar foliation defined by biotite.

Fault and fault zones in the underground portion of the Project are present and are generally associated with the northeast-striking joint sets. Single fault planes with few associated fractures have offsets up to 6 inches (vertical separation). The fault zones have complex fracturing with several planes and offsets ranging from less than 1 inch to greater than 12 ft. Breccias up to 6 inches thick are developed along some of the fault planes and consist of rock, quartz/feldspar, and vein quartz fragments in a fine-grained matrix of chlorite-epidote. In some fault zones the rock is shattered between fault planes with chlorite-quartz mineralization throughout the fracture zone. The brecciation and mineralization of the fault zones occurred at the same time as the brecciation along the shear zones. The faults and shear zones are similar to others within the southern Appalachians that have been healed under greenschist metamorphic conditions, suggesting the last movement occurred at least 300 Ma (Gilbert et al. 1982).

All site structural data from mapping in areas of the west dam, main dam, reservoir area, and underground areas are included in Attachment 1.



Source: Talwani et al. 1999

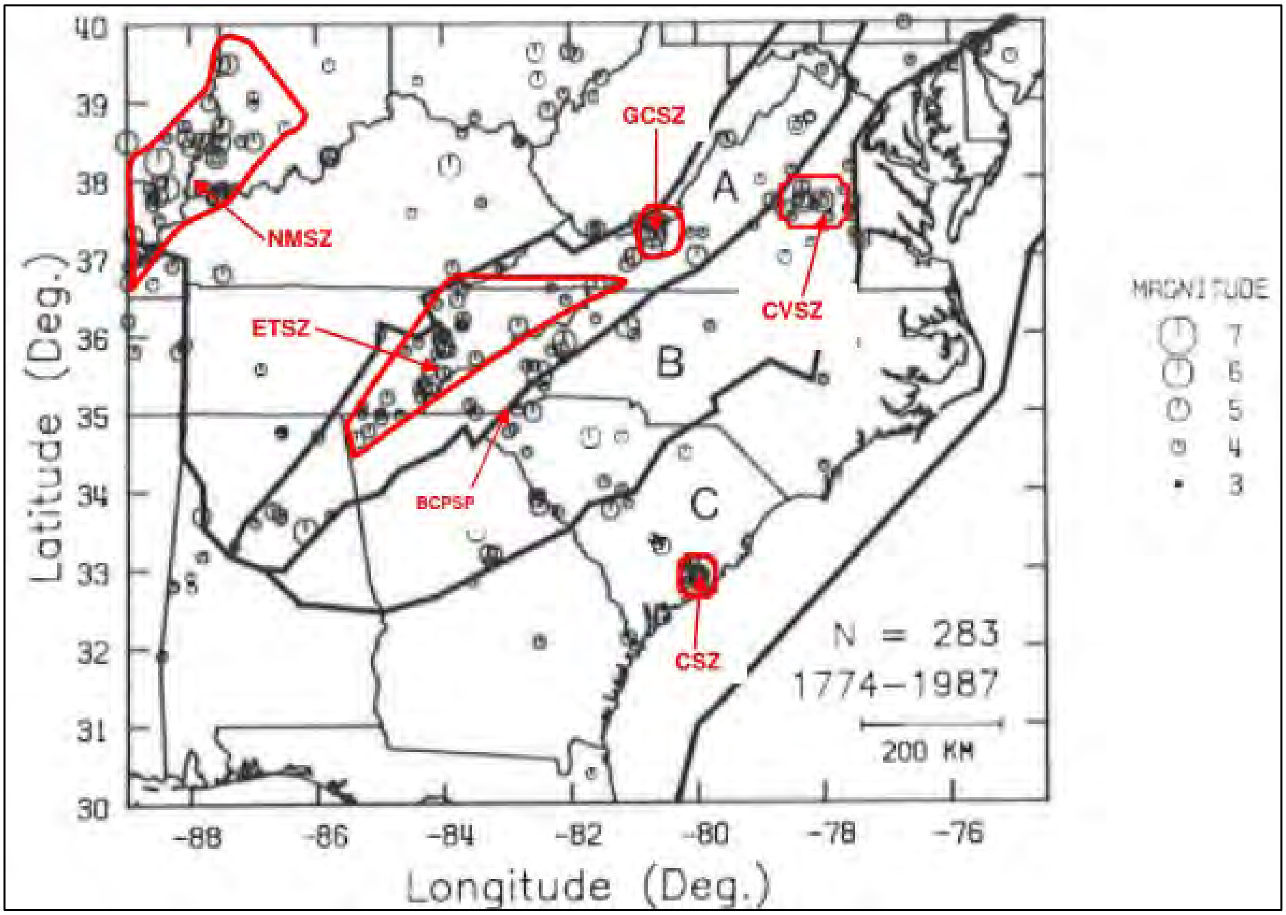
Figure 3-3. Cross-section of Existing Bad Creek Underground from the Upper Intake to the Discharge/Intake Structure on Lake Jocassee showing Location of Shear Zones A, B, C, and D

3.2.3 In-Situ Stress Measurements

Two methods of in-situ stress measurement were employed for the design of the existing Bad Creek Project tunnels, caverns, and shafts: hydrofracturing and overcoring. Hydrofracturing tests were performed in a deep borehole (B-52) from the ground surface and the overcoring technique was employed in the proposed powerhouse location in the pilot tunnel. Overcoring stress values were among the input parameters for finite element modeling performed for the design of the existing Bad Creek Project powerhouse and tunnels. Results of the finite element modeling analysis were used to determine the shape of the powerhouse and tunnels; other factors such as geologic structure, support methods, and other functional requirements played a major role. The most useful information from the finite element modeling results was an estimate of the how much rock movement should be expected during and after powerhouse excavation. These estimates became the basis for evaluating the data from installed instruments during and after construction of the existing powerhouse.

3.3 Seismicity

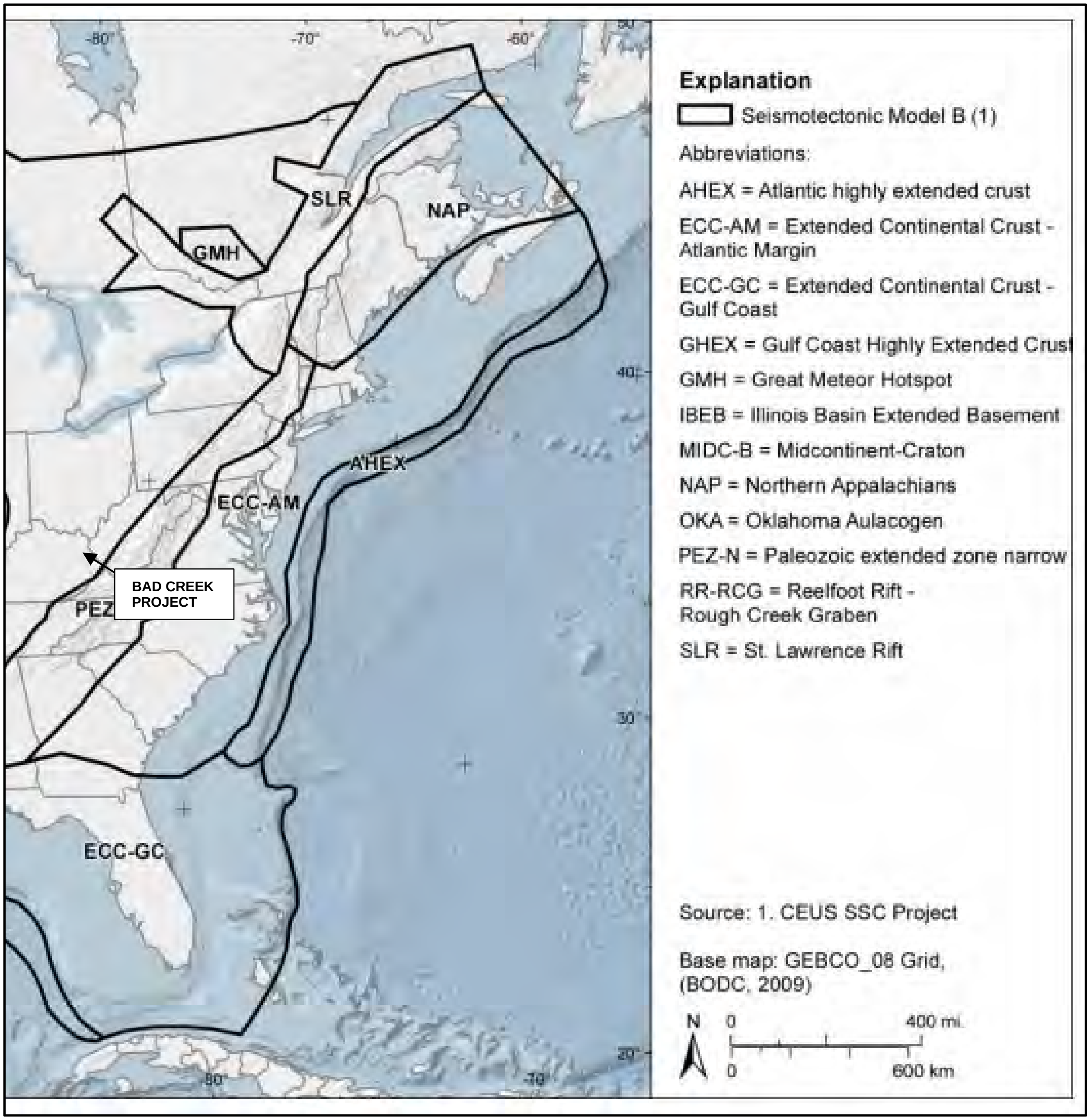
The East Tennessee Seismic Zone (ETSZ), closest to the Bad Creek Project, is one of the most active seismic zones in eastern North America (Bollinger et al. 1985) and is located primarily in the Valley and Ridge physiographic province of Tennessee with a portion in the Valley and Ridge and Blue Ridge physiographic province of western North Carolina (Figure 3-4). The zone is approximately 300 kilometers (km) long and 50 km wide and has not produced a damaging earthquake in historical time (Powell et al. 1994). The earthquakes occur at depths of to 5 to 25 km within Precambrian crystalline basement rocks beneath the thrust sheets of Paleozoic sedimentary rocks of the Valley and Ridge (Bollinger et al. 1976; Bollinger et al. 1991). The structures likely responsible for the seismicity in the zone are reactivated Precambrian to Cambrian normal faults formed during the rifting (extension) that formed the Iapetus Ocean and are located beneath the later accreted Appalachian thrust sheets (like the Giles County Seismic Zone in Virginia; Wheeler 1995). In the recent EPRI (2012) Central and Eastern United States seismic source characterization, the site is in the Paleozoic extended crust zone (Figure 3-5) as described in the previous two sentences. Despite its relatively high rate of activity, the largest known earthquake in the ETSZ is M_w 4.7[2] (1973 Alcoa-Marysville earthquake; Bollinger et al. 1991).



Note: BCPSP = Bad Creek Pumped Storage Project; A = Valley and Ridge and Blue Ridge; B = Piedmont; C= Coastal Plain. GCSZ = Giles County Seismic Zone (not discussed in text); ETSZ = East Tennessee Seismic Zone; CVSZ = Central Virginia Seismic Zone; CSZ = Charleston Seismic Zone (not discussed in text); NMSZ = New Madrid Seismic Zone (not discussed in text). Figure modified from Bollinger et al. 1991).

Figure 3-4. Southeastern U.S. Seismicity (1774 to 1987), Physiographic Provinces and Seismic Zones

[2] M_w = Moment Magnitude.



Source: EPRI 2012

Figure 3-5. Central and Eastern United States Seismotectonic Zones and Location of the Bad Creek Pumped Storage Project

Recent work between Vonore and Maryville, Tennessee, centered on the Tellico Reservoir and the Little Tennessee River, has yielded evidence of paleoseismic features within a narrow northeast-trending zone (Hatcher et al. 2015; Glasbrenner et al. 2015; Warrell et al. 2017). The evidence includes faulted Quaternary river sediments and folded terrace deposits with faults that have offsets of up to 2 meters that involve bedrock (Hatcher et al. 2015; Warrell et al. 2017). Warrell et al. (2017) dated features within the zone and determined that at least three large earthquakes occurred in the ETSZ during the late Pleistocene (1.0 (?) to 0.012 Ma) with at least one or more exceeding M_w 6.

The Central Virginia Earthquake of September 1, 2011 (M_w 5.7 - 5.8) was the largest and most damaging in the central and eastern United States since the 1886 Charleston, South Carolina earthquake (estimated M_w 6.8 - 7.0). The earthquake occurred on a north or northeast-striking plane with reverse faulting within a previously recognized seismic zone, the "Central Virginia Seismic Zone." The Central Virginia Seismic Zone (CVSZ) has produced small and moderate earthquakes since at least the 18th century. The previous largest historical shock from the Central Virginia Seismic Zone occurred in 1875. The CVSZ is in the Appalachian Piedmont Province between Richmond and Charlottesville, Virginia. The zone has an elliptical area, with a north-south dimension of 100 km and an east-west dimension of 120 km, as defined by historical earthquake activity (Bollinger and Sibol 1985; Coruh et al. 1988). The depth of the earthquakes ranges from near surface to 12 km, placing them above the Appalachian detachment (Chapman 2015) in contrast to the ETSZ where earthquakes occur below the detachment.

On August 9, 2020, a 5.1 M_W magnitude earthquake occurred on August 9, 2020, with an epicenter approximately 2.5 miles southeast of Sparta, just south of the Virginia-North Carolina border (Figure 3-4). The earthquake caused damage to over 500 buildings and other infrastructure (Hill 2020; Figueiredo et al. 2022). Surface ruptures were attributed to a south-southwest-dipping reverse fault (Little River Fault) and were traced for ~2.5 km along the northwest trend (Hill 2020; Figueiredo et al. 2022). The Little River Fault produced a maximum vertical displacement of 25.2 cm, with similar vertical displacements along much of the fault trace (Hill 2020; Figueiredo et al. 2022). The hanging wall was to the south (northeast side up; reverse fault as shown by the initial USGS focal mechanisms [USGS 2020a]). There is no recorded historical seismicity in and around Sparta, but Hill (2020) speculated that the Little River Fault may be associated with the Giles County Seismic Zone, which is centered in Virginia approximately 100 km to the north. The depth of the main shock, 4.1 km (USGS 2020b), suggests that it occurred above the master decollement (depths of 5 to 12 km) and is not related to the Giles County Seismic Zone or ETSZ where the earthquakes typically occur below the decollement in the Paleozoic extended crust. The estimated magnitude of the Skyland 1916 earthquake is M_W 5.1 (Figure 3-5) similar to the magnitude of the Sparta 2020 earthquake.

Prior to filling Lake Keowee in 1968, none of the historical seismic activity occurred in the vicinity of the Bad Creek Project. Because seismic activity appeared to have increased after impoundment of the Keowee Hydro Project (as evidenced by a swarm of seismic events associated with Lake Keowee in 1978 and other recorded events), the potential of reservoir-induced seismicity was studied by Duke Power Company (Schaeffer 1991). Both Lake Keowee and then later Lake Jocassee were associated with reservoir-induced seismicity (sometimes referred to as reservoir-triggered seismicity). Most of the events have been small, with the largest having a Local Magnitude of 3.8. Activity at Lake Jocassee has decreased significantly since first filling in 1976 while activity at Keowee has also decreased (Schaeffer

2000). During the study of the reservoir-induced seismicity, seismic activity was closely recorded by the stations of the seismic network operated by Duke Power Company and that of the South Carolina Seismic Network. Only a minor increase in seismicity was reportedly related to initial filling of the Bad Creek upper reservoir – from about 5 events per month to about 10 per month. However, no correlation could be made with the observed increase with Bad Creek reservoir filling and operation of the plant (up to 160 ft of potential change in the reservoir level). Of the minor earthquakes in the area, none were located under or very near to the Bad Creek reservoir. Seismic activity clearly related to Lakes Keowee and Jocassee decreased to near background levels by 2000 (Schaeffer 2000). The cluster of earthquakes on Figure 3-6 near the site are primarily related to the induced seismicity at Lakes Jocassee and Keowee.

Earthquakes with $M_w \geq 3$ and contours of Peak Ground Acceleration (PGA) for V_{s30}[3] equals 760 m/sec with 2 percent probability of exceedance in 50 years (2475-year return period) from the 2018 National Seismic Hazard Maps developed by the U.S. Geological Survey (USGS 2018) are shown on Figure 3-6. The PGA at the Bad Creek Project site is 0.24g for V_{s30} of 760 m/sec (Site Class B/C[4] Boundary) and 0.21g for V_{s30} of 2000 m/sec (Site Class A[4]) as shown in Figure 3-7 as are the hazard curves for spectral acceleration at selected periods and a Uniform Hazard Spectrum (UHS at 5% Damping) for both values of V_{s30} (USGS 2014b).

[3] V_{s30} is the shear wave velocity of the upper 30 meters of earth materials.

[4] Site Class A = Hard Rock (V_s > 1524 m/sec); Class B = Rock (762 m/sec < $V_s \leq$ 1524 m/sec); Class C = Very Dense Soil and Soft Rock (366 m/sec < $V_s \leq$ 762 m/sec).

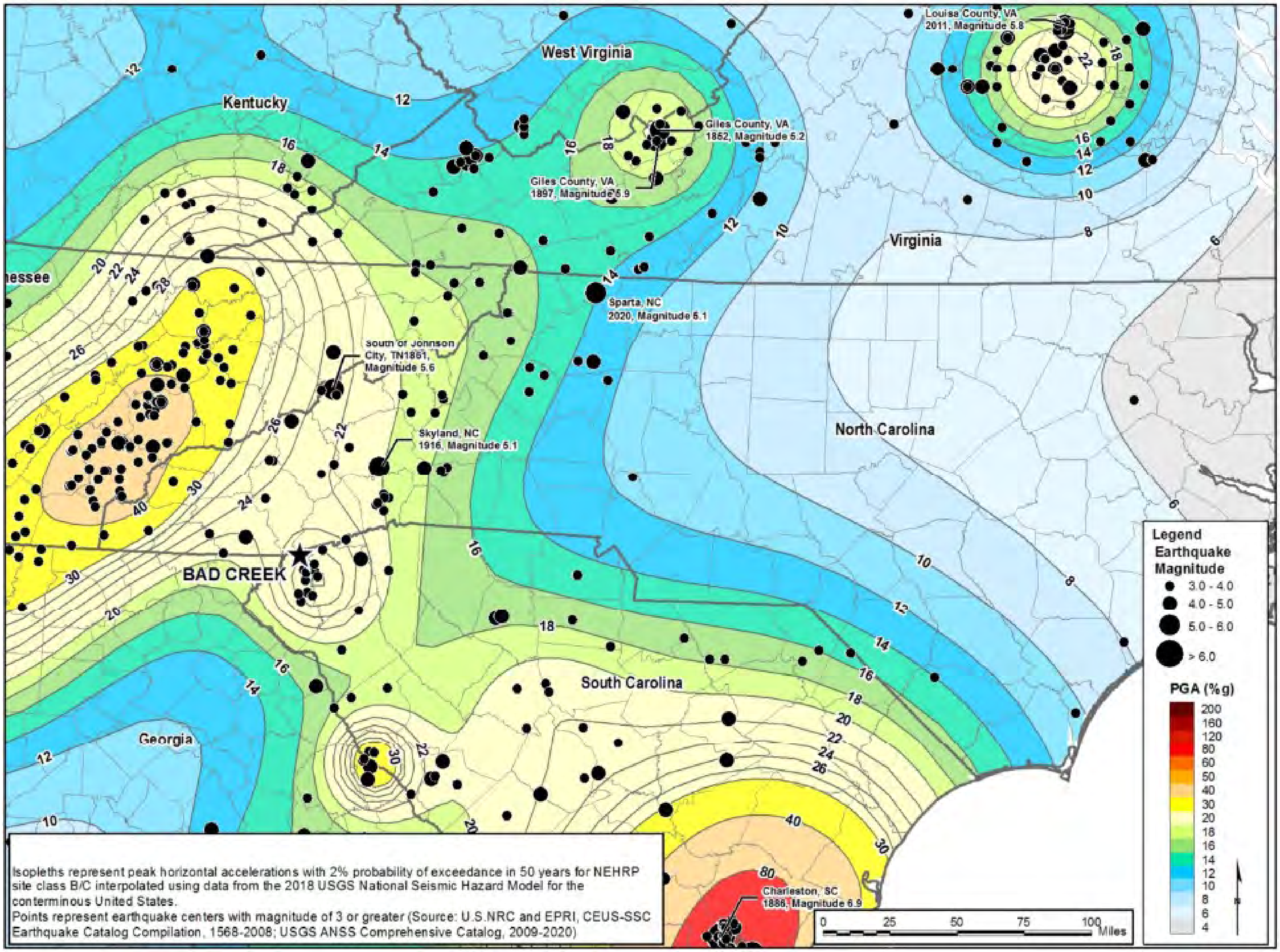
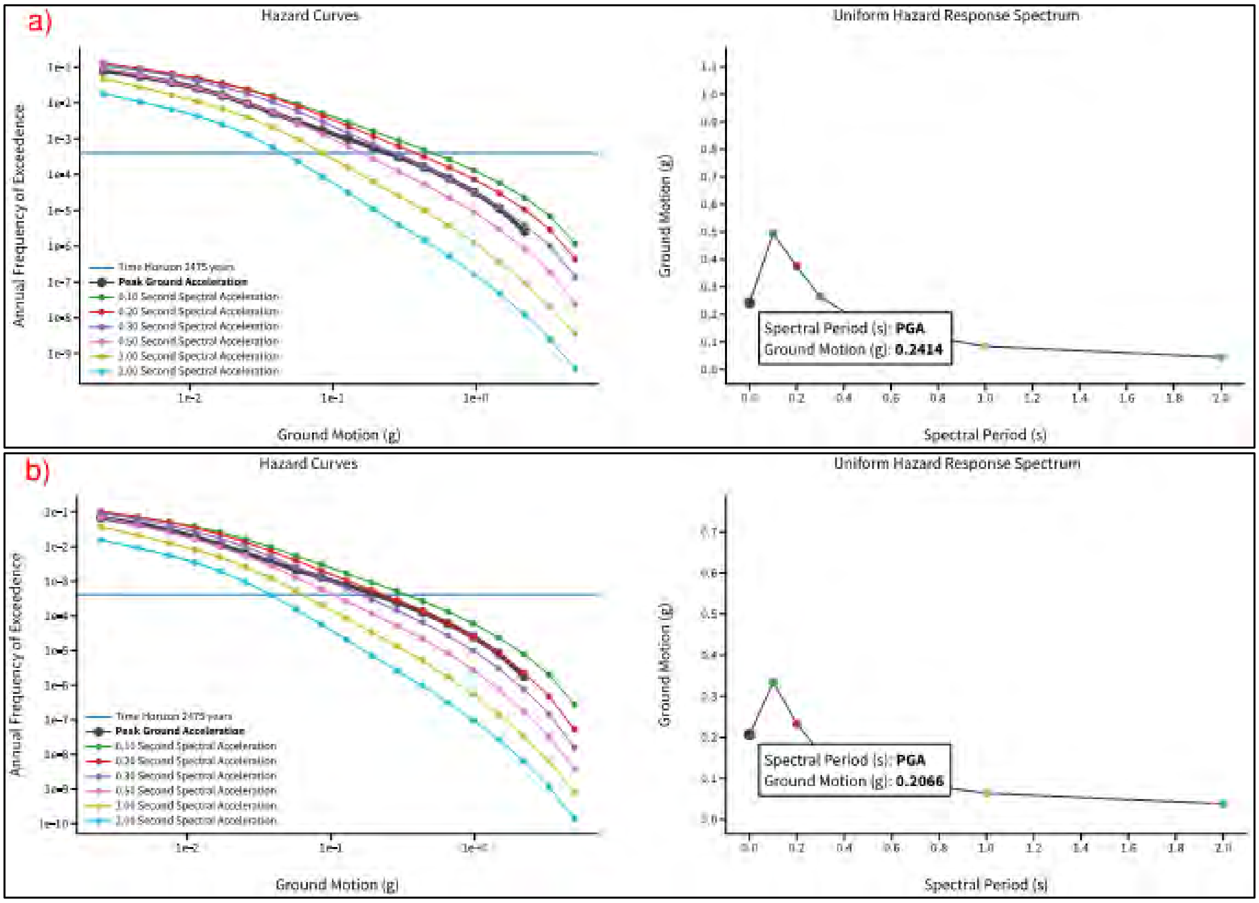


Figure 3-6. Seismic Hazard and Historic Earthquake Centers near the Bad Creek Pumped Storage Project



Note: This figure is not intended to be used for design or any type of analyses.
Source: USGS 2014a

Figure 3-7. Hazard Curve and Uniform Hazard Response Spectrum (2475-year return period; 5% Damping) for a) V_{s30} = 760 m/sec and b) V_{s30} = 2000 m/sec

3.4 Evaluation of Geologic Characteristics

The geologic characteristics of the bedrock in which the underground structures are to be excavated and constructed for Bad Creek II are summarized in Table 1. This information is based on the geological and geotechnical studies performed for the design of and geologic mapping and studies performed during construction of the existing Bad Creek Project underground structure.

Table 3-1. Summary of Geologic Characteristics

Geologic Characteristic	Relation to Project Area
High seismic risk/active faulting within the project area	The Project area is considered to have low to moderate seismic risk. No known Quaternary/active faults in the site vicinity (USGS 2014a, 2014b, 2018).
Active landslides in project area	There is an old landslide at the intake/discharge of the Bad Creek Project on Lake Jocassee (see Appendix B in Attachment 1; Schaeffer 2016). The slide material was removed during construction of the existing plant and a retaining wall was installed on the slope that stabilized part of the original landslide above the retaining wall and below the present control room//switchyard complex. Figure 3-2 and Figure 3-8 show the extent of a landslide/rockslide at

Geologic Characteristic	**Relation to Project Area**
	the proposed Bad Creek II I/O structure on Lake Jocassee. The landslides/rockslides at the proposed Lower Reservoir I/O works will be an issue during excavation in this area to construct the works. The landslide may possibly be in the crown of the tailrace tunnels as it approaches the I/O works and may be present around the main access tunnel portal (Figure 3-2 and Figure 3-8; see Attachment 1)
Deep weathering profile	Total soil thickness and the depth of overburden (soil/saprolite) and weathered bedrock at the Upper Reservoir I/O works, low pressure headrace gates area, and vertical headrace shafts area varies from 10 ft to greater than 90 ft. At the Lower Reservoir I/O on Lake Jocassee, the overburden is primarily landslide deposits that are up to 100+ ft thick based on the interpretation of the one borehole (B-21-4) in the area and the seismic refraction and MASW lines (see Attachment 1.) The landslide deposits are not deeply weathered.
Highly permeable rock	Most of the water encountered in the Bad Creek Project underground excavations, past the initial ~200 ft of the main access and tailrace tunnels from their portals on Lake Jocassee, were associated with specific geologic features - the foliation parallel shear zones and some of the high-angle fault zones (Figure 3-2 and Figure 3-8; Schaeffer 1987, 2016; Duke Power Company 1991).
Soluble rock material	Not present in the TGn.
Low strength, vibration-sensitive, friable, highly abrasive, slaking, or unlithified rock material	Weathered rock associated with shear zones and biotite schist and biotite-hornblende schist will have lower shear strengths than the unweathered TGn.
Highly faulted, folded, or fractured rock material	Most of the faults/fractures in the TGn have secondary mineralization and are not highly fractured/faulted. The shear zones mapped in the reservoir and in the existing Bad Creek Project underground structures have weathered sheared rock and later brittle faulting associated with them.
Thinly laminated, structurally deformed, fine-grained rock masses	Phyllonitic material present along some of the foliation-parallel shear zones in the underground excavations and thin, foliation parallel biotite-hornblende schist layers.
Rock Mass In-Situ Stress Field	High in-situ stresses that can result in rock burst and stress-related issues in the larger underground opening including the powerhouse, voltage bus/excitation galleries, draft tube gate and access gallery tunnel, draft tube gate annexes, and draft tube gate vertical shafts and at intersections of tunnels and shafts (Schaeffer 2016; Attachment 1, Appendix B).

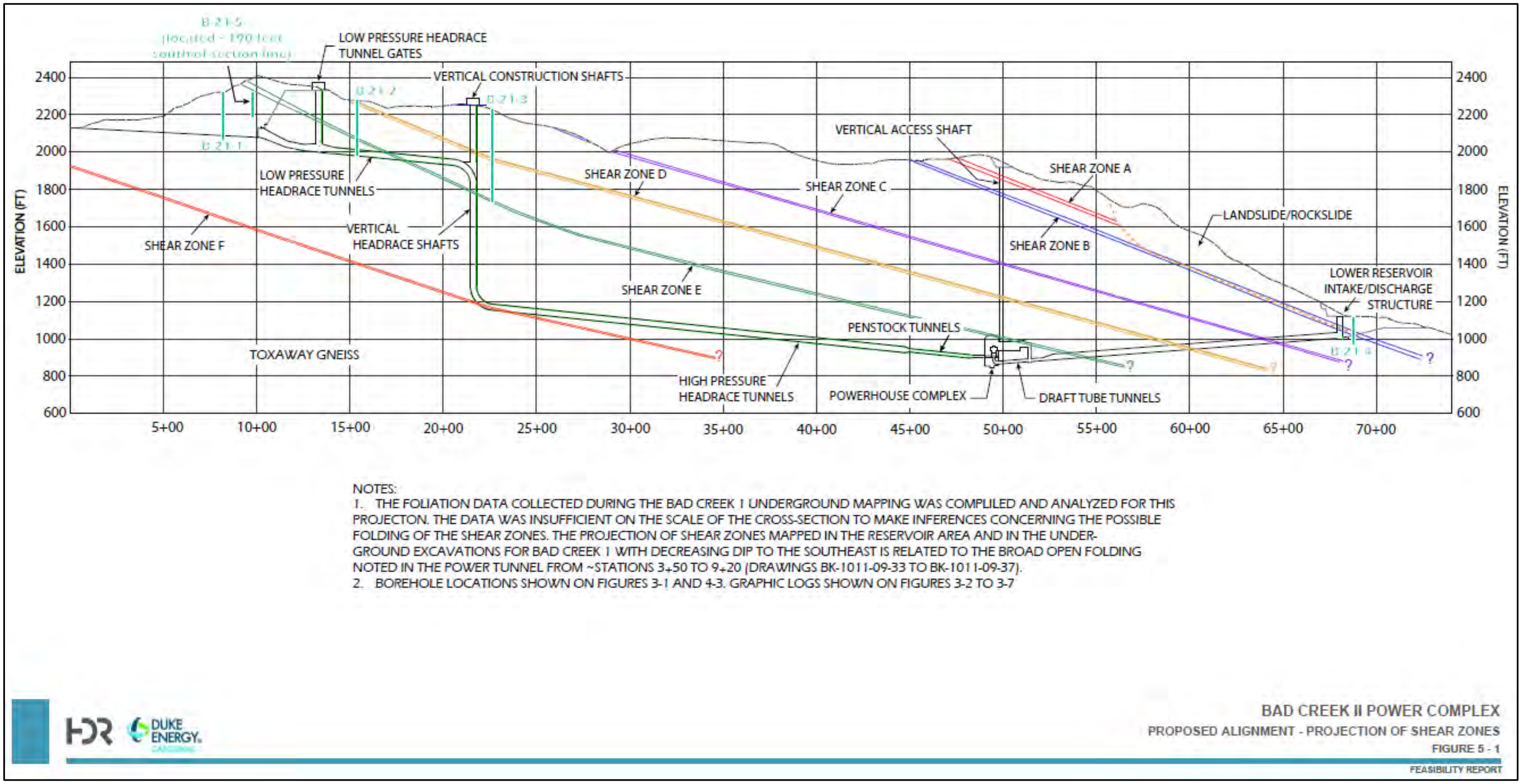


Figure 3-8. Bad Creek II Power Complex – Proposed Alignment – Projection of Shear Zones

3.5 Slope Stability

There is minor active slope movement in the Project area and evidence of previous mass wasting events, as described below. These areas are routinely monitored (monthly) and the Project vicinity is considered to have low to moderate seismic risk (there are no known Quaternary/active faults in the site vicinity), therefore, no further Protection, Mitigation, and Enhancement (PM&E) measures are proposed for the existing Project. Slope monitoring at the upper and lower tie-back walls, tunnel portal slope, west abutment, and reservoir rim are monitored routinely as described in Dam Safety Surveillance and Monitoring Plan (in compliance with FERC's *Engineering Guidelines for the Evaluation of Hydropower Projects*); monitoring will continue during the New License term.

3.5.1 Historic Landslides

In 1980, a geologic survey of the alignment of the main access road was performed to identify geologic features that could influence the stability of cuts and fills. Potential stability problems related to rock cuts and the presence of old landslides consisting of colluvial materials (boulders in a finer-grained matrix) were identified during the survey. The results of this study are summarized in this section and details are included in Schaeffer (2016) (Attachment 1, Appendix B).

Four old landslides were identified on the last mile of the access road (see Figures 32 and 33 in Attachment 1, Appendix B). The depth to sound rock under Slides 1 and 2 was shallow enough to allow excavation of all the colluvium under the access road (within 1 meter of grade). Cuts above the road in these slide areas were laid back at 3:1. The depth of the colluvial material in Slide 3 was up to 8 meters below road grade. Because of stability concerns, all of the colluvial material down to sound rock were removed; however, there would not be enough area from the access road to Lake Jocassee to build a structural fill with the nominal 2:1 slopes when finished, therefore, a retaining wall was constructed across the Slide 3 area. The depth of colluvial material in Slide 4 is up to 25 meters. Because of the volume of material that would have to be excavated and the height and length of the required retaining wall that would be needed across the area, an alternate approach for stabilization was considered. Seven slope indicators were installed in the slide area in 1980 (Figure 35; Attachment 1, Appendix B). Very small movements at the colluvium-sound rock contact were noted in three of the slope indicators located above the access road. The movements were less than one millimeter per month and discontinuous along the contact. Boring data indicated that the water table was generally within one meter of the contact between the colluvium and sound rock. Because access road construction in the area did not start until 1983, subhorizontal drains were installed in an attempt to drain the slide above the contact to stop the discontinuous slope movement. The drains did stop the movement of the slope (in the 3 slope indicators that showed movement before the installation of the drains). Therefore, the access road was constructed across the colluvial material of Slide 4. No movement of the area has been noted since the completion of the access road.

There is also an area indicating a previous landslide above the I/O structure that was reactivated during the initial portal preparation at Bad Creek before Lake Jocassee was filled in 1974. In 1984, the slide progressed up the slope towards the switchyard. The area was mapped in 1986 to provide geologic input for stabilization efforts to prevent localized slides during construction and permanent plant operation. The final design for the stabilization of the area called for the removal of all older colluvium and more recent slide material from the slope, laying back the saprolite/soil area south of the east-west fault zone on 2:1 slopes, and construction of a retaining wall along the general alignment of the ditch (Figures 39 and 40, Attachment 1, Appendix B). An insert wall was constructed to stabilize the soil-saprolite below the existing wall consisting of anchor bars, anchor plates, and a toe buttress wall tied to underlying rock with grouted rock anchors.

Initial work in the main dam area (west abutment) began in the spring of 1986 and tension cracks indicative of slide movement were noted. Because of continued deterioration of the abutment slope, an exploration program was undertaken in July of the same year which included soil borings, installation of crack monitors, shear tubes, and inclinometers, which are measured monthly under the current monitoring program.

3.5.2 Ongoing Monitoring

The Project contains an extensive collection of monitoring instrumentation. Table 3-2 provides an overview of the current active instrumentation.

Table 3-2. Active Instrumentation at the Project

Instrument Type	Main Dam*	West Dam	East Dike	Tunnels/Penstocks/ Draft tubes	Powerhouse	I/O Area
Observation well	15	1	2	--	--	--
Piezometers	32	13	4	18	--	--
Seepage Monitoring Points	2	3	1	1	6	
Inclinometers	6	--	--	--	--	7
Extensometers		--	--	--	31	
Surface monuments	49	11	8		--	--
Strong motion instruments	2	--	--	--	--	--

*Includes west abutment buttress; Information based on 2016 Dam Safety Surveillance and Monitoring Plan Report

3.6 Geotechnical Study

In addition to the geologic investigation, a limited geotechnical field exploration program was carried out to support the feasibility study (HDR 2022) of the Bad Creek II Complex water conveyance I/O structures, tunnels and shafts, access tunnels and shafts, underground powerhouse, and appurtenant structures. An evaluation of boreholes and seismic line data collected at the upper and lower reservoir I/O works is provided in Attachment 1, Appendix D. The complete Geotechnical Studies Report (with select appendices) is provided in Attachment 2.

A total of five borings were drilled at the Bad Creek II site; these locations are shown on Figure 3-2. Borings B-21-1 and B-21-5 are located at the upper reservoir I/O, Boring B-21-2 is in the area of the low-pressure headrace tunnels just downstream of the low-pressure headrace gates, Boring B-21-3 is downstream of the vertical intake shaft, and Boring B-21-4 is at the lower reservoir I/O structure. The borings were drilled to obtain geotechnical data including soil properties, depth to top of weathered rock, depth to top of competent rock, lithology and rock hardness, rock recovery, and rock quality designation, depth and thickness of shear zones, and rock permeability data water pressure (i.e., packer tests). Downhole geophysical logging of the borings was performed to assess rock mass fractures, foliation/banding, and other rock mass discontinuities. The borings were drilled vertically to depths ranging from 120.3 to 500.3 ft below existing grade. Sampling methods included Standard Penetration Test sampling and HQ coring methods. Boring logs and photos are included in Attachment 2, Appendix B while soil sample laboratory testing reports are included in Attachment 2, Appendix G.

A boring summary is provided in Table 3-3.

Table 3-3. Boring Summary

Boring	Total Depth (ft)	Inclination	Azimuth	Soil Depth (ft)	Number of Water Pressure Tests	Well screen depths (ft)[1]	Acoustic and Optical Televiewer
B-21-1	250.8	90	NA	4.0	5	NA	Yes
B-21-2	300.8	90	NA	4.0	11	50-70	Yes
B-21-3	500.4	90	NA	6.4	7	70-90	Yes
B-21-4	150.4	90	NA	29.9	-	NA	Yes
B-21-5	120.3	90	NA	46.6	2	NA	Acoustic only

[1] Well screens are 2-inch diameter PVC

In addition to drilling and testing, surface geophysics including seismic refraction and MASW line surveys were completed by GEL Solutions. Geophysical surface investigations were carried out to better understand the subsurface conditions at the proposed locations of the upper reservoir I/O structure, the lower reservoir I/O structure, the low-pressure gate shafts and tunnels and the vertical water intake shafts.

Approximately 6,000 ft (linear) of surface geophysical investigation was performed including seismic refraction surveys to establish compressional wave velocities (Vp) and MASW to establish shear wave velocities (Vs) of subsurface materials that are utilized in the interpretation of subsurface materials (overburden, weathered rock, firm/sound rock). A complete evaluation of seismic line data is included in Attachment 1, Appendix D.

3.7 Summary

Detailed summaries of the relationship between geology and constructability at individual areas (i.e., upper reservoir, lower reservoir, tunnels, vertical shafts, powerhouse cavern) assessed for Bad Creek II are included in Attachment 1 (Geology and Seismology Studies Report). There are no geological fatal flaws associated with the construction and operation of a second powerhouse. After 30+ years, the underground excavations at the existing Bad Creek Project have stabilized and the support installed in them during construction has and is serving its function well. Several recommendations have been made, including adding more borings to verify certain components where assumptions were made, as well the installation of inclinometers above the location of the retaining wall planned for the lower reservoir I/O works excavations to provide a baseline or potential movement before and after excavation/construction and during plant operations.

4 Lower Reservoir CFD Modeling

4.1 Background

A three-dimensional CFD model was developed by HDR to support the feasibility design of the Bad Creek II Complex. The goal of the desktop study was to quantify and evaluate potential hydraulic impacts within the Whitewater River cove of Lake Jocassee to establish velocity and flow patterns along the channel and near the east bank of the cove opposite of the discharge structure under existing conditions and under proposed conditions (i.e., two I/O structures). Results aid in identifying potential operational impacts of the Bad Creek II Complex during turbine mode and effects on shoreline erosion potential of the east bank of the Whitewater River arm of Lake Jocassee.

Note that additional CFD modeling will be carried out as a licensing study activity (Water Resources Study Plan) to determine vertical mixing and flow patterns in the Whitewater River cove under a two-discharge scenario.

4.2 Methods

Model simulations were carried out assuming both existing and proposed powerhouses were operating both simultaneously and independently under several scenarios. The modeling utilized Lake Jocassee bathymetry and the existing and proposed Bad Creek II Complex I/O structures to evaluate velocities and flow patterns within the Whitewater River cove to assess operational impacts. Simulations were run at elevations of 1,110 ft above mean sea level (msl) (i.e., normal full pool elevation) and 1,080 ft msl (minimum normal elevation) to calibrate the CFD model velocities and flow patterns to the 1986 physical model results reported by Alden Research Laboratory (ARL) (Larsen and White 1986) assuming the same discharge flows modeled.

Bad Creek is currently undergoing upgrades to the pump-turbine units. Upgraded operations at Bad Creek as well as proposed Bad Creek II operations (and I/O structure operations) were subsequently added to the model. 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. The elevation of 1,096 ft msl was selected as an intermediate lake elevation operating scenario for the following reasons:

1. The surface water elevation threshold for implementation of protective operational measures to minimize fish entrainment is 1,099 ft msl.
2. The surface water elevation below which fish entrainment becomes elevated at Bad Creek and historically occurs less than 22 percent of the time is 1,096 ft msl.

4.3 Study Results

The hydraulics for both the existing and proposed inlet/outlet structures were simulated to target outflow convergence to establish flow and velocity patterns along the east bank of the discharge area to assess potential for erosion. While the generation flow predicted by the physical model had higher velocities than that predicted by the CFD model, the overall flow patterns (including major recirculation patterns) were accurately captured in the CFD model. These observations are seen in both the full pond and maximum drawdown elevation scenarios for Lake Jocassee under existing conditions (16,000 cubic ft per second discharge). East bank velocities along the existing inlet/outlet structure centerline predicted by the physical model range between about 0.5 fps and 2.25 fps at reservoir level 1,110 ft msl. At the maximum drawdown reservoir elevation of 1,080 ft msl, the velocities are slightly lower ranging from 0.5 fps to 1.3 fps.

The proposed Bad Creek II powerhouse inlet/outlet structure configuration was then added to the CFD model, assuming full generation at both inlet/outlet structures (a combined 39,560 cubic ft per second) to determine impacts on flow velocity along the east bank of Lake Jocassee in the Whitewater River cove, opposite from the structures. Under full pond reservoir elevation, modeling showed that flow from the proposed structure forces flow from the existing structure to the center of the Whitewater River cove, lowering the velocities along the east bank. Four designated elevations within the water column were assessed, including surface elevations, and results indicated that the higher velocity region along the east bank moved approximately 600 ft to the north with peak velocities at 2.5 fps (along tunnel centerlines).

4.4 Summary

Under maximum drawdown reservoir elevation, flow patterns were similar to the full reservoir configuration, with increased velocities throughout, as expected. Lower elevations in Lake Jocassee increased the effect of the concentrated flow from the inlet/outlet structures and surface velocities have the potential to exceed 5.0 fps, while flow along the east bank generally peaked at approximately 3.5 fps along the tunnel centerlines.

The peak velocities for the proposed Bad Creek II Complex I/O configuration along the east bank do not exceed the modeled velocities shown in the existing Bad Creek configuration at Lake Jocassee elevation 1,110 ft msl. The proposed Bad Creek II Complex I/O configuration predicted minor increases to peak velocities along the east bank when compared to the existing Bad Creek modeled velocities. The location of the peak velocities is spatially closer to the proposed Bad Creek II Complex I/O structure and similar in magnitude to the physical model simulation results (Larsen and White 1986).

The results of this study indicate that the additional generation flows resulting from Bad Creek II (in combination with the Bad Creek Station) do not appear to increase the potential for erosion along the east/opposite bank of the Whitewater River cove in Lake Jocassee, assuming the geology is consistent along the bank (i.e., predominantly bedrock). The modeled velocities were approximately equivalent to the physical model study velocities, which are representative of the existing conditions. To HDR's knowledge, flow from the existing configuration and operations have not resulted in erosion along the east bank and velocities are within the general range from the proposed configuration.

For complete details, please refer to the full study report in Attachment 3.

4.5 Future Studies to Support Relicensing

Expansion of the existing submerged weir downstream of the I/O structure is planned during the construction of the Bad Creek II Complex; during initial CFD modeling studies described above, velocities in the water column above the submerged weir increased as the flow depth decreased. Velocities along the eastern bank near the expanded weir were higher when compared to the simulations using existing weir. The CFD model will be used to provide information on flows and mixing in the vicinity and above the weir as a task under the Water Resources Study for the Bad Creek relicensing. In addition, the CFD model results will be used to support the Recreational Resources study in determining maximum surface velocities for public/boater safety.

5 Conclusion

There are no known additional adverse effects to geology or soils in the upper or lower reservoir areas due to the continued operation of the Project or construction of the expanded Project, therefore, no additional PM&E measures beyond the existing Shoreline Management Plan for Lake Jocassee (pursuant to the Keowee-Toxaway [KT] Project No. 2503 Operating License) to limit/prevent/mitigate potential erosion are warranted. Duke Energy plans to continue operating the KT Project with the existing restrictions on land and shoreline development in the vicinity of the Bad Creek Project Boundary as defined in the KT Project Shoreline Management Plan. Further, Duke Energy believes the results of the geology/geotechnical studies and lower reservoir CFD modeling study for the Bad Creek II Complex is sufficient to inform the relevant geological requirements of the draft and final license applications, including preparation of a preliminary Supporting Design Report for the Bad Creek II Complex.

The effects of construction of the Bad Creek II Complex and potential spoil disposal on soil erosion and sedimentation will be assessed as part of (1) the future Water Quality Monitoring Plan, (2) the environmental permitting process, and (3) development of an erosion and sedimentation control plan that will be integral to the construction and monitoring of the expanded Project.

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Attachment 1

Attachment 1 – Geology and Seismology Studies Report

Bad Creek II Power Complex Feasibility Study

Volume 7: Geology and Seismology Studies

Salem, South Carolina
September 1, 2022

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Contents

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Acronyms and Abbreviations

Bad Creek II or Project	Bad Creek II Power Complex
Bad Creek Project	Bad Creek Pumped Storage Project
CVSZ	Central Virginia Seismic Zone
cm	centimeters
Duke Energy	Duke Energy Carolinas, LLC
EPRI	Electric Power Research Institute
ETSZ	East Tennessee Seismic Zone
FEM	finite element modeling
FERC	Federal Energy Regulatory Commission
HDR	HDR Engineering, Inc.
I/O	inlet/outlet
km	kilometers
LRF	Little River Fault
MASW	multi-channel assessment of surface waves
PGA	Peak Ground Acceleration
psi	pounds per square inch
RQD	rock quality designation
SR	seismic refraction
TFF	Tallulah Falls Formation
TGn	Toxaway Gneiss
UHS	Uniform Hazard Spectrum
USGS	United States Geological Survey
Vs	shear wave velocity
Vp	compressional wave velocity

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1 Introduction

Duke Energy Carolinas is interested in the potential to develop a pumped storage hydroelectric project utilizing the existing Bad Creek Pumped Storage Project (Bad Creek Project) upper reservoir and building an additional underground powerhouse and associated infrastructure. Pumped storage is an efficient means to store energy when the demand for power is low and to generate power with the stored energy when the demand for power is high. Pumped storage is also recognized as one of the most useful methods for regulating intermittent renewable generation resources, such as wind and solar.

The proposed Bad Creek II Power Complex (Bad Creek II or Project) will be constructed and operated by Duke Energy. During peak energy demand periods, water from the upper reservoir will be released to the lower reservoir through turbines to generate power. During periods of low power demand, water will be pumped back from the lower reservoir to the upper reservoir. The power grid benefits of such operations include, but are not limited to, the integration of intermittent power generation sources, enhancement of grid stability, and supply of other ancillary services.

As part of the overall feasibility study effort, HDR performed a geological/geotechnical field investigation with the following objectives:

1. Provide a well-structured study plan, utilizing the geologic mapping data and special geologic studies during the construction of the Bad Creek Project, additional geologic assessments conducted to date, topographic data, and preliminary layout studies to function as a bridge between the site feasibility study and potential future site studies.
2. Assess, to the extent possible, site geological/geotechnical conditions in support of site layouts, conceptual designs, basic construction methods, and construction materials. Results of the geological/geotechnical studies will be used to develop recommendations regarding project structures, locations, and layout; provide input for Project cost opinions and schedule; and plan future geological/geotechnical investigations for the Project.

HDR’s geologic study involved 1) a review of existing geological information from the investigations for and during construction of the Bad Creek Project and 2) incorporation of geotechnical and geophysical data from HDR’s geotechnical exploration program, which included geophysical field testing and the drilling of five exploration boreholes, as documented in Volume 8 (Geotechnical Studies) of this feasibility study report. The study documented in this volume included a field review of rock core from the five boreholes drilled for this study, review of seismic refraction (SR) and multichannel analysis of surface waves (MASW) lines and other geophysical data (downhole geophysical measurements), review of geotechnical testing data, and a field reconnaissance to assess geologic features and site conditions as related to the construction and operation of the proposed Project.

Geologic characteristics that could impact the proposed Project were identified and it is recommended that further evaluation of these characteristics be performed during the next study phase. The findings, inferences, conclusions, and recommendations drawn from HDR’s desktop review of existing geologic information, field investigations, and data collection efforts performed by HDR and its subcontractors are provided in the following sections.

2 Description of Project

2.1 Existing Bad Creek Pumped Storage Project

The existing Bad Creek Project (Federal Energy Regulatory Commission [FERC] Project No. 2740) is located in Oconee County, South Carolina, approximately eight miles north of Salem. The Bad Creek Reservoir was formed from the damming of Bad Creek and West Bad Creek, and serves as the Bad Creek Project's upper reservoir. Lake Jocassee, licensed as part of Duke Energy's Keowee-Toxaway Hydroelectric Project (FERC Project No. 2503), serves as the Bad Creek Project's lower reservoir.

The Bad Creek Project is operated by Duke Energy under the terms of an Original License issued by the FERC on August 1, 1977, as subsequently amended. Construction of the Bad Creek Project took approximately 10 years, and operations commenced in 1991. The structures and features included in the Bad Creek Project license include the upper reservoir and dams, inlet/outlet (I/O) structures in the upper and lower reservoirs, water conveyance system, underground powerhouse, tailrace tunnels, transmission facilities, and an approximately 9.25-mile-long transmission line corridor extending from the Bad Creek Project to the Keowee-Toxaway Project's Jocassee switchyard.

2.2 Proposed Bad Creek II Power Complex

Bad Creek II would utilize the existing Bad Creek Project's upper and lower reservoirs (Bad Creek Reservoir and Lake Jocassee, respectively) and would consist of a new Upper Reservoir I/O (within the existing upper reservoir), water conveyance system, underground powerhouse, and Lower Reservoir I/O (along the shoreline of Lake Jocassee). No modifications to the existing upper and lower reservoirs would be required for Bad Creek II other than construction of an Upper Reservoir I/O structure within the Bad Creek Reservoir and a Lower Reservoir I/O structure within Lake Jocassee. Duke Energy currently owns all property that would be required for construction of Bad Creek II.

3 Geotechnical Exploration Summary

As part of the Bad Creek II feasibility study, a geotechnical field exploration program was performed at the existing Bad Creek Project site from February 2021 through June 2021. Geotechnical site investigation efforts were organized and implemented by HDR and various subcontractors with logistical and site access support provided by Duke Energy. The Bad Creek II Geotechnical Investigation was performed to support a feasibility study of the Bad Creek II water conveyance tunnels and shafts, access tunnels and shafts, underground powerhouse, and appurtenant structures including the proposed Upper Reservoir I/O works and Lower Reservoir I/O works.

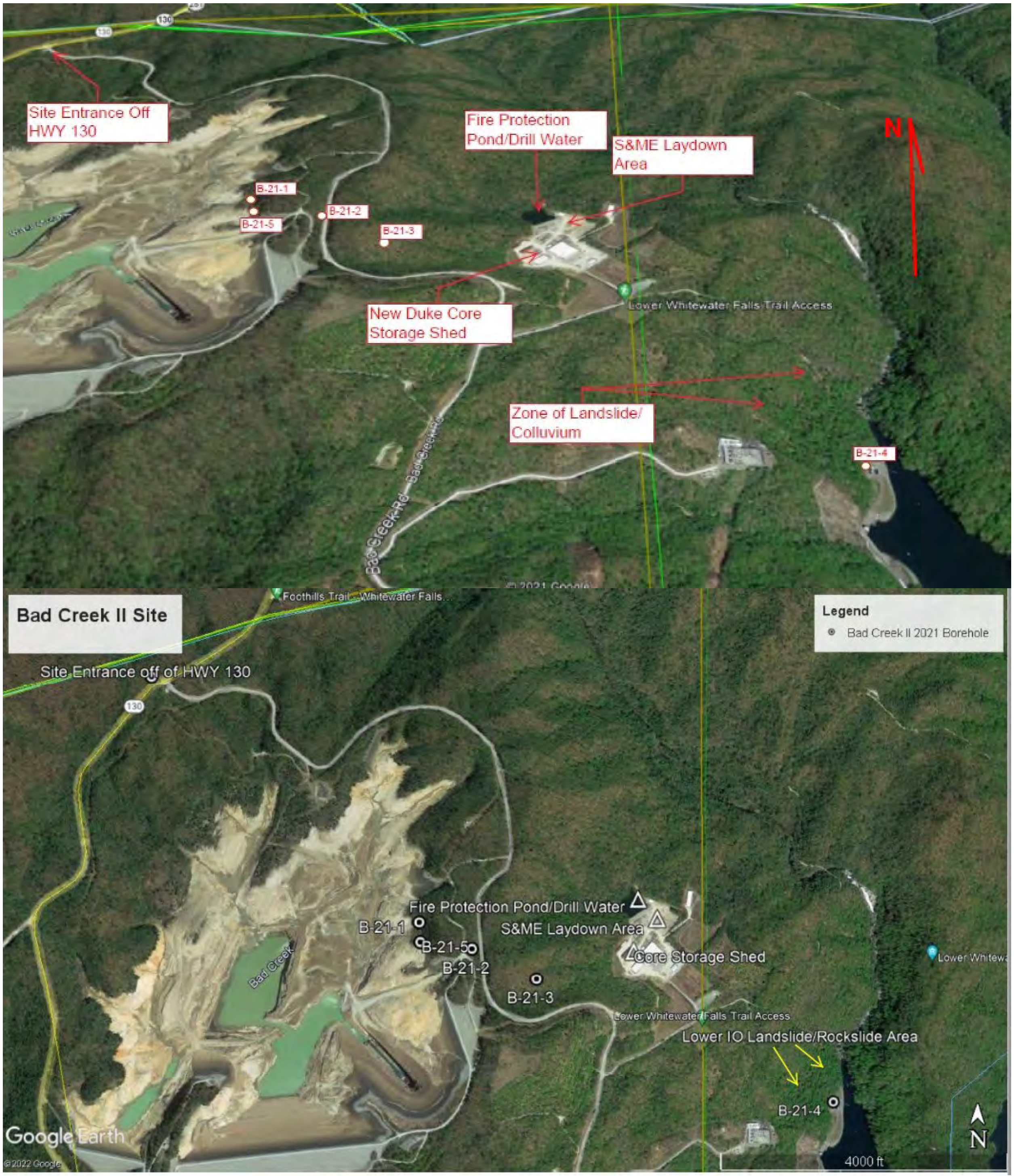
Five borings were drilled vertically at the Project site to depths ranging from 120.3 to 500.3 feet below existing grade and included downhole logging, packer testing, and water level monitoring wells in two of the borings (see Figure 1 and Figure 10). Four of the five borings (B-21-1, B-21-2, B-21-3, and B-21-4) were drilled at locations along the proposed water conveyance alignment. Boring B-21-1 is located at the Upper Reservoir I/O, Boring B-21-2 is located in the area of the low-pressure headrace tunnels just downstream of the low-pressure headrace gates, Boring B-21-3 is located downstream of the vertical intake shaft, and Boring B-21-4 is located at the Lower Reservoir I/O.

Boring B-21-5 was completed to investigate the Upper Reservoir I/O area, verify subsurface geophysical profiles, and to determine the location in the subsurface of a previously mapped shear zone in the Bad Creek Project upper reservoir. The borings were drilled to obtain geotechnical data including soil properties, depth to top of weathered rock, depth to top of competent rock, lithology and rock hardness, rock recovery and Rock Quality Designation (RQD), depth and thickness of shear zones, and rock permeability data using water pressure tests(i.e., packer tests). Sampling methods included Standard Penetration Test sampling and HQ coring methods.

Downhole geophysical logging of the borings was performed to assess rock mass fractures, foliation/banding, and other rock mass discontinuities. Stereonets of the downhole structural data are included in Appendix A, Figures A-1 through A-9.

Surface geophysical investigations were performed including seismic refraction surveys to establish compressional wave velocities (Vp) and multi-channel assessment of surface waves (MASW) to establish shear wave velocities (Vs) of subsurface materials that are utilized in their interpretation.

Graphic logs of Borings B-21-1 and B-21-5 are shown on Figure 2 through Figure 7 and will be referenced in later report sections. The geotechnical field exploration program is discussed in detail in Volume 8 (Geotechnical Studies) of this feasibility study report.



Note: Location of Boreholes B-21-1 to B-21-5 also shown on Figure 3.

Figure 1. Bad Creek II Geotechnical Investigation General Site Features

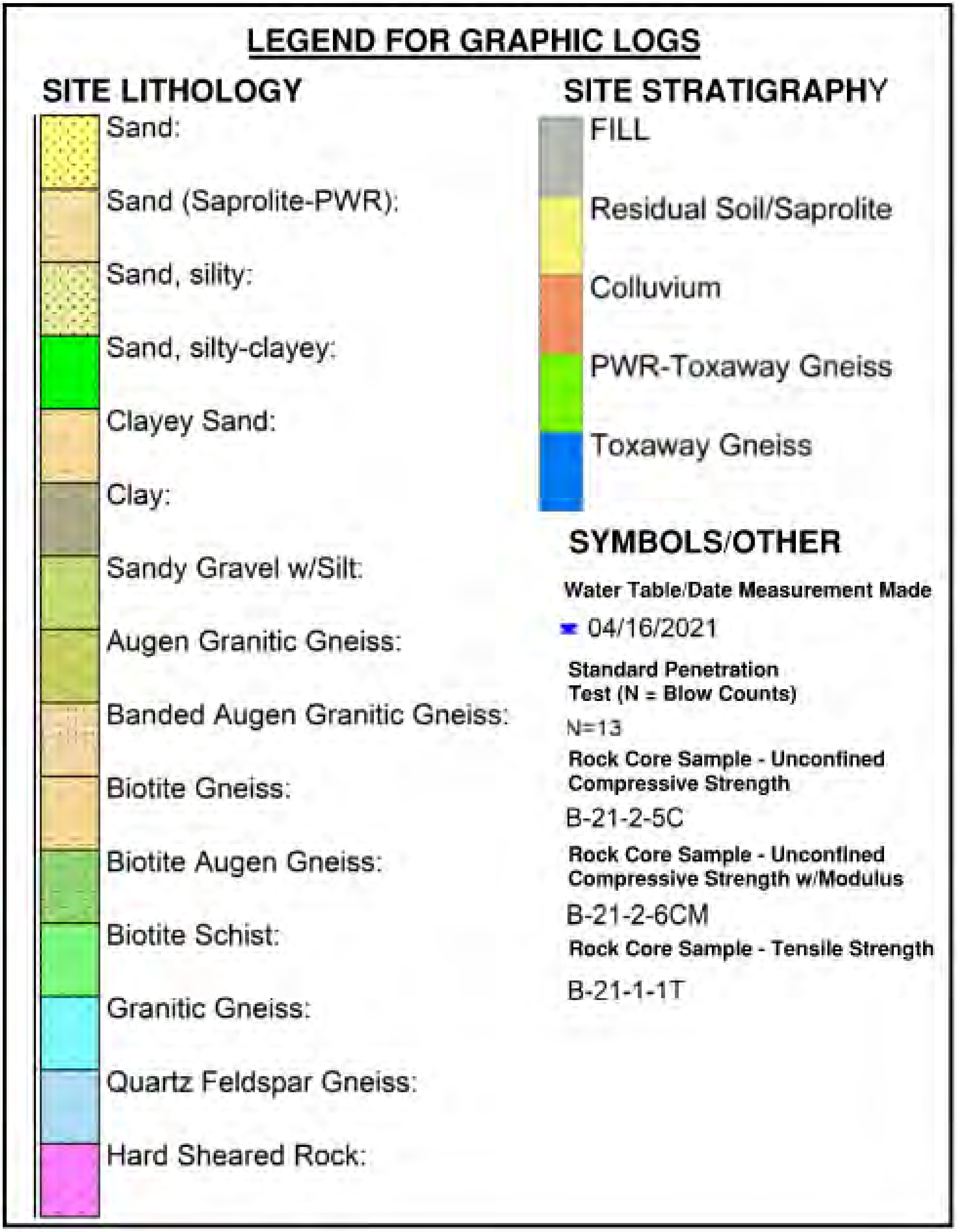


Figure 2. Legend for Graphic Logs in Figures 3 to 7

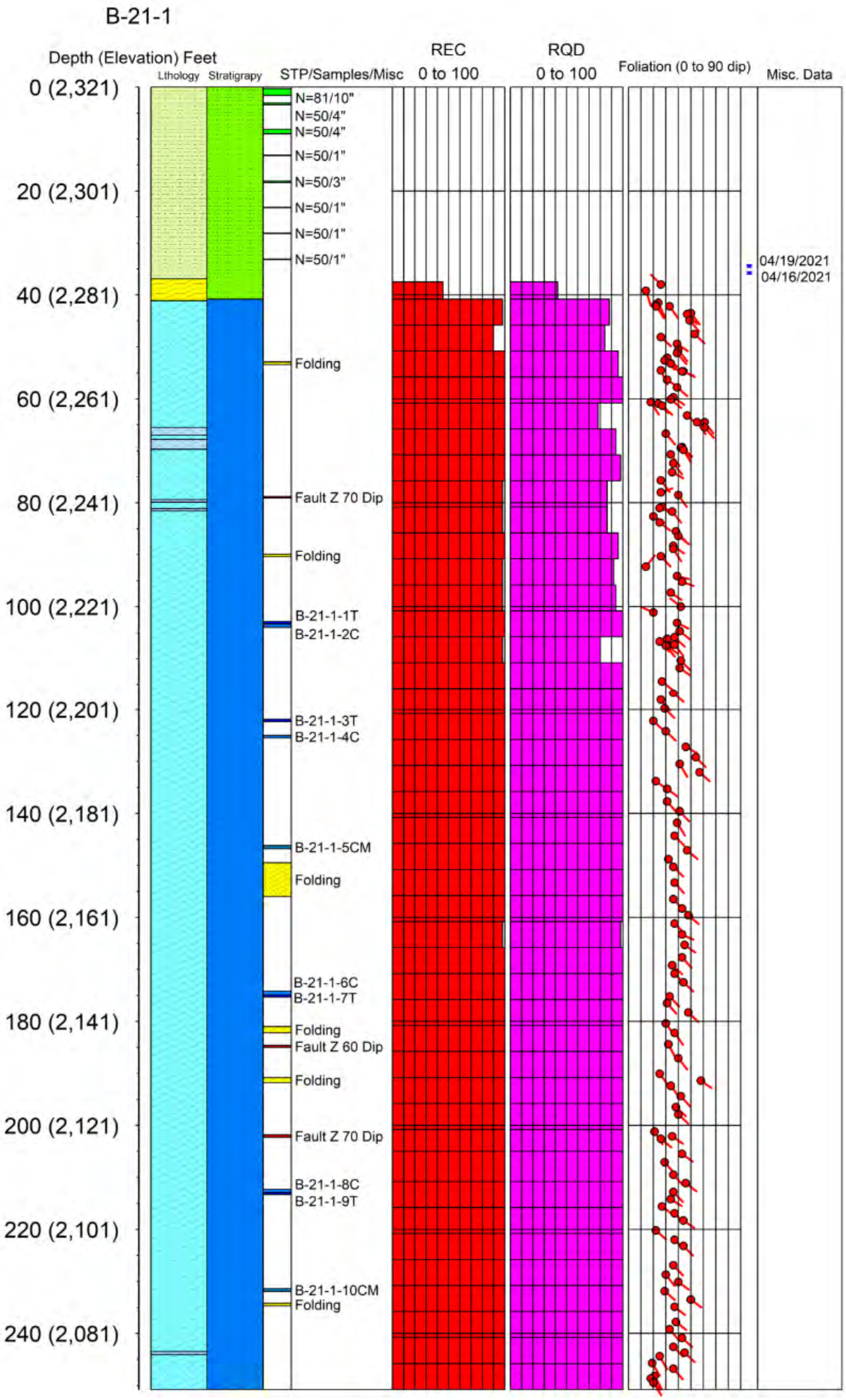


Figure 3. Graphic Log for Borehole B-21-1

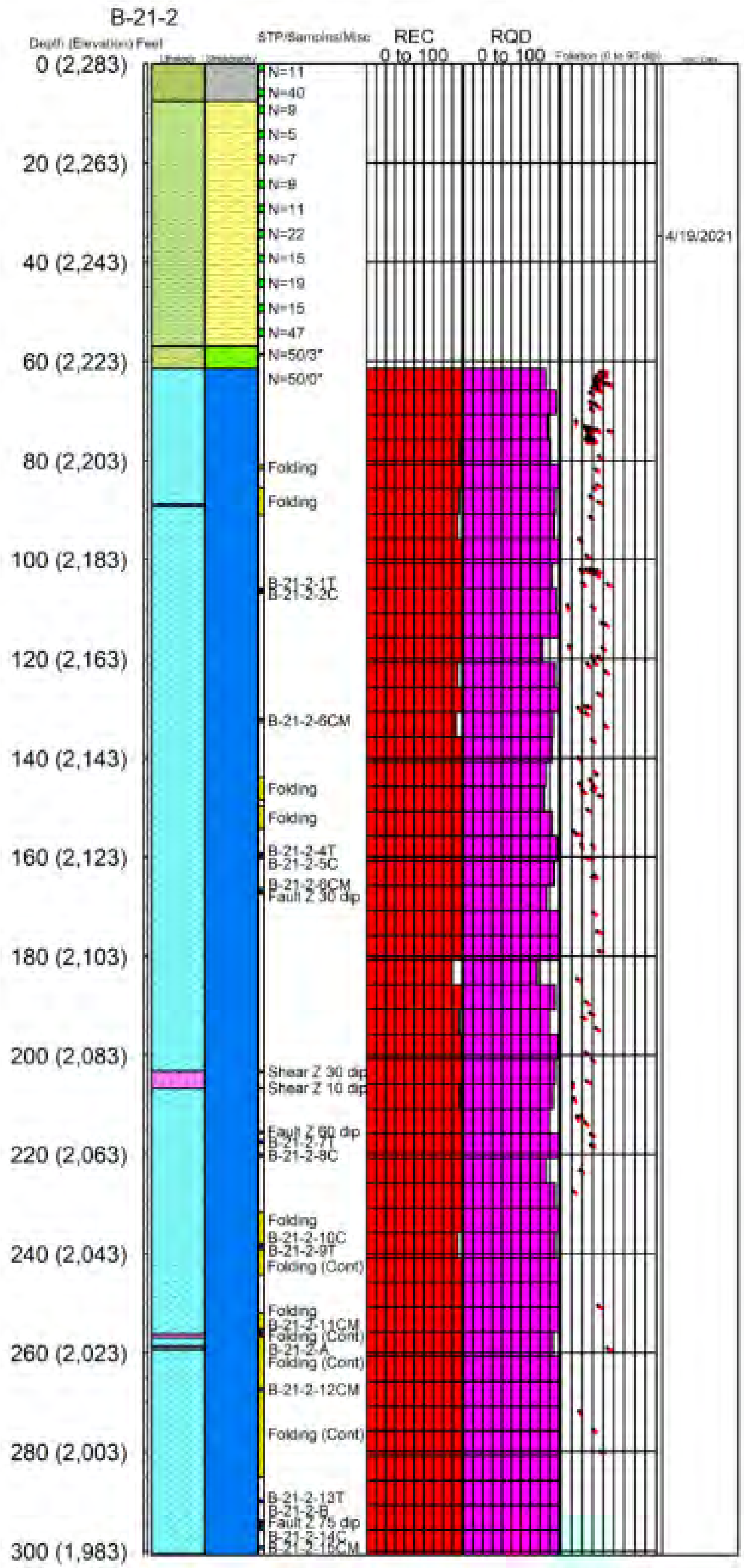


Figure 4. Graphic Log for Borehole B-21-2

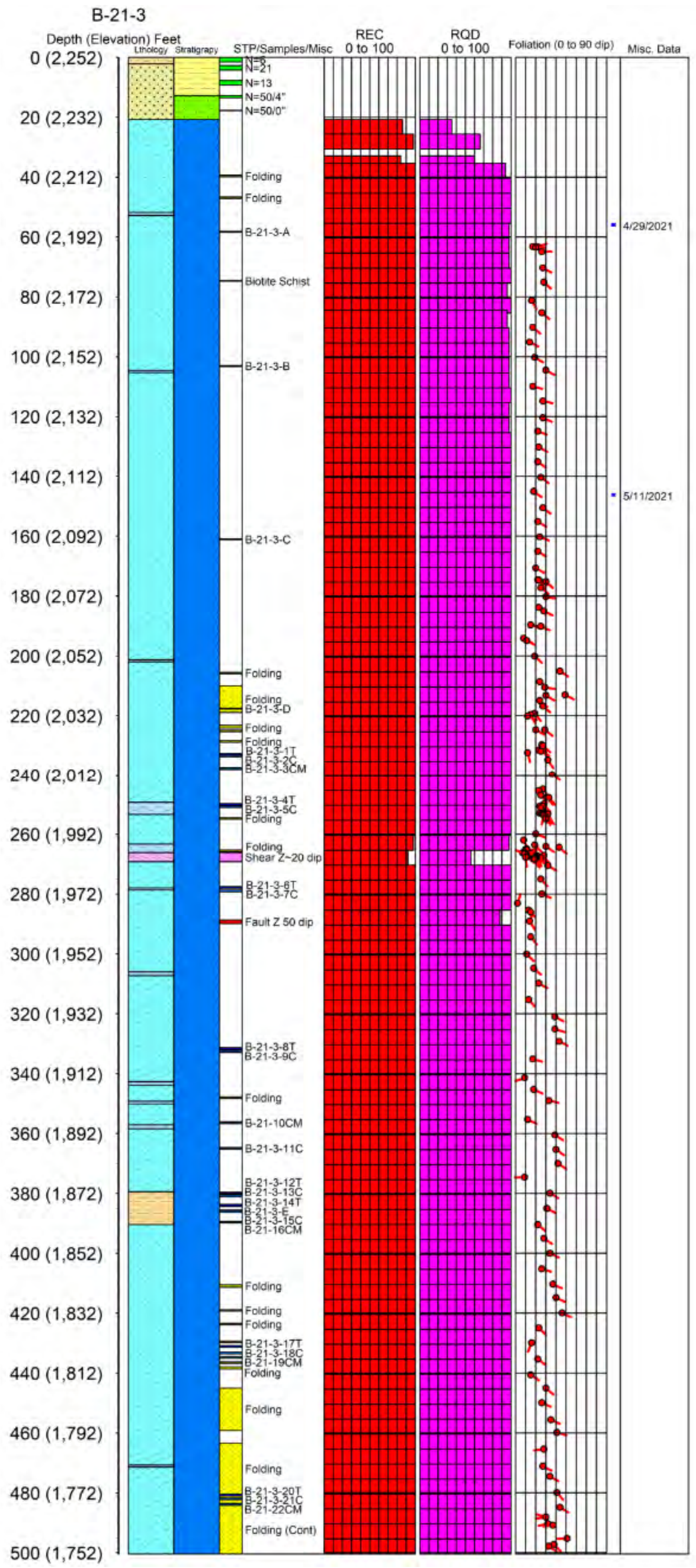


Figure 5. Graphic Log for Borehole B-21-3

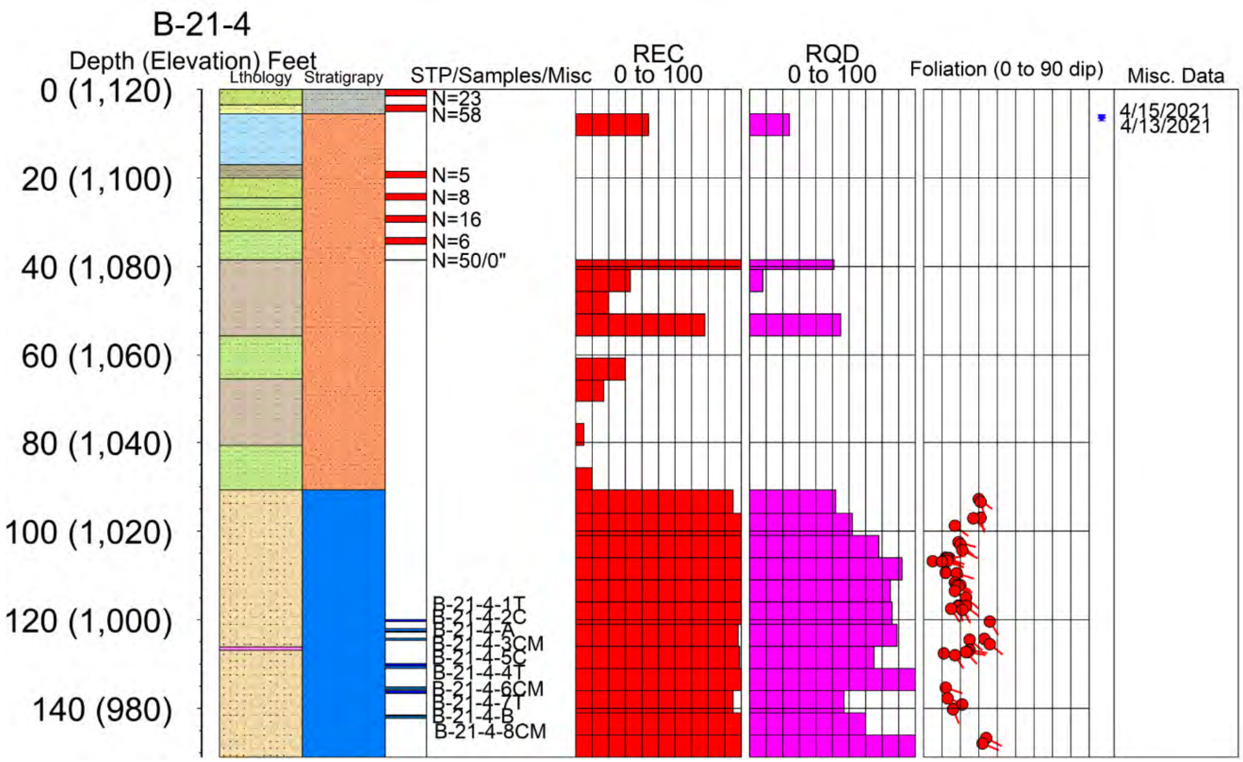


Figure 6. Graphic Log for Borehole B-21-4

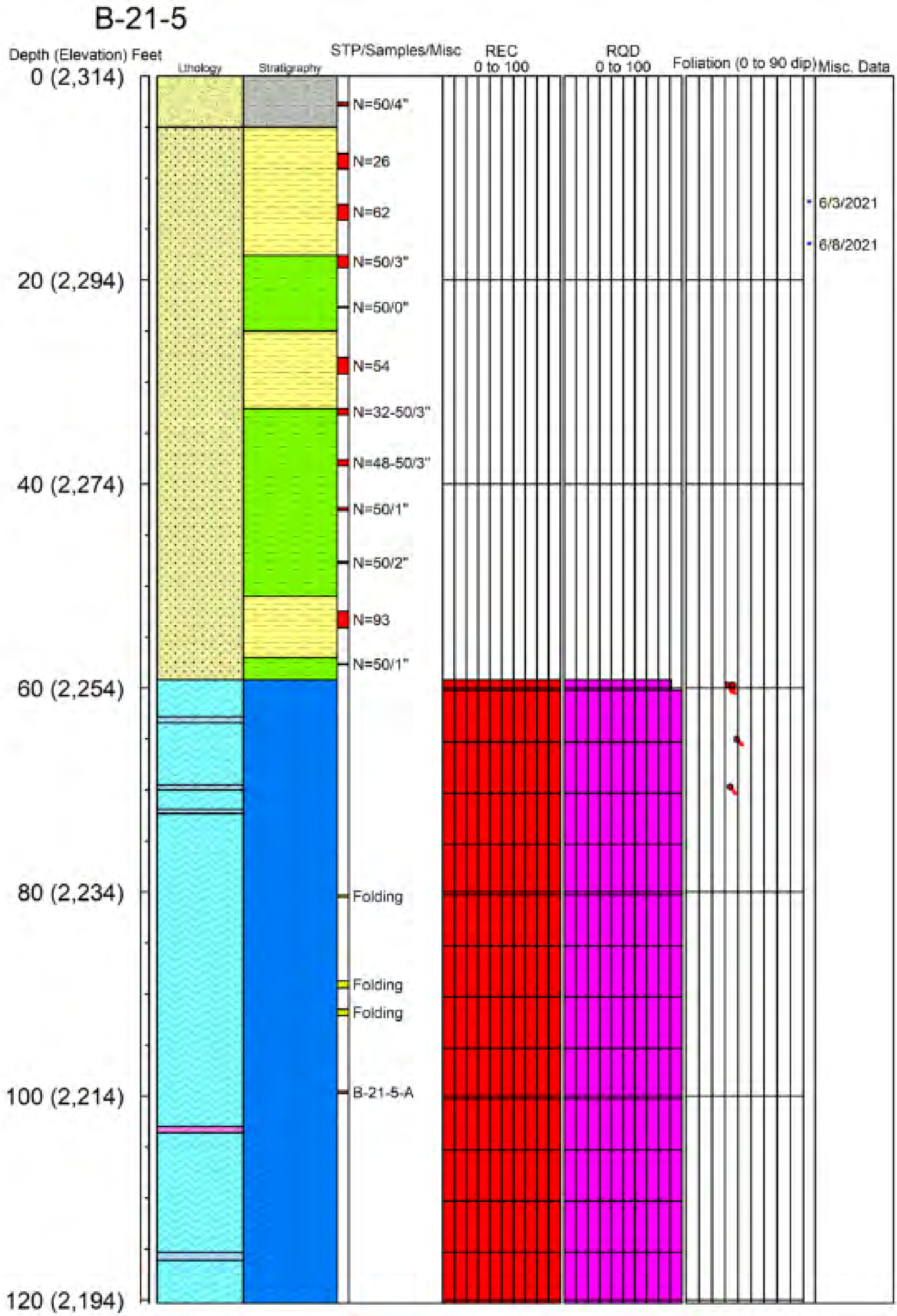


Figure 7. Graphic Log for Borehole B-21-5

4 Geology and Seismicity

4.1 Regional Physiography

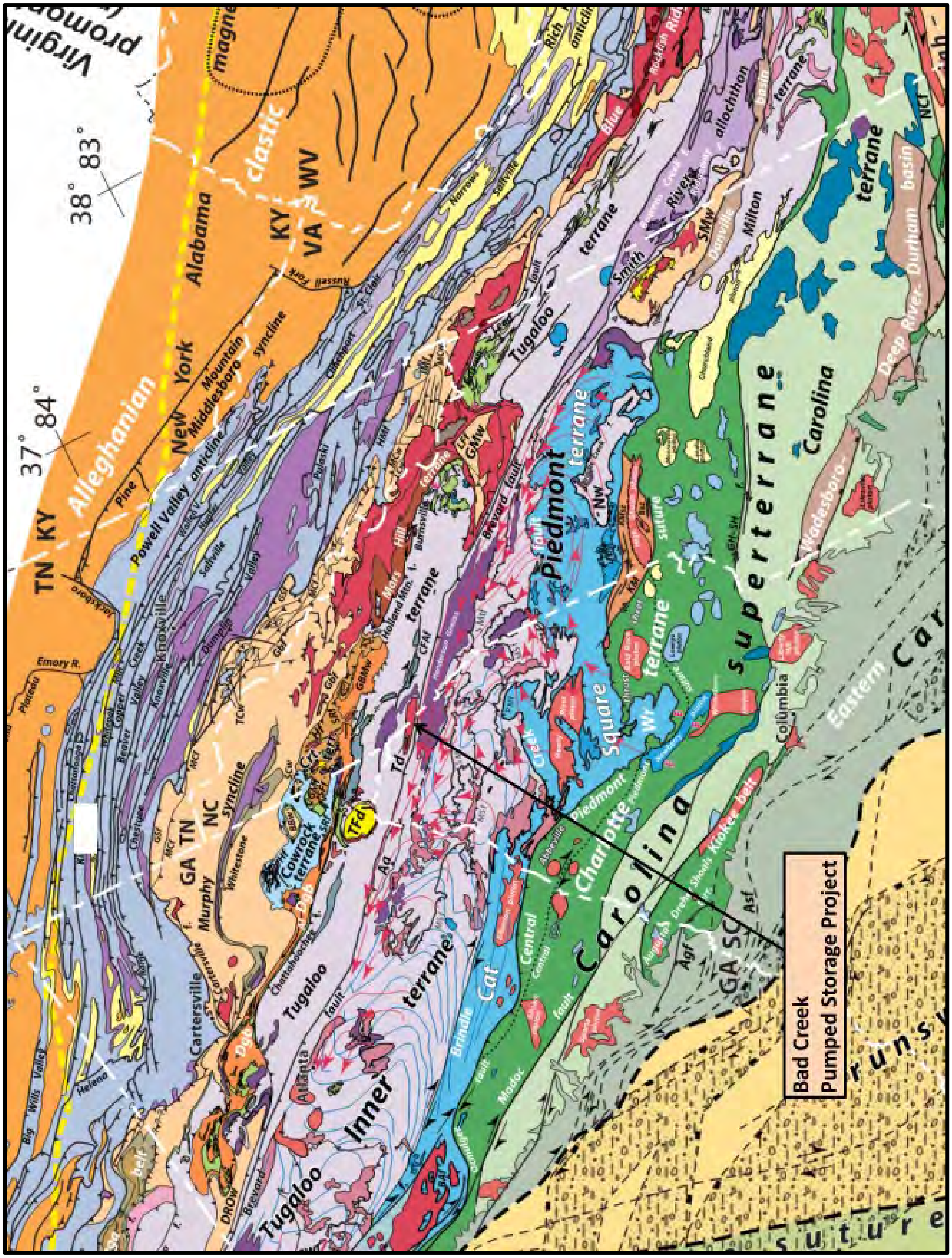
The Bad Creek Project is located in the Blue Ridge physiographic province (Blue Ridge), a mountainous zone that extends northeast-southwest from southern Pennsylvania to central Alabama, varying in width from less than 15 miles to 70 miles maximum. It is characterized by rugged terrain with valleys ranging in elevation from 1,000 feet in the south to greater than 1,500 feet in the north. Several mountain peaks have elevations greater than 6,000 feet with relief of up to 3,500 feet. In North Carolina, massive and resistant gneissic and metasedimentary rocks underlie most of the province, with the valleys tending to follow weaker-rock outcrops (e.g., schist or minor carbonate rocks) and fractures or fault/shear zones. The underlying geologic structure has a strong influence on local topography.

Drainage is generally to the west; however, the slopes separating the Blue Ridge from the Piedmont physiographic province are typically steep and provide the initial run-off (headwaters) for some of the largest streams of the Piedmont, which drain to the east and southeast. The Bad Creek Project site is located just northwest of the steep slope (Blue Ridge Scarp) separating the two physiographic provinces.

4.2 Regional Geology

The crystalline rocks of the southern Appalachians occur in northeast-trending parallel geologic terranes. The Bad Creek Project is within the Tugaloo terrane, which includes rocks of the eastern Blue Ridge northwest of the Brevard zone (Figure 8; Hatcher et al. 2007; Hatcher 2002). The Blue Ridge is a complex crystalline terrane consisting of Precambrian gneissic basement rocks structurally overlain by a vast thickness of metasedimentary and metavolcanic rocks of Precambrian to lower Paleozoic age (Hatcher 1978a, 1978b). Numerous igneous bodies of mafic to felsic composition intrude into the basement core and into the overlying metasedimentary and metavolcanic sequences. The structure of the Blue Ridge is controlled by major thrust faults, associated complex polyphase folding, and subsequent brittle faulting (Hatcher 1978a; Clendenin and Garihan 2007a, 2007b).

The southern Blue Ridge is divided into three belts: 1) a western belt of imbricate thrust sheets involving upper Precambrian and lower Paleozoic rock and some basement rocks, 2) a central belt containing most of the basement rocks exposed in the Blue Ridge terrane along with higher grade upper Precambrian and possible lower Paleozoic metasedimentary rocks, and 3) an eastern belt of high-grade early Paleozoic metasedimentary and metavolcanic rocks (Hatcher 1978a, 1978b; Hatcher et al. 2007). The eastern belt of the southern Blue Ridge comprises those portions of the Tugaloo terrane that occur northwest of the Brevard zone (Figure 8).



Source: Hatcher et al. 2007

Figure 8. Tectonic Map of the Southern and Central Appalachians and Location of the Bad Creek Pumped Storage Project(from Hatcher et al. 2007). Td = Toxaway Gneiss.

The principal rock unit of the western Tugaloo terrane (eastern Blue Ridge belt) is the Tallulah Falls Formation (TFF). The TFF generally consists of biotite gneiss (metagraywacke), pelitic schist, mafic volcanic rocks, and quartzite; in places the rocks of the TFF are migmatitic[1]. These rocks are intruded by Paleozoic granitoid rocks and overlie 1,150 to 1,200 million years ago (Ma) Precambrian Grenville basement rocks in the Toxaway Dome (see Section 4.3.1). More specifically, the TFF consists of four members described in ascending order: 1) the quartzite-schist member, 2) the lower graywacke-schist-amphibolite member, 3) the garnet-aluminous schist member, and 4) the upper graywacke-schist member (Hatcher 1977). The lowest member contains quartzite with interlayered schist. The lower graywacke-schist-amphibolite member contains biotite gneiss, amphibolite, muscovite schist, and biotite schist. Layers of granitic gneiss and pegmatites also occur in this member. Overlying the lower member is the garnet-aluminous schist member. It consists of muscovite-garnet-kyanite schist with interlayered amphibolite, muscovite schist, biotite gneiss, granitic gneiss, and pegmatites. It is generally easily recognizable by abundant garnet and kyanite. The upper graywacke-schist member contains biotite gneiss, mica schist, garnet mica schist, with minor amounts of amphibolite, granitic gneiss, quartzite, calc-silicate rocks, and pegmatites.

The Toxaway Gneiss (TGn), part of the Precambrian Grenville basement of the eastern Blue Ridge, is exposed in the core of the Toxaway Dome. It is typically a medium- to coarse-grained banded biotite-plagioclase-microcline-quartz gneiss with some massive and augen varieties, which do not appear to be significantly different in chemical/mineralogical composition (Schaeffer 1987, 2016; Merschat et al. 2003). The TGn has an Rb/Sr whole-rock isochron age of 1203±54 Ma (Fullagar et al. 1979). A derived zircon age for the TGn is 1,150 Ma (Carrigan et al. 2003 in Hatcher et al. 2007).

The TFF rocks are metamorphosed to the upper amphibolite facies (kyanite-sillimanite zone; Hatcher 1977; Butler 1991; Schaeffer 2016). Dominant metamorphic fabric and peak metamorphism in the eastern Blue Ridge is circa 450 Ma, based on metamorphic ages of detrital monazite and zircon grains from TFF rocks (Miller et al. 1997, 2000; Moecher et al. 2011; Cattanach et al. 2012). The Grenvillian basement rocks of the Blue Ridge, including the TGn, were subjected to granulite facies[2] metamorphism approximately 1000 Ma (Hatcher and Butler 1979).

4.3 Site Geology

4.3.1 Introduction

The Bad Creek Project is located immediately northwest of the Brevard zone in the Tugaloo terrane within the Toxaway Dome (Figure 8). The Toxaway Dome consists of a core of TGn and a sliver of TFF. It is an elongate feature that has a steeply dipping to overturned northwest limb and a more moderately inclined southeast limb. At the ends, the structure plunges gently northeast and southwest, resulting in a structural dome defined by the upward arching of the dominant foliation in the TGn. Detailed mapping performed during the construction of the Bad Creek Project indicates that the basement (TGn)/cover (TFF) contact is repeated several times due to isoclinal folding and transposition. Textural evidence (grain size reduction and truncated foliation and fold axis in the TGn at the contact) suggests that the original basement/cover contact was a pre-metamorphic fault (before Taconic age [~450 Ma] and after Grenville age [~1000 Ma] metamorphisms).

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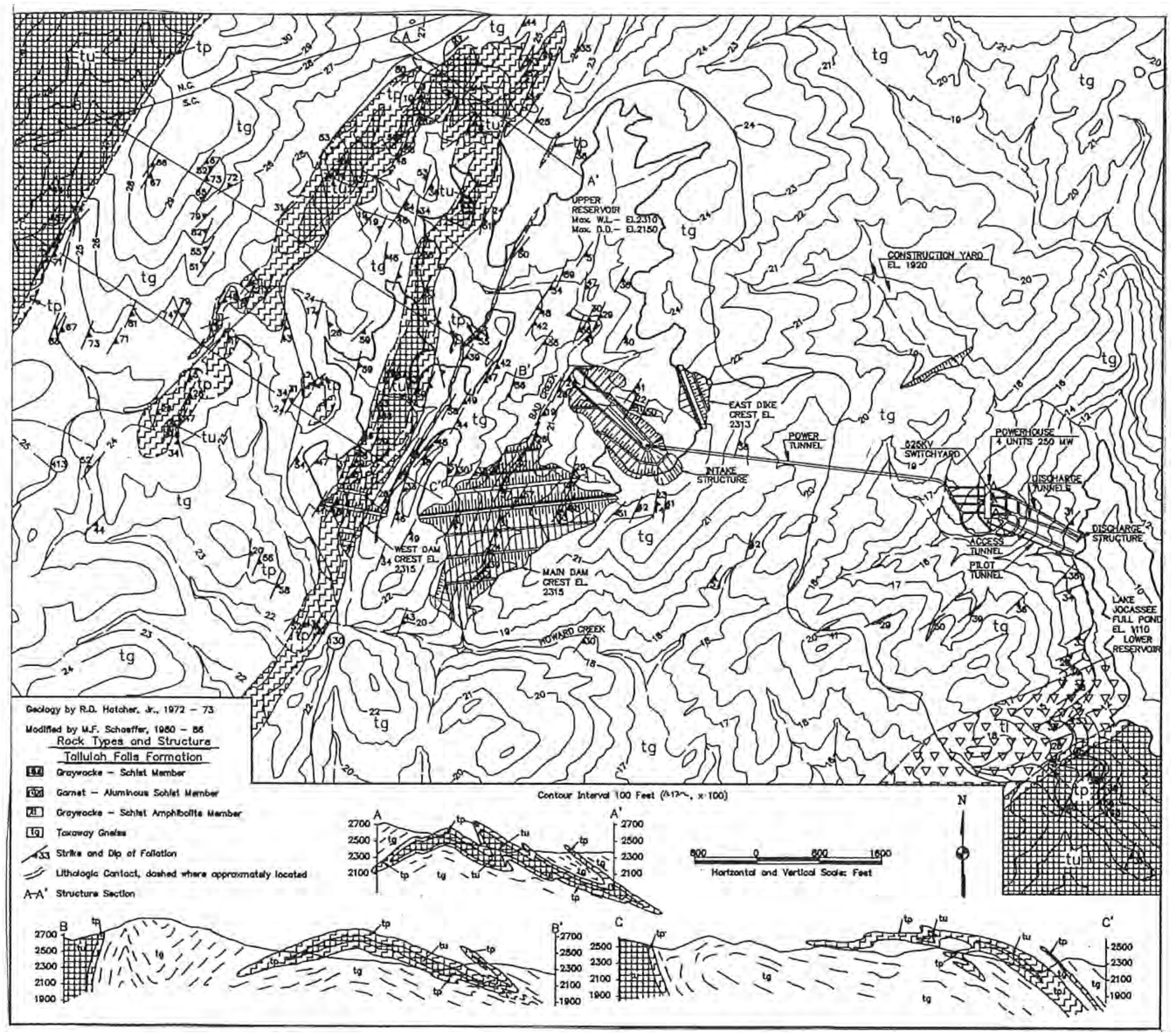
[1] Migmatite – Rock consisting of alternating layers or lenses of granitic material in gneisses and schists; related to partial melting of the rock during deformation and metamorphism and then re-crystallization of the melt during the waning stages of metamorphism.

[2] Granulite facies – Rocks that have been subjected to high temperature and moderate pressure metamorphism and the rocks generally represent, as is the case of the Toxaway Gneiss, deep continental crust.

Most of the site is underlain by TGn (Figure 9 and Figure 10). All the tunnels, shafts, and the powerhouse cavern for the existing Bad Creek Project were excavated in the TGn and based on the geologic information available and obtained from the geotechnical investigation program for this study phase, so will the underground structures for the proposed Bad Creek II (Figure 9 and Figure 10). The Main Dam and East Dike are founded on the TGn. The West Dam and a portion of the reservoir are underlain by a sequence of schistose rocks belonging to the TFF (Figure 9). The TFF rocks are predominantly the garnet-aluminous schist member; however, in places portions of the upper graywacke-schist member is present. This belt of TFF rocks is isolated from similar rocks on northwest and southeast of the Toxaway Dome by the refolding of earlier folds (Figure 9; Hatcher 1978a; Schaeffer 1987, 2016).

The TGn, part of the Precambrian basement of the eastern Blue Ridge, is a medium- to coarse-grained gneiss of granitic to quartz monzonitic composition. It is composed of microcline, plagioclase, quartz, and biotite with minor amounts of epidote, garnet, allanite, muscovite, zircon, sphene, apatite, and opaques. The TGn can be divided into two major types: 1) a banded, medium- to coarse-grained granitic gneiss composed of alternating light-colored quartz-feldspar rich bands and dark biotite-quartz-feldspar bands and 2) a coarse-grained augen granitic gneiss consisting of a poorly foliated feldspar-quartz-biotite gneiss with feldspar and locally hornblende augen up to 3 centimeters (cm) in length and a medium- to coarse-grained quartz-feldspar-biotite gneiss with a more distinct foliation and feldspar augen up to 1 cm. Layers of biotite-hornblende schist (sills or dikes, possibly feeders for the mafic volcanic rocks of the TFF) are present with thicknesses up to 20 feet. Their orientation is parallel to the dominant foliation/banding in the TGn. At least two generations of quartz-feldspar-mica pegmatites occur within the TGn. They are distinguished by the fact that the later generation is undeformed except by fracturing, whereas the earlier generation is folded. Most of the early pegmatites parallel the dominant foliation, the later generation cuts across foliation. Small cross-cutting quartz veins are also present.



Source: Duke Power Company 1991; Schaeffer 1987, 2016

Figure 9. Geologic Map of the Bad Creek Pumped Storage Project Site

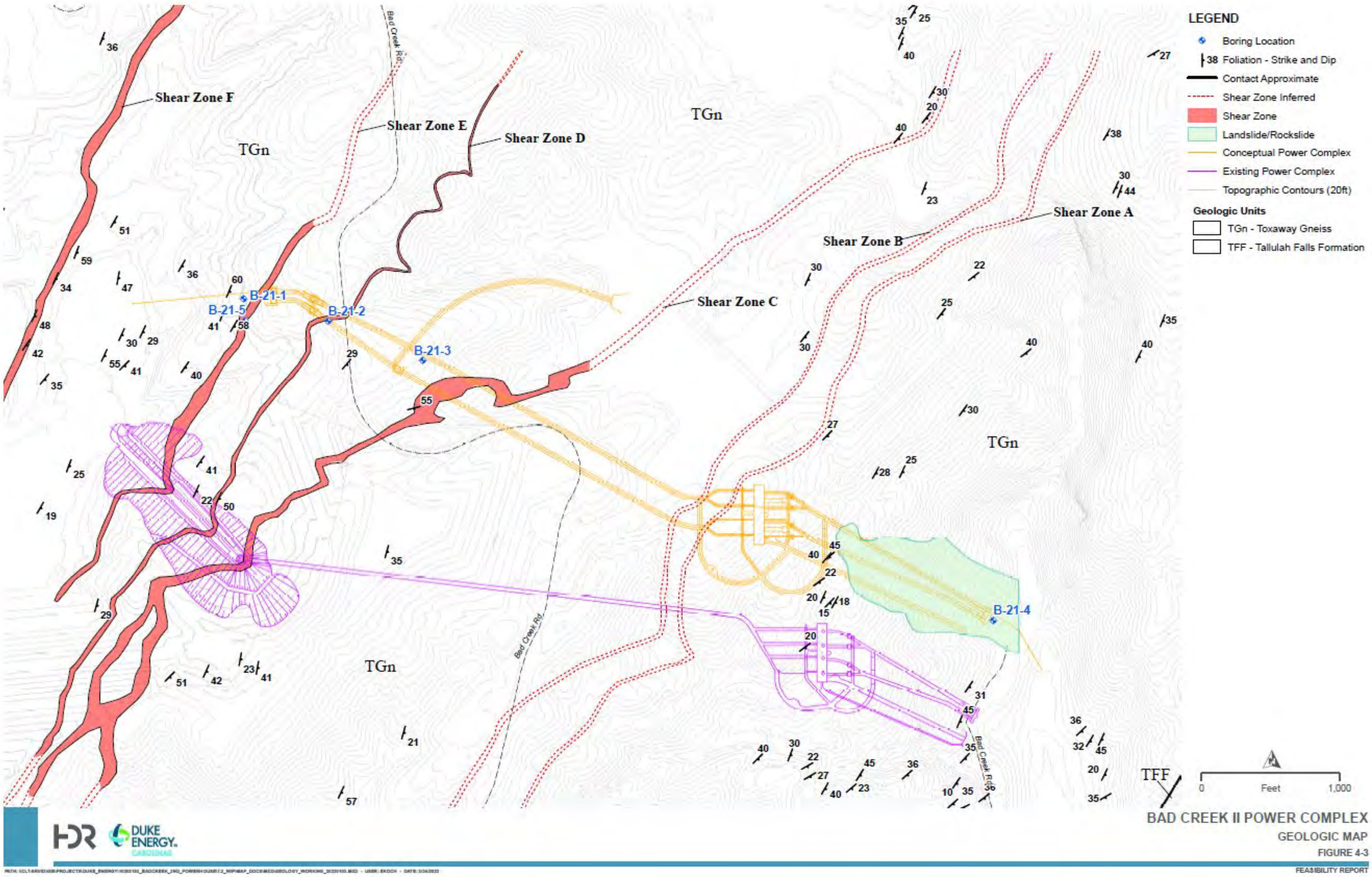


Figure 10. Geologic Map

The TFF consists of three members in the site vicinity (Hatcher 1977; Schaeffer 1987, 2016; Figure 9). The lower graywacke-schist-amphibolite unit consists of meta-graywacke (biotite gneiss), amphibolite, muscovite schist, biotite schist, pegmatites, and minor granitic gneiss. The garnet-aluminous schist member includes muscovite-garnet-kyanite schist with minor interlayered amphibolite, muscovite schist, and meta-graywacke. The upper graywacke-schist member consists of metagraywacke (biotite gneiss), muscovite schist, and muscovite biotite schist with minor amounts of interlayered amphibolite, granitic gneiss, and pegmatite. The units have undergone regional metamorphism to the kyanite zone of the amphibolite facies.

During the original design studies for the Bad Creek Project (pre-1985), the subsurface exploration program had the following primary objectives related to the underground excavations and structures: 1) examine the rock characteristics and geologic structure of the proposed powerhouse location, 2) determine the most feasible powerhouse orientation and location with respect to the geologic structure and in-situ stresses, 3) provide the data and experience necessary to facilitate an efficient design of the underground portions of the project, and 4) serve as a model for the instrumentation and monitoring to be incorporated into the permanent underground structures.

Early in the project it was decided that a pilot tunnel into the proposed powerhouse location would be the primary activity of the underground exploration program. Preliminary core drilling, laboratory testing of core samples, and deep borehole hydrofracturing stress measurements (see Section 4.3.4) had been conducted before the design of the pilot tunnel program (Duke Power Company 1978; Schaeffer and Steffens 1979). Data from these tests showed generally good rock conditions, but with high horizontal in-situ stresses present. However, due to the magnitude of the project, the pilot tunnel program was considered a prudent investment. The pilot tunnel excavation and testing lasted from October 1976 through September 1977. The work was divided into three main components: 1) excavation monitoring, 2) rock testing including the measurement of the in-situ rock mass stress orientation and magnitude utilizing the overcoring methodology (see Section 4.3.4), and 3) geologic mapping and investigations (Duke Power Company 1978; Schaeffer and Steffens 1979; Schaeffer et al. 1979).

The geologic program conducted during construction of the Bad Creek Project (from 1985 to 1991) provided additional geologic information for construction and design personnel to make necessary changes to the design and construction techniques due to geologic conditions and to document the conditions encountered. The geologic studies included observation, measurement, sampling, photographs, mapping, and evaluation of the exposed rock and foundation surfaces. The geologic conditions encountered in the underground works were documented by geologic mapping of at least one rib of all tunnels; the walls of the two vertical shafts; and the walls, crown, and floor of the powerhouse cavern at a scale of 1 inch = 6.56 feet. The aboveground structures including dam foundations, intake excavation, and discharge excavation were mapped at a scale of 1 inch = 20 feet. The upper reservoir area was mapped at a scale of 1 inch = 200 feet after all excavation and borrow work was completed. The mapping was the primary input into construction and design considerations as work progressed and was supplemented by additional studies as needed. The geologic work during construction, including additional studies beyond the geologic mapping (for documentation), are described and discussed in Duke Power Company (1991) and Schaeffer (2016; included in Appendix B). The drawings documenting the underground geologic mapping and specific geologic studies are part of the as-built Bad Creek Project documentation (Drawing Series BK-1011-09 to -15).

The intake, underground structures (tunnels, powerhouse, vertical shafts), and intake/discharge structure of Bad Creek II will be excavated in the TGn based on the geotechnical investigation and the previously collected geologic data (Figure 9 and Figure 10).

An alternate interpretation of the geology along Lake Jocassee at the intake/discharge area is shown in Figure 11 (Clendenin and Garihan 2007a). It shows TGn in the Bad Creek II underground structure area, but a more complex relationship between the TGn and TFF rock units than shown in Figure 9 as well as two northwest-trending faults that are discussed later in Section 4.3.3 of this report.

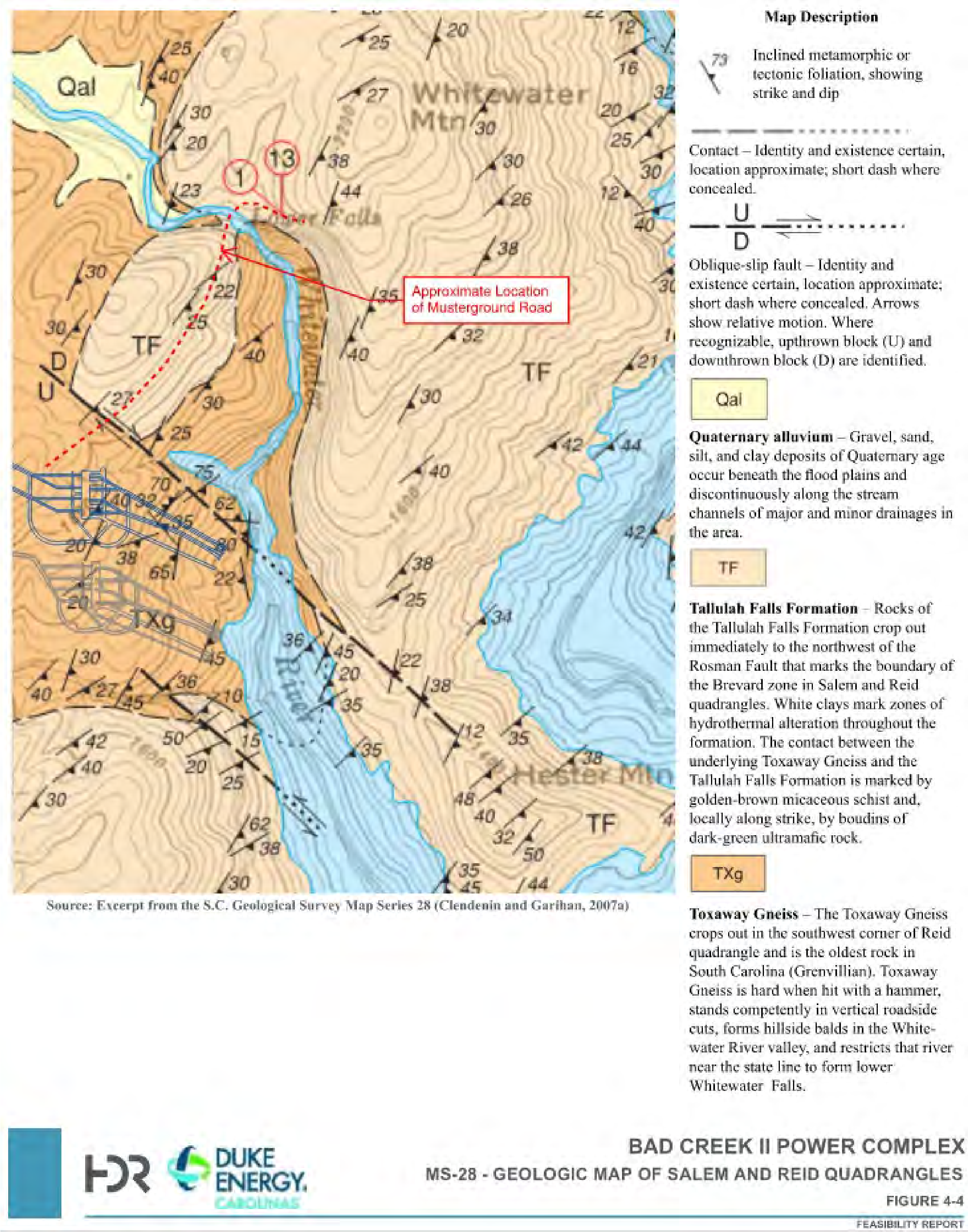


Figure 11. MS-28 – Geologic Map of a Portion of the Salem and Reid Quadrangles

4.3.2 Lithology

Detailed geologic mapping of the Bad Creek Project underground excavations resulted in a detailed subdivision of rock types within the TGn. The following units were recognized and mapped during the construction:

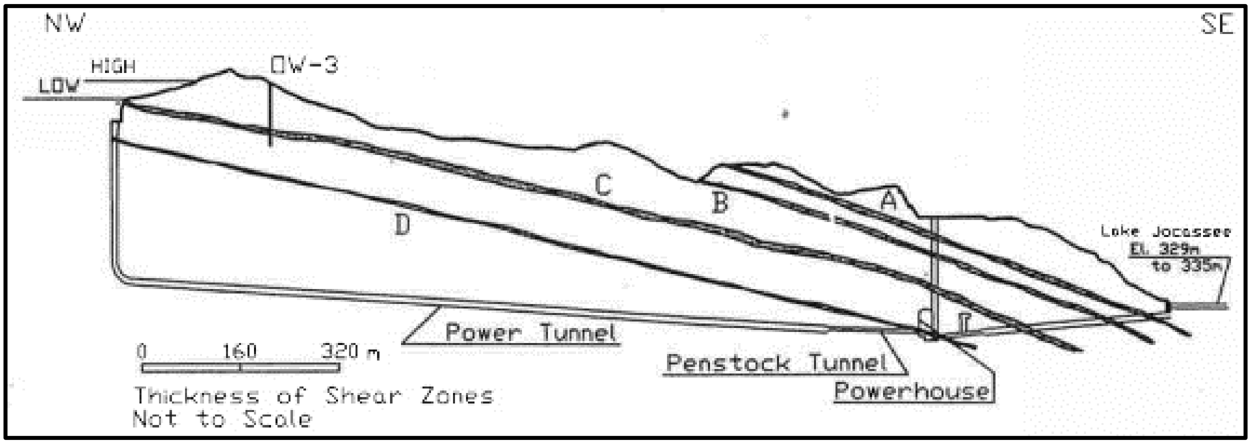
1. Granitic Gneiss, medium light gray to light gray, medium- to coarse-grained gneiss consisting of alternating layers of light-colored quartz-feldspar bands and darker biotite-quartz-feldspar bands, well-foliated;
2. Banded Augen Granitic Gneiss, medium light gray to light gray, medium- to coarse-grained gneiss consisting of a foliated (banded) quartz-feldspar-biotite gneiss containing feldspar augen up to 1 cm long;
3. Augen Granitic Gneiss, medium light gray, coarse-grained gneiss consisting of a coherent, massive, poorly foliated feldspar-quartz-biotite gneiss with feldspar and locally hornblende augen up to 3 cm long;
4. Biotite Schist, medium dark gray to dark gray, coarse-grained biotite-hornblende schist;
5. Biotite Gneiss, medium dark gray to dark gray, medium- to coarse-grained biotite-hornblende gneiss;
6. Biotite Augen Gneiss, medium gray to medium dark gray, medium- to coarse-grained, foliated biotite-feldspar-quartz gneiss with feldspar augen up to 1 cm long, biotite content generally greater than 30%;
7. Quartz-Feldspar Gneiss, very light gray to white, very coarse-grained, distinctly foliated quartz-feldspar gneiss with minor biotite (less than 10%);
8. Very Coarse-Grained Granitic Gneiss, light gray, very coarse-grained, distinctly foliated quartz-feldspar-biotite gneiss, biotite content greater than 10%;
9. Weathered Sheared Rock, moderate to moderately severe weathering, light gray to yellowish gray to greenish gray, original rock type granitic or augen granitic gneiss; and
10. Hard Sheared Rock, medium light gray to light gray, medium- to coarse-grained rock, original rock type granitic or augen granitic gneiss.

4.3.3 Structural Geology

The foliation in the TGn and TFF rocks is defined by the parallel orientation of platy minerals and by compositional layering. The average orientation of foliation in the Bad Creek reservoir area is N37E; 38SE and varies from N35-50E; 28-41SE in the underground works. Minor folds are present; some lie within foliation whereas others fold the dominant foliation. The earliest set of folds are isolated “z-”, “s-”, and crescent-shaped fragments, which are axial planar to the dominant foliation. The presence of these isolated fold fragments indicates that transposition of an older foliation has occurred. The second set of folds are isoclinal to open with variable development of a secondary foliation. In areas where this folding is isoclinal, an axial planar foliation (defined by secondary biotite) is present. Later open folding was recognized in several tunnels of the existing Bad Creek Project.

Shear zones with thicknesses up to 200 feet occur throughout the TGn and generally parallel the dominant foliation. Four major shear zones are present in the reservoir and dam areas (Shear Zones C, D, E, and F on Figure 10) and two additional major shear zones (Shear Zones A and B on Figure

10) were mapped in the underground tunnels (Figure 12; projections to the ground surface are shown on Figure 10).



Source: Talwani et al. 1999

Figure 12. Cross-section of Existing Bad Creek Underground from the Upper Intake to the Discharge/Intake Structure on Lake Jocassee showing Location of Shear Zones A, B, C, and D

Shear Zone A is in the vertical access shaft and in the excavation along Lake Jocassee for the intake/discharge structure. Shear Zone B is present in the vertical access shaft, the main access, Tailrace 1 & 2, and Tailrace 3 & 4 tunnels. Shear Zone C is present in the main access, penstock bypass, tailrace bypass, draft tube gate, Tailrace 1 & 2, and Tailrace 3 & 4 tunnels and the vertical access shaft. Shear Zone D is present in the manifold, Penstock 1, Penstock 2, Penstock 3, and Draft Tube 1 tunnels and in the west, north, and east wall and along the floor of the powerhouse cavern. The zones consist of hard sheared rock with layers of weathered sheared rock present. The zones are mineralized with chlorite, epidote, calcite, and quartz in various combinations. Originally white feldspars have been discolored to a pink or light orange-pink color within and adjacent to the shear zones. Along some of the shear planes, breccia is present with thicknesses of less than 1 inch to approximately 12 inches. The breccia consists of granitic gneiss, coarse quartz/feldspar (pegmatites), and vein quartz fragments in a matrix of fine-grained chlorite and epidote. Several of the shear zones have associated weathered zones up to 12 inches thick. Within the weathered zone there is up to 2 inches of gouge-breccia composed of granitic gneiss, coarse quartz/feldspar, and vein quartz fragments in a clay matrix. The hard sheared rock exhibits tight, complex isoclinal folding with sheared out limbs and a secondary axial planar foliation defined by biotite. This relationship indicates that the major shearing is related to the second fold event, although some of the shear zones may have been reactivated from the first fold event. The brecciation and mineralization of the zones is a later faulting event.

In the intake excavation, Shear Zone C (referred to as the D6/East Dike shear zone in the Bad Creek Design Report [Duke Power Company 1991]) was first mapped during the intake structure excavation. In the east dike foundation, the shear zone consists of a weathered zone 2 to 3 feet thick with alternating layers of hard material (quartz-feldspar pegmatites and breccia with an epidote-chlorite matrix) and soft material (weathered granitic gneiss, weathered sheared rock, discontinuous layers of biotite schist, and discontinuous layers of phyllonite ½ to 12 inches thick). Within portions of the shear, there is up to 8 inches of gouge-breccia composed of rock, quartz/feldspar fragments, and vein quartz fragments in a clay matrix. A relatively pure clay layer, 1 to 2 inches thick, is present along the hard layer of breccia. The harder layers within the zone are highly fractured with Mn and Fe staining along the fractures indicating water percolation.

For this phase of study, a representative sample of structural data collected during the geologic mapping of the Bad Creek 1 above- and underground structures that were still available in various files were analyzed. This included structural data from the following:

1. West dam foundation (only data collected from granitic gneiss (primarily TGn) and biotite gneiss (TFF);
2. Main dam foundation (all from TGn); and
3. All underground tunnels (main access, draft tube gate, penstock bypass, tailrace bypass, powerhouse bypass, manifold, penstocks [4], draft tubes [4], and tailrace tunnels [2]) and vertical shafts (intake and access shafts). The data were extracted from the as-built geologic maps of these structures. Structural data from the powerhouse mapping are not included in the underground data sets.

The compiled data is included on four Excel spreadsheets (including the GEL Solutions televiewer data) and the DIPS Version 8.008 files used for the stereonets of the structural data included in Appendix A (files are provided electronically including scans of the original field data compilation for the main and west dams).

The data from the main dam and reservoir mapping was utilized in the kinematic analysis of the proposed Upper Reservoir I/O rock cuts (the analysis is provided in Appendix C and discussed later in Section 6.1 of this report). The compiled data from the underground geologic mapping was used in the projection of the shear zones into the vicinity of the proposed Bad Creek II water conveyance alignment and is discussed in Section 6.3. The site structural data is summarized in Table 1.

Table 1. Structural Data from Bad Creek 1 Geologic Mapping

West Dam Mapping (1987-1990) - Granitic and Biotite Gneiss; Foliation from Reservoir Mapping - Joints, N = 1152; Foliation, N = 116	**Main Dam Mapping (1986-1990) Sampled Data. Joints N = 2689 of 6687 Measurements; Foliation = 1188 of 3619 Measurements**
N33E; 33SE (S)[1]	N34E; 34SE (S)
N62W; 83SW (Jt)[2]	N51W; 80SW (Jt)
N37E; 77NW (Jt)	N37E; 70 NW (Jt)
N89W; 76NE (Jt)	N85E; 78NW (Jt)
Reservoir Area - (1983-85 Mapping)	**Main Dam Mapping (1986-1990); Faults, N = 676; Shear Planes, N = 402**
N37E; 38SE (S)	N36E; 77SE (Flt)[3]
N47W; 88SW (Jt)	N49W; 82SW (Flt)
N77E; 82NW (Jt)	N35E; 33SE (Sh)[4]
N42E; 74NW (Jt)	
Underground Mapping (1985 to 1989)	**Underground Mapping (1985 to 1989)[5]. Joints, N = 764; Foliation, N = 1131; Faults, N = 193; Shear Planes, N = 72**
N35E; 30SE (S)	N84E; 67NW (Jt)
N70E-N70W; <50N & S (Jt)	N44E; 30SE (S)
N60E; 60NW (Jt)	N63E; 55NW (Flt)
N65E; 30SE (Jt)	N49E; 31SE (Sh)
N45W; 70-90SW or NE(Jt)	

[1]S - Foliation; [2]Jt - Joint; [3]Flt - Fault; [4]Sh - Shear Plane

[5]Underground data compiled (2021-2022); powerhouse structural data not included.

There are three dominant joint sets in the Bad Creek reservoir area based on the pre-construction mapping: 1) N77E; 82 NW, 2) N42E; 74NW (strike joints), and 3) N47W; 88SW (dip joints). The predominant joint set varies between N70W and N70E with steep north and south dips (>50º) in the underground works. Another set strikes N60E with moderate to steep northwest dips and a weakly developed set oriented N45W with steep southwest dips is present. All joint sets have some degree of mineralization, but the northeast and particularly the east-west set (N77E in the reservoir area) contain a greater percentage of mineralized joints. The dominant mineral fillings are quartz, chlorite, epidote, biotite, and calcite in various combinations. Iron oxide and manganese staining is present along weathered joint surfaces. Spacing within the joint sets varies from less than 1 inch to greater than 50 feet.

In the underground portion of the Bad Creek Project, the dominant joint set is oriented N70E to N70W (~N87E; see Table 1) with dips >50º north and south. Other sets are oriented N60E; 60NW, N65E; 30SE (foliation joints), and N45W; 70-90SW or NE. The joints are tight at depth with similar mineral fillings as noted in the reservoir area. Near the ground surface some joints are open and with weathering resulted in blocky conditions at the main access tunnel portal for approximately 200 feet into the tunnel that was supported by steel sets and a concrete lining.

Fault and fault zones in the underground portion of the Project are present and are generally associated with the northeast-striking joint sets. Single fault planes with few associated fractures have offsets up to 6 inches (vertical separation). The fault zones have complex fracturing with several planes and offsets ranging from less than 1 inch to greater than 12 feet. Breccias up to 6 inches thick are developed along some of the fault planes and consist of rock, quartz/feldspar, and vein quartz fragments in a fine-grained matrix of chlorite-epidote. Discoloration of feldspars to pink occurs along some of the fault planes. All fractures within the zones are mineralized by combinations of epidote, chlorite, quartz, and calcite. Along some of the fault planes, chlorite up to 2 inches thick is present. Subhorizontal slickensides on the chlorite indicate the primary movement was strike-slip. The thicker chlorite mineralization has a secondary shear foliation, indicating minor movement after the primary mineralization. In some fault zones the rock is shattered between fault planes with chlorite-quartz mineralization throughout the fracture zone. The brecciation and mineralization of the fault zones occurred at the same time as the brecciation along the shear zones. The faults and shear zones are similar to others within the southern Appalachians that have been healed under greenschist metamorphic conditions, suggesting the last movement occurred at least 300 Ma (Gilbert et al. 1982).

Clendenin and Garihan (2007a) mapped two northwest-trending oblique-slip faults northeast and southeast of the existing and proposed underground works. Northwest-trending faults were not encountered in any of the underground excavations for the Bad Creek Project and only minor northwest-trending faults were mapped in the Bad Creek reservoir and in the main dam, west dam, east dike, and intake channel/structure (see Appendix A, Figures A-13 [aboveground data] and A-18 [underground data]; in Appendix A; Duke Power Company 1991; Schaeffer 1987, 2016; Table 1). These northwest-trending faults mapped in the reservoir and dam/intake areas were short splays with minor offsets of the primarily northeast-trending faults as discussed in the previous paragraph. The previous mapping (Figure 9) and mapping during the feasibility study (Figure 10) did not identify these two faults along the present access road along Lake Jocassee to the location of the existing and the proposed Lower Reservoir I/O works. At both locations on the access road to the existing powerhouse complex, landslides (previously mapped in the early 1980s; Schaeffer 2016) are present and there is no indication of faulting on either side of the two landslides, although the landslides could be concealing the faults. However, the geologic sequence along the access road was checked during the field reconnaissance and confirmed that the earlier mapping shown in Figure 9 is correct regarding the location of the TGn/TFF contact indicating faulting shown in Figure 11 is not supported by geologic interpretations presented in this report. Along Musterground Road (see Figure 11), the rock identified by Clendenin and Garihan (2007a) is a coarser phase of the TGn and not migmatitic lithologies of the TFF. The northwest-fault in that vicinity was not identified or observed during the field reconnaissance and the determination of the lithologies northeast of the fault along Musterground Road as phases of the TGn makes the through-going northwest-striking fault shown on Clendenin and Garihan's map (Figure 11; 2007a) unlikely.

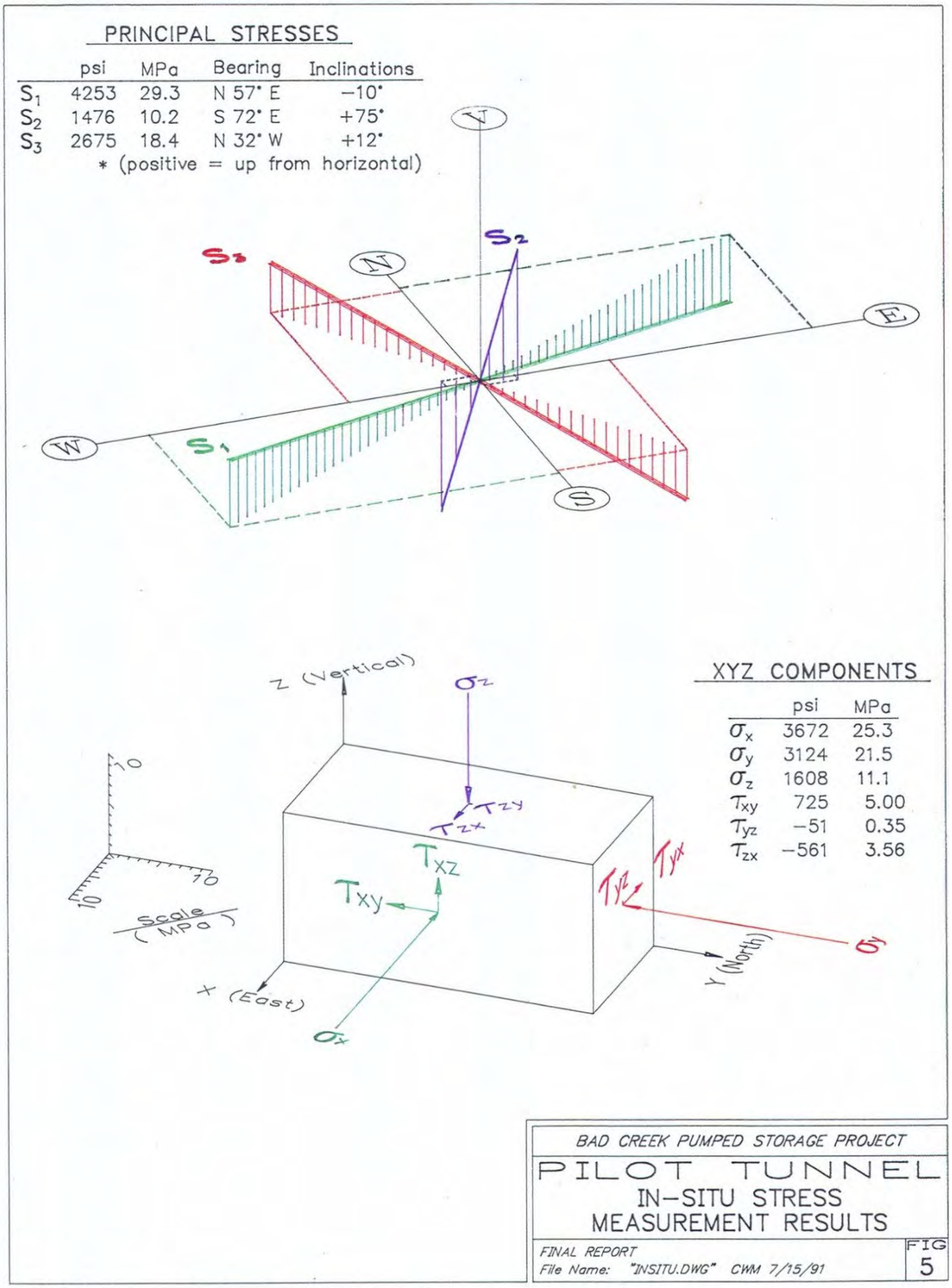
4.3.4 In-Situ Stress Measurements

Two methods of in-situ stress measurement were employed for the design of the existing Bad Creek Project tunnels, caverns, and shafts: hydrofracturing and overcoring. Hydrofracturing tests were performed in a deep borehole (B-52) from the ground surface and the overcoring technique was employed in the proposed powerhouse location in the pilot tunnel. Table 2 provides the in-situ stress values obtained from the hydrofracturing tests and Figure 13 depicts values from the overcoring tests. Preliminary calculations and the hydrofracturing measurements assumed a vertical stress (lithostatic) component equal to that due to overburden. At the overcoring test depth this would be approximately 690 psi. The vertical stress determined from overcoring was 1476 psi and was oriented 10º south of east at an angle of 14º from vertical (Figure 13). If this higher stress magnitude had been assumed in the hydrofracturing stress calculations, there would have been good agreement with the overcoring results. The direction of the horizontal stresses is in excellent agreement between the overcoring and hydrofracturing tests.

Table 2. Hydrofracturing Results in Borehole B-52

Stress	Pore Pressure	Stress Magnitude	Orientation of Principal Stress
Vertical Stress, σ_3		800 – 1000 psi	Vertical
Maximum Horizontal, σ_1	0 psi 300 psi	2500 – 4100 psi 2200 – 3800 psi	N60E N60E
Minimum Horizontal, σ_2		1950 – 2650 psi	N30W

Note: Several tests were performed at different depths in the vicinity of the proposed Bad Creek II powerhouse.



Source: Duke Power Company 1991

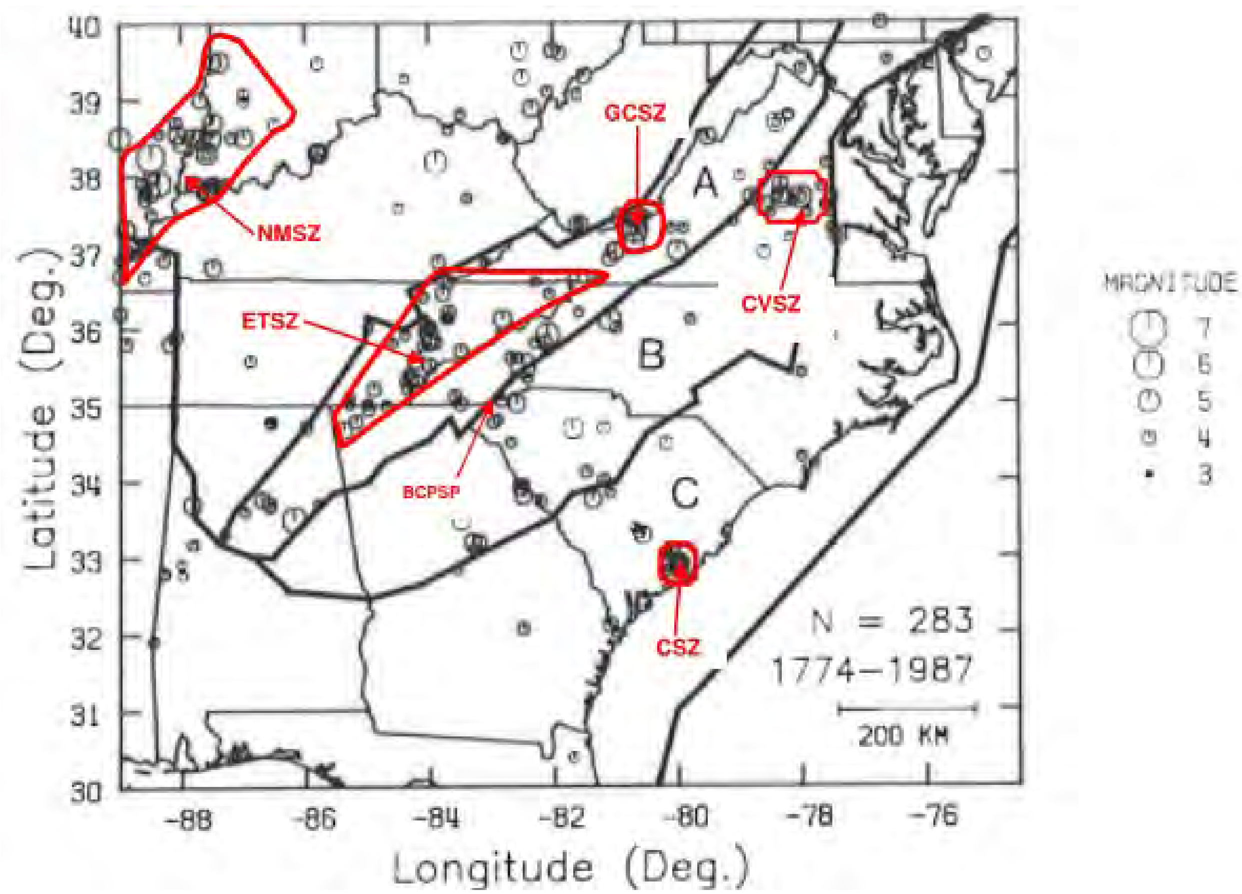
Figure 13. Result of Overcoring In-situ Stress Measurements in the Pilot Tunnel

Overcoring stress values were among the input parameters for finite element modeling (FEM) performed for the design of the existing Bad Creek Project powerhouse and tunnels. Results of the FEM analysis were used to determine the shape of the powerhouse and tunnels; other factors such as geologic structure, support methods, and other functional requirements played a major role. The most useful information from the FEM results was an estimate of the how much rock movement should be expected during and after powerhouse excavation. These estimates became the basis for evaluating the data from installed instruments during and after construction of the existing powerhouse.

4.4 Seismicity

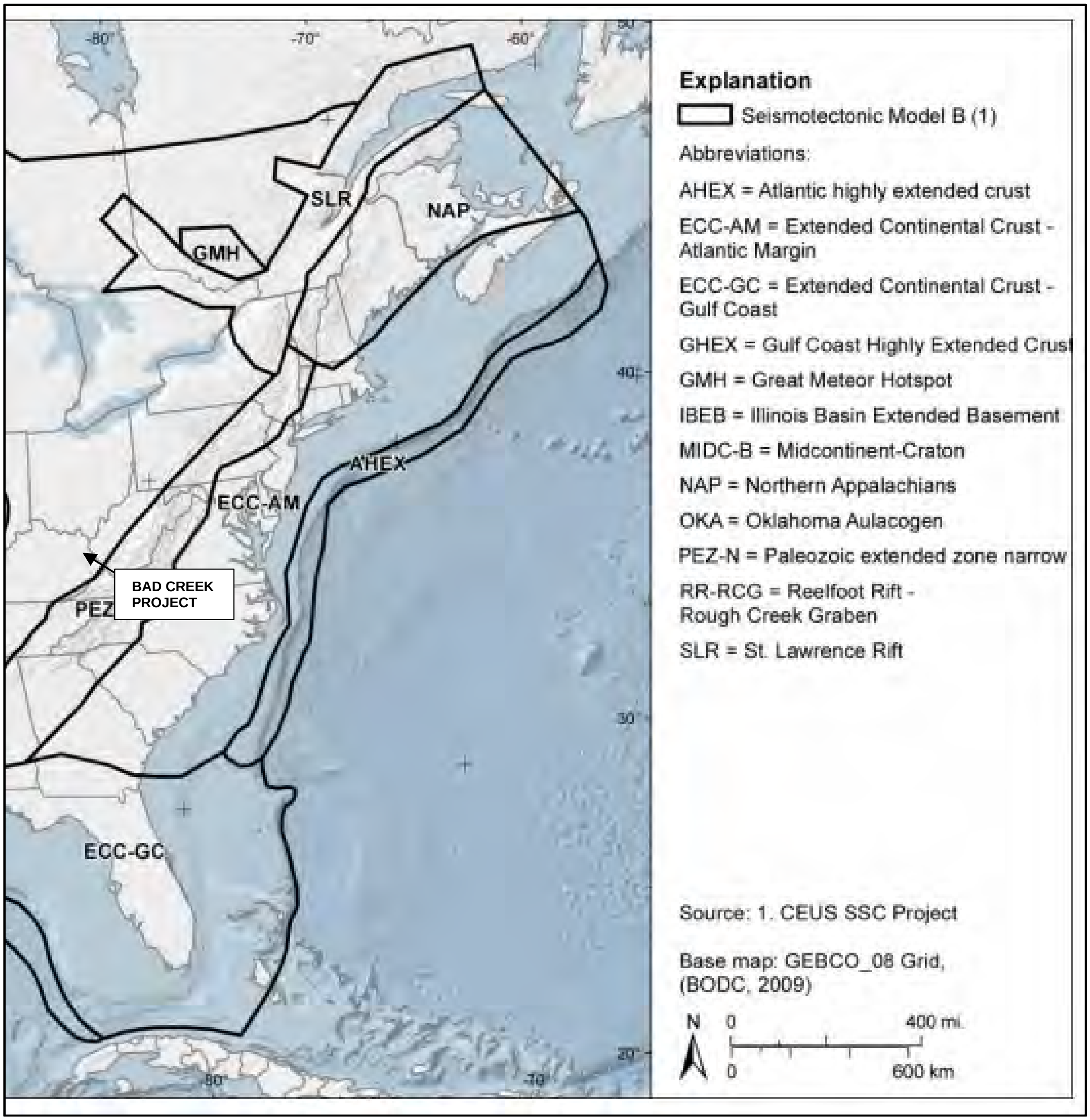
The East Tennessee Seismic Zone (ETSZ), closest to the Bad Creek Project, is one of the most active seismic zones in eastern North America (Bollinger et al. 1991) and is located primarily in the Valley and Ridge physiographic province of Tennessee with a portion in the Valley and Ridge and Blue Ridge physiographic province of western North Carolina (Figure 14). The zone is approximately 300 kilometers (km) long and 50 km wide and has not produced a damaging earthquake in historical time (Powell et al. 1994). The earthquakes occur at depths of to 5 to 25 km within Precambrian crystalline basement rocks beneath the thrust sheets of Paleozoic sedimentary rocks of the Valley and Ridge (Bollinger et al. 1976; Bollinger et al. 1991). The structures likely responsible for the seismicity in the zone are reactivated Precambrian to Cambrian normal faults formed during the rifting (extension) that formed the Iapetus Ocean and are located beneath the later accreted Appalachian thrust sheets (like the Giles County Seismic Zone in Virginia; Wheeler 1995). In the recent EPRI (2012) Central and Eastern United States seismic source characterization, the site is in the Paleozoic extended crust zone (Figure 15) as described in the previous two sentences. Despite its relatively high rate of activity, the largest known earthquake in the ETSZ is M_w 4.7[3] (1973 Alcoa-Marysville earthquake; Bollinger et al. 1991).

[3] M_w = Moment Magnitude.



Note: BCPSP = Bad Creek Pumped Storage Project; A = Valley and Ridge and Blue Ridge; B = Piedmont; C= Coastal Plain. GCSZ = Giles County Seismic Zone (not discussed in text); ETSZ = East Tennessee Seismic Zone; CVSZ = Central Virginia Seismic Zone; CSZ = Charleston Seismic Zone (not discussed in text); NMSZ = New Madrid Seismic Zone (not discussed in text). Figure modified from Bollinger et al. 1991).

Figure 14. Southeastern U.S. Seismicity (1774 to 1987), Physiographic Provinces and Seismic Zones



Source: EPRI 2012

Figure 15. Central and Eastern United States Seismotectonic Zones and Location of the Bad Creek Pumped Storage Project

Recent work between Vonore and Maryville, Tennessee, centered on the Tellico Reservoir and the Little Tennessee River, has yielded evidence of paleoseismic features within a narrow northeast-trending zone (Hatcher et al. 2015; Glasbrenner et al. 2015; Warrell et al. 2017). The evidence includes faulted Quaternary river sediments and folded terrace deposits with faults that have offsets of up to 2 meters that involve bedrock (Hatcher et al. 2015; Warrell et al. 2017). Warrell et al. (2017) dated features within the zone and determined that at least three large earthquakes occurred in the ETSZ during the late Pleistocene (1.0 (?) to 0.012 Ma) with at least one or more exceeding M_w 6.

The Central Virginia Earthquake of September 1, 2011 (M_w 5.7 - 5.8) was the largest and most damaging in the central and eastern United States since the 1886 Charleston, South Carolina earthquake (estimated M_w 6.8 - 7.0). The earthquake occurred on a north or northeast-striking plane with reverse faulting within a previously recognized seismic zone, the "Central Virginia Seismic Zone." The Central Virginia Seismic Zone (CVSZ) has produced small and moderate earthquakes since at least the 18th century. The previous largest historical shock from the Central Virginia Seismic Zone occurred in 1875. The CVSZ is in the Appalachian Piedmont Province between Richmond and Charlottesville, Virginia (Figure 14). The zone has an elliptical area, with a north-south dimension of 100 km and an east-west dimension of 120 km, as defined by historical earthquake activity (Bollinger and Sibol 1985; Coruh et al. 1988). The depth of the earthquakes ranges from near surface to 12 km, placing them above the Appalachian detachment (Chapman 2015) in contrast to the ETSZ where earthquakes occur below the detachment.

On August 9, 2020, a 5.1 M_W magnitude earthquake occurred on August 9, 2020, with an epicenter approximately 2.5 miles southeast of Sparta, just south of the Virginia-North Carolina border (Figure 16). The earthquake caused damage to over 500 buildings and other infrastructure (Hill 2020; Figueiredo et al. 2022). Surface ruptures were attributed to a south-southwest-dipping reverse fault (Little River fault [LRF]) and were traced for ~2.5 km along the northwest trend (Hill 2020; Figueiredo et al. 2022). The LRF produced a maximum vertical displacement of 25.2 cm, with similar vertical displacements along much of the fault trace (Hill 2020; Figueiredo et al. 2022). The hanging wall was to the south (northeast side up; reverse fault as shown by the initial USGS focal mechanisms [USGS 2020a]). There is no recorded historical seismicity in and around Sparta, but Hill (2020) speculated that the LRF may be associated with the Giles County Seismic Zone, which is centered in Virginia approximately 100 km to the north. The depth of the main shock, 4.1 km (USGS 2020b), suggests that it occurred above the master decollement (depths of 5 to 12 km) and is not related to the Giles County Seismic Zone or ETSZ where the earthquakes typically occur below the decollement in the Paleozoic extended crust. The estimated magnitude of the Skyland 1916 earthquake is M_W 5.1 (Figure 16) similar to the magnitude of the Sparta 2020 earthquake.

Prior to filling Lake Keowee in 1968, none of the historical seismic activity occurred in the vicinity of the Bad Creek Project. Because seismic activity appeared to have increased after impoundment of the Keowee Hydro Project (as evidenced by a swarm of seismic events associated with Lake Keowee in 1978 and other recorded events), the potential of reservoir-induced seismicity was studied by Duke Power Company (Schaeffer 1991). Both Lake Keowee and then later Lake Jocassee were associated with reservoir-induced seismicity (sometimes referred to as reservoir-triggered seismicity). Most of the events have been small, with the largest having a local Magnitude (M_L) of 3.8. Activity at Lake Jocassee has decreased significantly since first filling in 1976 while activity at Keowee has also decreased (Schaeffer 2000). During the study of the reservoir-induced seismicity, seismic activity was closely recorded by the stations of the seismic network operated by Duke Power Company and that of the South Carolina Seismic Network. Only a minor increase in seismicity was reportedly related to initial filling of the Bad Creek upper reservoir – from about 5 events per month to about 10 per month. However, no correlation could be made with the observed increase with Bad Creek reservoir filling and operation of the plant (up to 160 feet of potential change in the reservoir level). Of the minor earthquakes in the area, none were located under or very near to the Bad Creek reservoir. Seismic activity clearly related to Lakes Keowee and Jocassee decreased to near background levels by 2000 (Schaeffer 2000). The cluster of earthquakes on Figure 16 near the site are primarily related to the induced seismicity at Lakes Jocassee and Keowee.

Earthquakes with $M_w \geq 3$ and contours of Peak Ground Acceleration (PGA) for V_{s30}[4] equals 760 m/sec with 2 percent probability of exceedance in 50 years (2475-year return period) from the 2018 National Seismic Hazard Maps developed by the U.S. Geological Survey (USGS 2018) are shown in Figure 16. The PGA at the Bad Creek Project site is 0.24g for V_{s30} of 760 m/sec (Site Class B/C[5] Boundary) and 0.21g for V_{s30} of 2000 m/sec (Site Class A[4]) as shown in Figure 17 as are the hazard curves for spectral acceleration at selected periods and a Uniform Hazard Spectrum (UHS at 5% Damping) for both values of V_{s30} (USGS 2014b).

[4] V_{s30} is the shear wave velocity of the upper 30 meters of earth materials.
[5] Site Class A = Hard Rock (V_s > 1524 m/sec); Class B = Rock (762 m/sec < $V_s \leq$ 1524 m/sec); Class C = Very Dense Soil and Soft Rock (366 m/sec < $V_s \leq$ 762 m/sec).

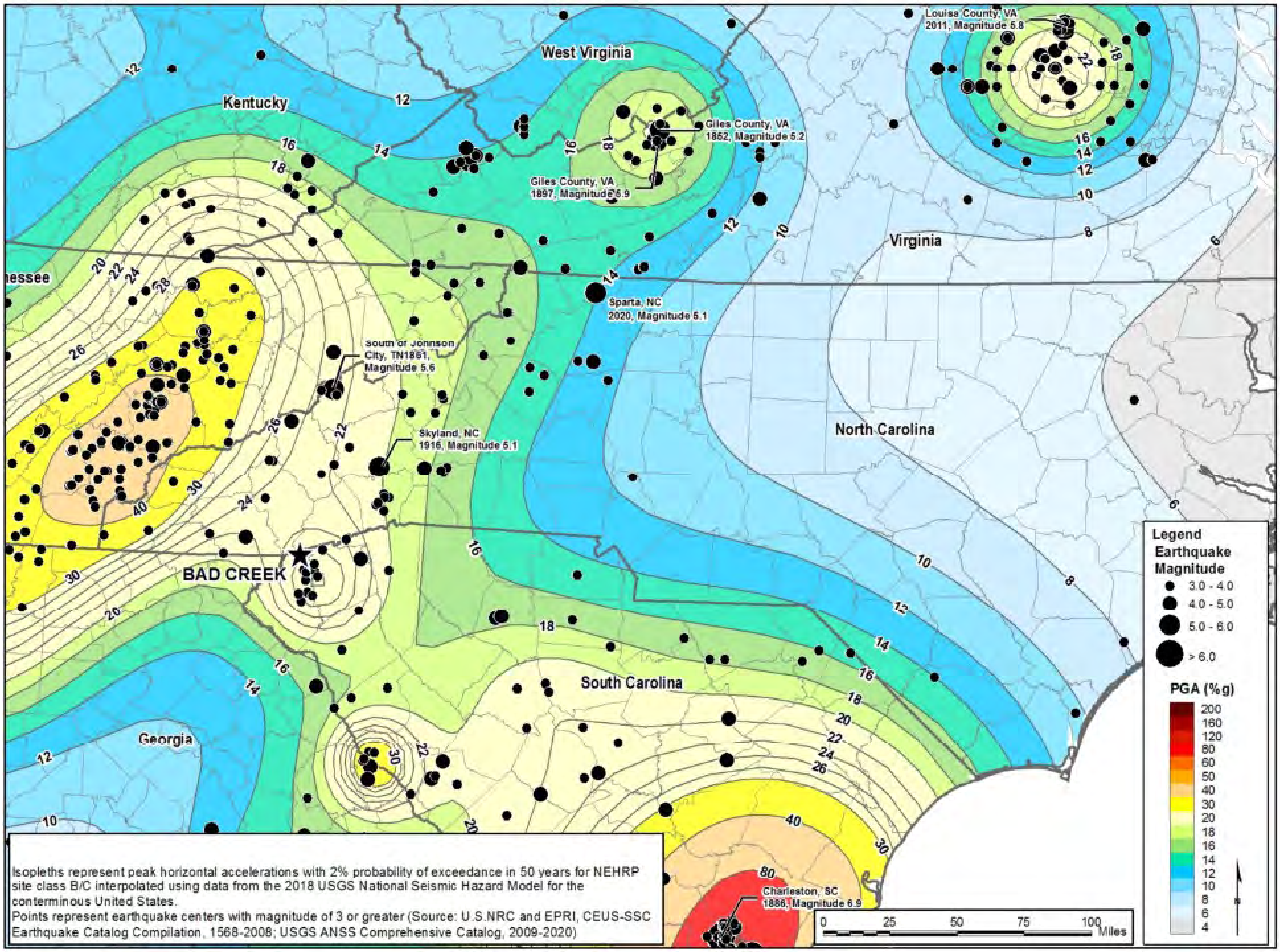
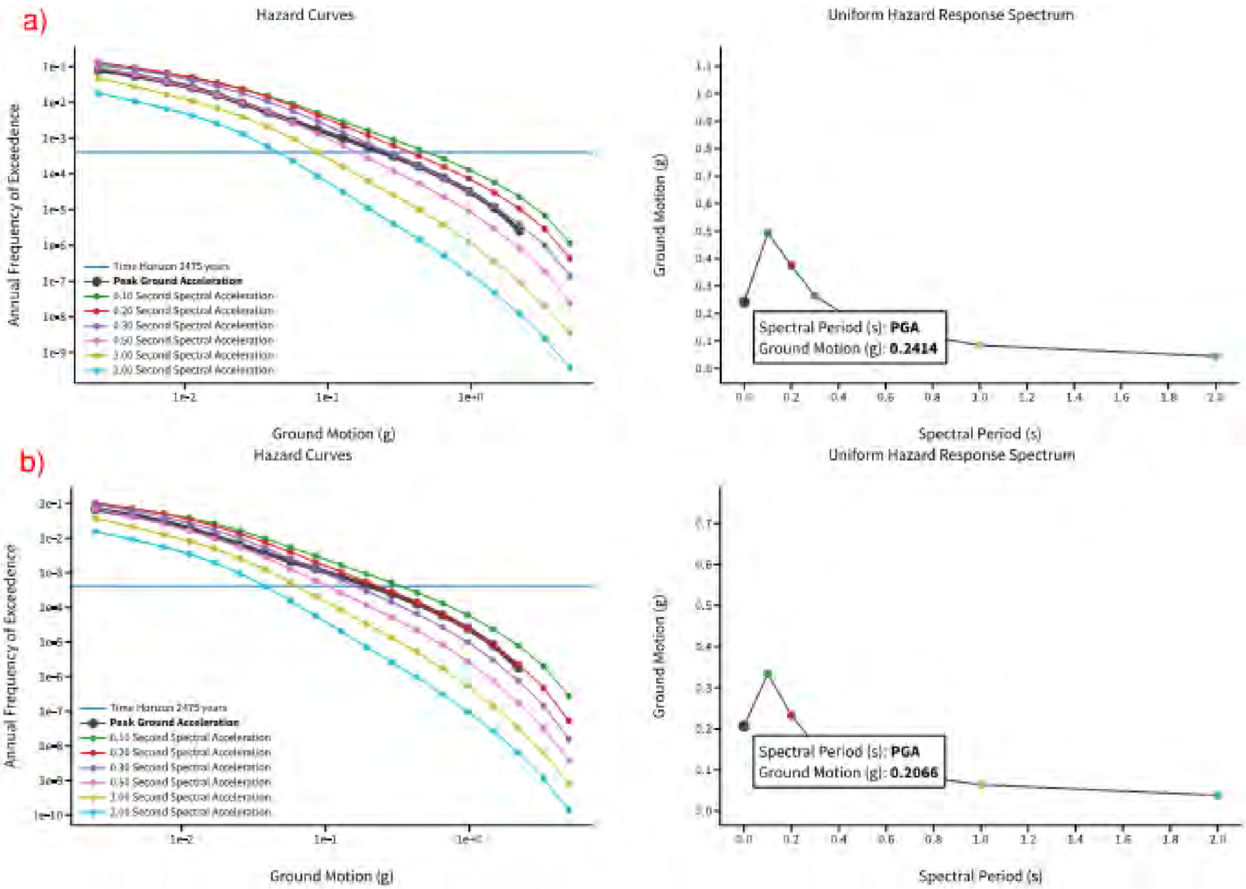


Figure 16. Seismic Hazard and Historic Earthquake Centers near the Bad Creek Pumped Storage Project



Note: This figure is not intended to be used for design or any type of analyses.
Source: USGS 2014a

Figure 17. Hazard Curve and Uniform Hazard Response Spectrum (2475-year return period; 5% Damping) for a) V_{s30} = 760 m/sec and b) V_{s30} = 2000 m/sec

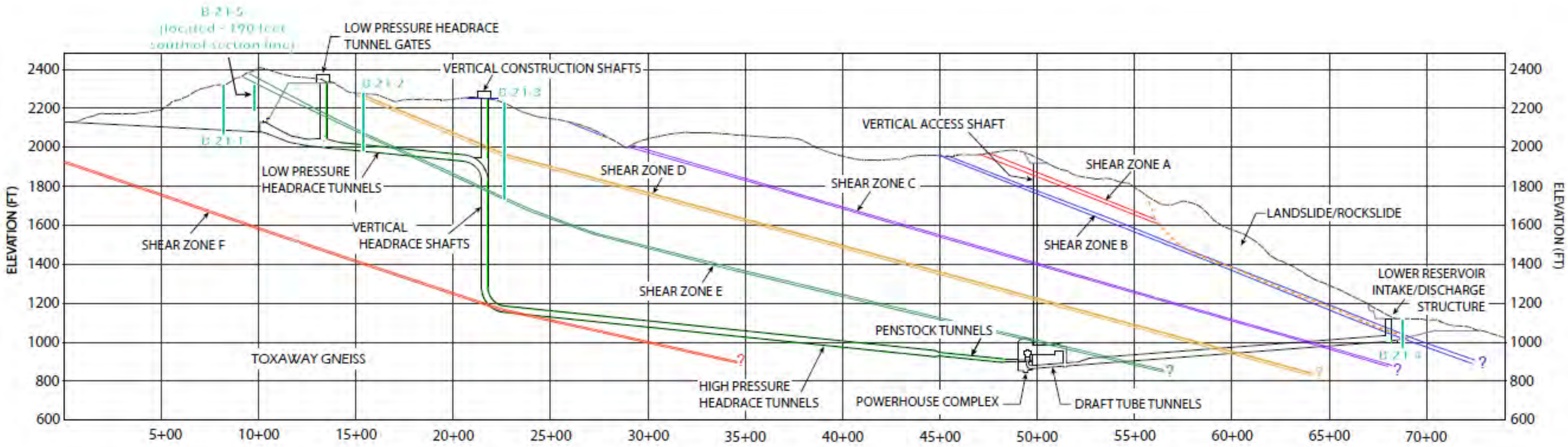
5 Evaluation of Geologic Characteristics

The geologic characteristics of the bedrock in which the underground structures are to be excavated and constructed for Bad Creek II are summarized in Table 3. This information is based on the geological and geotechnical studies performed for the design of and geologic mapping and studies performed during construction of the existing Bad Creek Project underground structure.

Table 3. Summary of Geologic Characteristics

Geologic Characteristic	Relation to Project Area
High seismic risk/active faulting within the project area	The project area is considered to have low to moderate seismic risk. No known Quaternary/active faults in the site vicinity (USGS 2014a, 2014b, 2018).
Active landslides in project area	There is an old landslide at the intake/discharge of the Bad Creek Project on Lake Jocassee (see Appendix B; Schaeffer 2016). The slide material was removed during construction of the existing plant and a retaining wall was installed on the slope that stabilized part of the original landslide above the retaining wall and below the present control room//switchyard complex. Figure 10 and Figure 18 show the extent of a landslide/rockslide at the proposed Bad Creek II I/O structure on Lake

Geologic Characteristic	Relation to Project Area
	Jocassee. The landslides/rockslides at the proposed Lower Reservoir I/O works will be an issue during excavation in this area to construct the works. The landslide may possibly be in the crown of the tailrace tunnels as it approaches the I/O works and may be present around the main access tunnel portal (Figure 10 and Figure 18; Appendix D, Photographs 1 and 2).
Deep weathering profile	Total soil thickness and the depth of overburden (soil/saprolite) and weathered bedrock at the Upper Reservoir I/O works, low pressure headrace gates area, and vertical headrace shafts area varies from 10 feet to greater than 90 feet. At the Lower Reservoir I/O on Lake Jocassee, the overburden is primarily landslide deposits that are up to 100+ feet thick based on the interpretation of the one borehole (B-21-4) in the area and the seismic refraction and MASW lines (Appendix D) The landslide deposits are not deeply weathered.
Highly permeable rock	Most of the water encountered in the Bad Creek Project underground excavations, past the initial ~200 feet of the main access and tailrace tunnels from their portals on Lake Jocassee, were associated with specific geologic features - the foliation parallel shear zones and some of the high-angle fault zones (Figure 10 and Figure 18; Schaeffer 1987, 2016 in Appendix B; Duke Power Company 1991).
Soluble rock material	Not present in the TGn.
Low strength, vibration-sensitive, friable, highly abrasive, slaking, or unlithified rock material	Weathered rock associated with shear zones and biotite schist and biotite-hornblende schist will have lower shear strengths than the unweathered TGn.
Highly faulted, folded, or fractured rock material	Most of the faults/fractures in the TGn have secondary mineralization and are not highly fractured/faulted. The shear zones mapped in the reservoir and in the existing Bad Creek Project underground structures have weathered sheared rock and later brittle faulting associated with them.
Thinly laminated, structurally deformed, fine-grained rock masses	Phyllonitic material present along some of the foliation-parallel shear zones in the underground excavations and thin, foliation parallel biotite-hornblende schist layers.
Rock Mass In-Situ Stress Field	High in-situ stresses that can result in rock burst and stress-related issues in the larger underground opening including the powerhouse, voltage bus/excitation galleries, draft tube gate and access gallery tunnel, draft tube gate annexes, and draft tube gate vertical shafts and at intersections of tunnels and shafts (Schaeffer 2016; see pages 66 to 70 in Appendix B).



NOTES:
1. THE FOLIATION DATA COLLECTED DURING THE BAD CREEK 1 UNDERGROUND MAPPING WAS COMPLILED AND ANALYZED FOR THIS PROJECTON. THE DATA WAS INSUFFICIENT ON THE SCALE OF THE CROSS-SECTION TO MAKE INFERENCES CONCERNING THE POSSIBLE FOLDING OF THE SHEAR ZONES. THE PROJECTION OF SHEAR ZONES MAPPED IN THE RESERVOIR AREA AND IN THE UNDER-GROUND EXCAVATIONS FOR BAD CREEK 1 WITH DECREASING DIP TO THE SOUTHEAST IS RELATED TO THE BROAD OPEN FOLDING NOTED IN THE POWER TUNNEL FROM ~STATIONS 3+50 TO 9+20 (DRAWINGS BK-1011-09-33 TO BK-1011-09-37).
2. BOREHOLE LOCATIONS SHOWN ON FIGURES 3-1 AND 4-3. GRAPHIC LOGS SHOWN ON FIGURES 3-2 TO 3-7

BAD CREEK II POWER COMPLEX
PROPOSED ALIGNMENT - PROJECTION OF SHEAR ZONES
FIGURE 5 - 1
FEASIBILITY REPORT

Figure 18. Bad Creek II Power Complex – Proposed Alignment – Projection of Shear Zones

6 Geology and Constructability

6.1 Intake/Discharge Structure – Upper Reservoir

The intake discharge channel will be excavated primarily in weathered rock/sound rock as most of the soil in that area was removed and used in the cores of the upper reservoir's dams and dike. The thickness of overburden (fill/soil/saprolite) and weathered rock overlying firm/sound rock is shown on the figures in Appendix D. Shear Zone E will be present in the upper part of the excavation, but should not be a major stability issue since it dips away from the excavation face. The Upper Reservoir I/O excavation will require sinking cuts to keep a portion of the weathered rock /sound rock as a temporary cofferdam to allow the existing Bad Creek Project to continue to operate during the Upper Reservoir I/O construction.

A kinematic analysis of the sinking rock cuts in the four walls was performed and is documented in Appendix C. The results indicated that a 0.5H/1V cut was the most stable configuration. Cuts in rock up to vertical are feasible based on the experience at the Bad Creek Project intake structure. The rock cuts, regardless of dip angle, will require some degree of stabilization including pattern rock bolts and possibly wire mesh.

The thickness of overburden (fill/soil/saprolite) and weathered rock overlying firm/sound rock underlying along the low-pressure headrace tunnels, the low-pressure gate shafts, and the vertical headrace shaft areas are shown on the figures in Appendix D.

6.2 Intake/Discharge Structure – Lower Reservoir

The Lower Reservoir I/O works on Lake Jocassee will be constructed through landslide deposits that overlie TGn (Figure 1 and Figure 18). The base of the landslide is consistent with the projected location of Shear Zone B (Figure 18; Appendix D). It is approximately 91 feet thick at the location of B-21-4 (Figure 1 and Figure 10) and may be over 100 feet thick in places based on the seismic refraction and MASW lines (see figures in Appendix D). The cuts to the north, west, and east for construction of the works will require support (such as a tie- back wall or series of tie-back walls) through the landslide deposits and rock bolts or other types of support in bedrock. The best interpretation of the data to date suggests that the crown of tailrace tunnels at the I/O works may be landslide deposits. Additional exploration is needed in the area to better understand the geologic conditions. The ground conditions at the proposed location of the main access tunnel portal for Bad Creek II are not yet known, but will be near the southern boundary of the landslide.

6.3 Tunnels, Vertical Shafts, Powerhouse Cavern.

The major factors affecting the design of the underground structures are the structural geology of the site and the orientation and magnitude of the in-situ stresses. The underground structures of the existing Bad Creek Project and likely the new Bad Creek II powerhouse are in the TGn. The rock is of good to excellent quality. The foliation is consistent with an average orientation of N35-44E; 30SE in the existing underground works and may or may not be the same in the underground works for Bad Creek II. The dominant joint set is oriented N70E to N70W (east-west) with dips >50º north and south. Other sets are oriented N60E; 60NW, N65E; 30SE (foliation joints), and N45W; 70-90SW or NE. The joints are tight at depth. Near the surface some joints are open, and weathering resulted in blocky conditions that will require support and/or ground reinforcement measures and minor water in-flow at the tunnel portals. Shear zones are present with orientations parallel to foliation and faults with minor offsets are present and related to the northeast-striking joint set. Most of the shear zones and some of the faults made small amounts of water and were the only sources of water encountered during the excavation of the existing underground excavations. Zones of closely spaced joints, faults, and the shear zones may cause local zones of instability in the underground works.

The rock that will be encountered in the underground for Bad Creek II should be similar to that in the original underground tunnels where the tunnels and vertical shafts generally stood unsupported after excavation. The high in situ stresses caused some spalling to occur, primarily in the tunnel and powerhouse crowns, but also in the northwest and southeast corners of the powerhouse excavation. The spalling was continuously observed during the pilot tunnel work and was noted in the Pilot Tunnel Geologic Report (Duke Power Company 1978) and in the bid documents. The spalling rock occurred as thin slabs of rock and was most prominent in the more massive gneiss bodies in the underground works. Near the ground surface where stresses had been relieved over time, spalling did not occur. Only after a depth had been reached where the stresses had not been relieved did spalling occur. Other than the blocky rock near the main access portal, no support of the main access tunnel was needed (outside of spot rock bolts in the ribs) until the tunnel had advanced approximately 770 feet, where the overburden was about 500 feet, and spalling occurred. At this point, the spalling was controlled by using 10-foot-long, resin-anchored rock bolts (#9 bars) on a 5-foot by 5-foot spacing in the tunnel crown and a 1-inch-thick layer of fiber reinforced shotcrete. The need for rock bolts and shotcrete varied somewhat, depending on the rock type, but pattern rock bolts and shotcrete were used routinely in the tunnel crowns for safety purposes in all the tunnels after the first 770 feet in the main access tunnel. Similar conditions are likely for the Bad Creek II underground works. Similar support measures in the tunnels and vertical shafts will likely be required for Bad Creek II.

The Bad Creek 1 powerhouse cavern was oriented long-axis north-south based on the geologic conditions documented during the Pilot Tunnel studies in 1976-1977 (Duke Power Company 1978; Schaeffer and Steffens 1979; Schaeffer 2016) and the results of hydrofracturing stress measurements in borehole B-52 and overcoring stress measurements in the Pilot Tunnel (Duke Power Company 1978; Schaeffer et al. 1979). The magnitude and direction of the in-situ stresses determined by the overcoring technique are: σ_1, maximum principal stress, 29.3 MPa (4253 psi) @ N57E, σ_2, intermediate principal stress, 18.4 MPa (2675 psi) @ N32W, and σ_3, least principal stress, 10.2 MPa (1476 psi) subvertical. All stresses are compressive. The subvertical stress is approximately two times that expected from overburden, indicating the Toxaway Gneiss at this location is overstressed. The in-situ stresses are high enough that they caused shallow spalling of excavated surfaces. Most of the spalling during the pilot tunnel studies occurred in the enlarged powerhouse test chamber where the shape of the crown arch was such that large tangential stresses were produced. The optimum orientation of the long-axis of the powerhouse cavern with respect to the in-situ stresses would be N57E-S57W; that is, the short wall would be perpendicular to the direction of the maximum stress and the long wall of the cavern would be perpendicular to the direction of the intermediate stress. The main set of discontinuities in the powerhouse area are joints of Set #1 (N75E; 86NW – closer to east-west strike in the powerhouse). These combined with the foliation could produce large wedges in the crown. A north-south orientation of the powerhouse minimizes the potential size of the wedges. The north-south orientation was selected as the most stable with respect to both the discontinuities and the in-situ stresses. A north-south orientation for the Bad Creek II powerhouse is also recommended.

For the Bad Creek Project powerhouse, with high horizontal stresses, a flat crown in the powerhouse cavern would be advantageous, but a crown 20 feet high above the springline was deemed necessary to provide frictional support for potential rock blocks delineated by the east-west joint set and the foliation. An analysis of potential rock blocks in the cavern walls and crown was performed using stereographic methods including rock bolt forces. Pattern rock bolts were specified in the walls and crown of the powerhouse based on the analysis and successful experience in similar powerhouses. In the crown and wall of the powerhouse above the structural concrete, 20-foot-long, #9 Grade 60 rock bolts on a 5-foot by 5-foot pattern were specified. In the areas of the structural concrete a 6-foot by 6-foot pattern was specified. The pattern in the end walls varied somewhat and was modified based on rock conditions. All the rock bolts were of the fully polyester resin encapsulated type. The bolts were designed as dowels (no pre-stressing), but to ensure they were "snugged up" in order to mobilize their strength in case of rock movement, a two-part resin system was used with nominal 350 foot-pounds of torque applied to provide nominal pretension. In addition to the pattern rock bolts, the powerhouse crown received two 2-inch layers of shotcrete with welded wire fabric installed between the layers. The pattern rock bolts have extensions through the shotcrete allowing the false ceiling to be coupled to them for support. Additional rock bolts were installed in rock wedges in the crown and portions of the Powerhouse crown had 12.5-foot by 25-foot wire rope panels overlying #11 galvanized chain link and finer fabric-mesh installed for further crown support.

Similar designed support will be required for the proposed Bad Creek II powerhouse. Potential issues for the Bad Creek II powerhouse include stress relief in the crown resulting in cracking and spalling shotcrete and are like those encountered in the Bad Creek Project powerhouse crown, which required changes in the excavation sequence and size of bench blasts and the wire rope support installed (see Appendix B; Schaeffer 2016, pages 66 to 70 for full description).

The major shear zones mapped in the upper reservoir and in the underground excavations for the existing Bad Creek Project are shown on Figure 10. Shear Zones B, D, and E were identified in Boreholes B-21-3 and B-21-2. A small shear zone was identified in B-21-4 and is presently interpreted as one of the smaller shears of limited thickness encountered both in the reservoir area and in the Bad Creek Project underground. The major mapped shear zones in the reservoir area and underground structures and constrained by the location of the shear zones in the boreholes were projected into the area of the proposed Bad Creek II structures. Their relationship to the underground structures for Bad Creek II are shown in Figure 18. Based on the projection, Shear Zones A, B, C, and D may be encountered in the Vertical Access shaft to the Powerhouse Complex and Shear Zones C and D may be present in the Tailrace Tunnels. Shear Zone E projects into the upper portions of the powerhouse crown and the voltage bus/excitation gallery and draft tube gate and access gallery tunnel (Figure 18). It should be noted that Shear Zone E died out to the southwest in the Bad Creek reservoir area and was not mapped in the foundation of the main dam. Shear Zone F projects into the ~ 90° elbow where the vertical headrace shafts enter the high-pressure headrace tunnels, there is the possibility that not all the shear zones projected into the area of the proposed Bad Creek II excavations and structures are present. Mapping in the power tunnel of the Bad Creek Project showed that broad open folds are present in the bedrock (TGn) and possibly folded the shear zones. In this case, the correlation of shear zones between the upper reservoir area and the underground excavations as presented on Figure 18 may not be entirely correct.

6.4 Construction Materials

Rock at the Bad Creek II site is generally not suitable for use in concrete aggregate due to its foliated/banded nature and was not used during the construction of Bad Creek 1. Sources of suitable sand and aggregate will be assessed during the next phase of work.

6.5 Summary

There are no geological fatal flaws associated with the construction and operation of a Bad Creek II powerhouse. After 30+ years, the underground excavations at the existing Bad Creek Project have stabilized and the support installed in them during construction has and is serving its function well.

7 Recommendations

The following are recommendations for the next phase of field geological/geotechnical investigations.

- Additional borings and seismic refraction/MASW lines in the area of the Upper Reservoir I/O works to better define the excavation required for its construction and for the design of a dewatering system and/or grout curtain to reduce inflow from the existing reservoir into the sinking cut required for construction.
- A deep boring in the vicinity of the proposed powerhouse to verify geologic assumptions including the projection of the shear zones into the proposed water conveyance alignment.
- Additional borings and seismic refraction/MASW lines in the area of the Lower Reservoir I/O works to better define the limits (both horizontally and vertically) of the landslide deposits in the area of the excavation required for its construction including the location and extent (length across and depth) of required support (tie-back) for the upslope landslide deposits, whether the landslide deposits may be present in the crown of the tailrace tunnels at the I/O works, and to assess the conditions at the location of the proposed main access tunnel portal.
- Borings with inclinometers should be install above the location of the retaining wall planned for the Lower Reservoir I/O works excavations to provide a baseline or potential movement before and after excavation/construction and during plant operations.

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Appendix A

Stereonet Data

Not included - Available upon request

Appendix B

Engineering Geology of the Bad Creek Pumped Storage Project, Northwestern South Carolina (Schaeffer 2016)

Not included - Available upon request

Appendix C

Kinematic Analysis of Proposed Sinking Cuts at the Upper Reservoir Inlet/Outlet Works and Associated Channel (Schaeffer 2021)

Not included - Available upon request

Appendix D

Evaluation of Boreholes and Seismic Line Data Collected at the Upper and Lower Reservoir Inlet/Outlet Works (Schaeffer 2021)

Technical Memorandum

Date:	Thursday, September 17, 2020
Project:	Bad Creek Powerhouse 2 Feasibility Study
To:	FILE
cc	Ed Luttrell, P.E., HDR; Ron Grady, P.E., HDR
From:	Malcolm Schaeffer. P.G.
Subject:	Evaluation of Boreholes and Seismic Line Data Collected at the Upper and Lower Reservoir Inlet/Outlet Works

Introduction

As part of the Bad Creek II Power Complex Feasibility Study, three boreholes and approximately 6,000 linear feet of seismic refraction and Multi-Channel Analysis of Surface Waves (MASW) were assessed by GEL Solutions (GEL 2021a, 2021b). The locations of the lines are shown on **Figure 1** for the upper reservoir area (3,500 linear feet; Bad Creek Reservoir) and **Figure 2** for the lower reservoir area (2,500 linear feet; Lake Jocassee). The seismic lines from the draft GEL Solutions report (2021a) were utilized for the interpretations.

The preliminary excavation drawings for the upper reservoir and lower reservoir on which the interpretations were placed were dated 05/20/20021 and 07/12/2021, respectively, and do not represent the final excavation configuration.

Interpretation of this data was used in conjunction with the data/information discussed in the following section to inform the excavation/grading plans for the upper and lower reservoir inlet/outlet works.

This memorandum documents HDR's interpretations of the subsurface conditions with the present data.

Analysis

HDR's analysis of seismic lines relied primarily on the refraction lines (Vp – Compressional Wave Velocity); borehole data (B-21-1, B-21-2, B-21-3, and B-21-4; Figures 1 and 2); previous geologic investigations, including foundation mapping of the dams, dike, and intake structure and upper reservoir; geologic mapping of the landslide and discharge structure at the location of the existing lower reservoir inlet/outlet works; and an understanding of the weathering patterns of the underlying granitic gneisses that underlie most of the Bad Creek site (Schaeffer 2016). The MASW lines provided verification of visual observations of the landslide/rockslide located at the proposed lower reservoir inlet/outlet works (**Figures 2** and **3** and **Photographs 1** and **2**).

Top of Partially Weathered Rock (TPWR) and Top of Firm Rock (TFR) were defined as a V_p (Compressional Wave Velocity) of 5,500 – 6,500 ft/sec and 8,500 – 9,500 ft/sec, respectively. In the boreholes, TPWR was defined as the final refusal of either augers or tri-cone rotary bits. TFR was defined as Rock Recovery (REC) greater than 95% and Rock Quality Designation (RQD) greater than 50%

Results

The analysis seismic lines with boreholes and excavation cross-sections for the upper reservoir and lower reservoir inlet/outlet works are provided in Attachments A and B, respectively. Note that both the inlet/outlet works and tunnel and gate details shown are not the final configurations.

The results of HDR's analysis are summarized below:

1) Upper reservoir inlet/outlet works

   a. Depths to TPWR and TFR were determined with the available data at the location of the sinking cut for the inlet/outlet works, the gate shaft, and the vertical access shaft to the vertical shaft. These depths were incorporated in the most recent excavation plan (08/06/2021).

   b. The soil/saprolite/weathered rock on the west side of the proposed sinking cut will be relatively thin when laid back at 1.5H:1V. A retaining wall was added to the most recent excavation plan (08/06/2021) to account for this characteristic. A grout curtain is also planned for this area.

2) Lower reservoir inlet/outlet works

   a. The landslide/rockslide will assert a major influence on the excavation methods and support for the excavation and construction of the inlet-outlet works. (Note the most recent excavation plan and sections are dated 07/20/2021.)

   b. The landslide extents near the works are shown in **Figure 3** and on the excavation plan in Attachment B.

   c. A retaining wall west of the inlet/outlet works will be needed to retain the slide material before excavation and for permanent stabilization.

   d. HDR's interpretation of the vertical extent of the landslide/rockslide at the works places the base of the slide at the TFR in the crown of the northernmost tailrace tunnel and just above the crown in the southernmost tailrace tunnel at the inlet/outlet (see Excavation Sections 1a-1a, 2-2a, and 3-3a in Attachment B). Options for supporting the tailrace tunnel crowns as they advance toward the inlet/outlet works need to be considered and included in the cost opinion.

   e. The portal face for the main access tunnel is within slide material based on HDR's interpretation of the data to date (see Excavation Section 7-7 in Attachment 2). Options for advancing the tunnel through the slide material until competent rock is encountered should be included in the cost opinion.

Recommendations

- Additional boreholes are needed in the locations of the upper reservoir inlet/outlet works, gate shafts, and vertical shafts to further define the TPWR, TFR, and condition of the rock in the gate shafts and the vertical access shafts.

- Additional boreholes (and possibly seismic lines) are needed at the lower reservoir inlet/outlet works to determine the lateral and vertical extent of the slide deposits at the location of the structure, at the location of the tie-back wall west of the works, and the portal area of the main access tunnel as presently configured.

- The cost opinion needs to take into account the uncertainties associated with the extent of the slide materials in the lower reservoir works. A larger than normal contingency is justified due to the unknowns at this stage of study.

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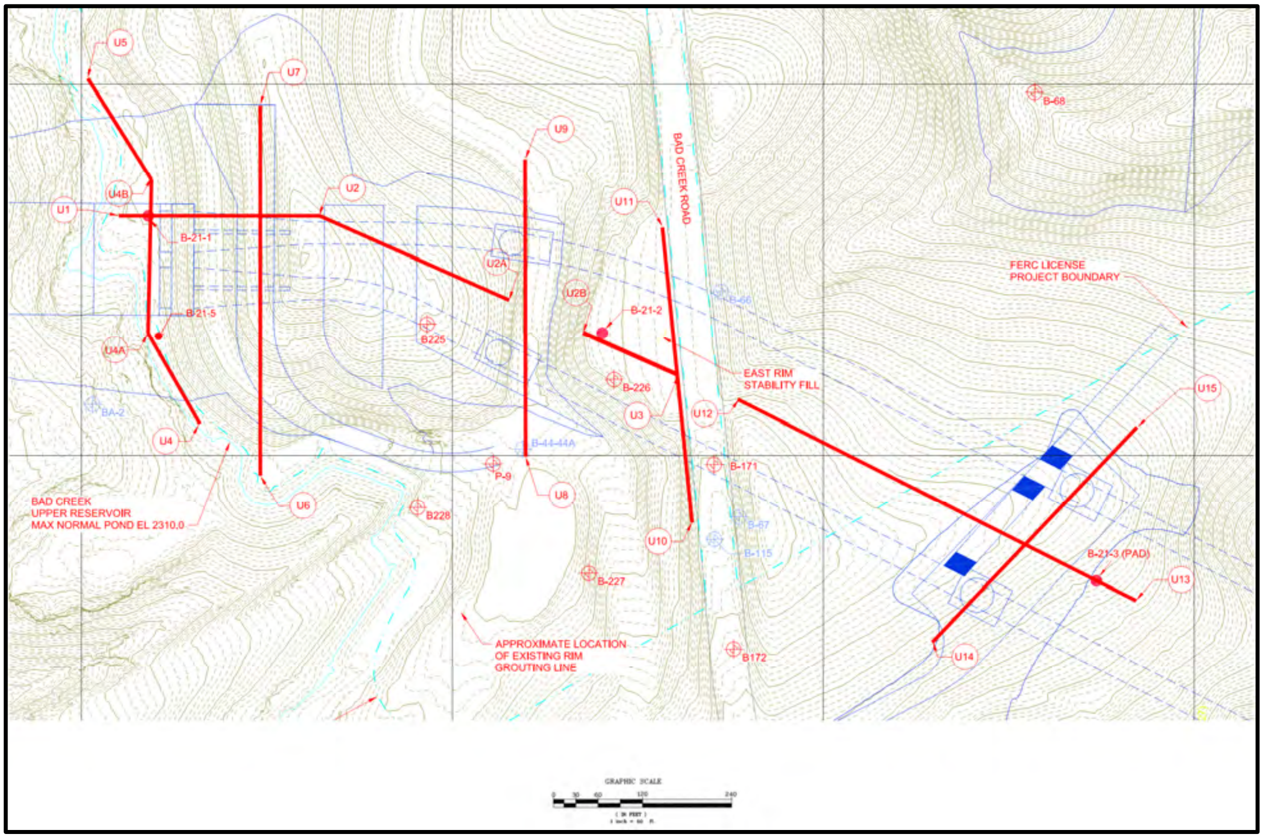


Figure 1: Profile lines at upper reservoir inlet/outlet works, gate shafts, and vertical shafts.

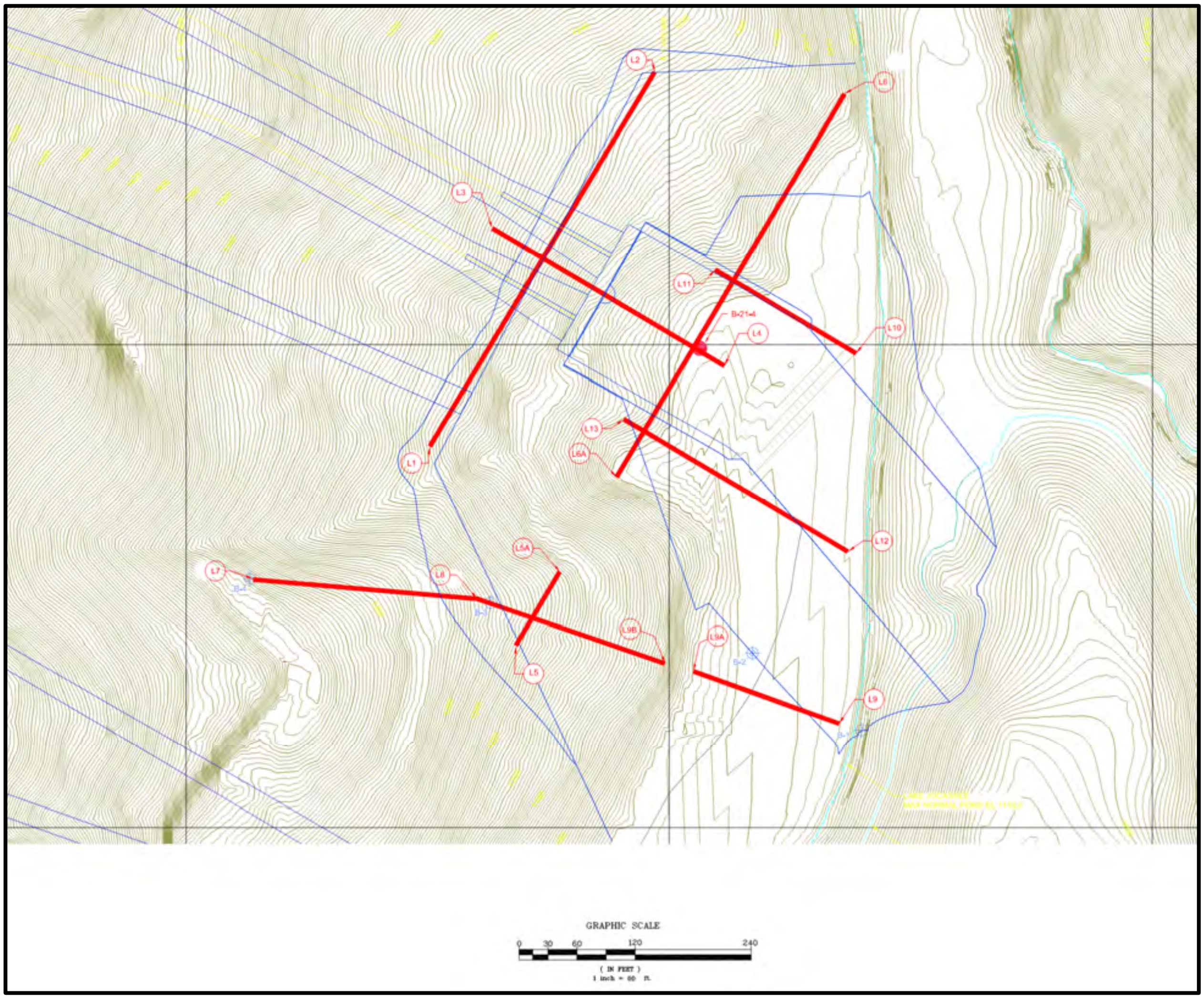


Figure 2: Profile lines at lower reservoir inlet/outlet works and main access tunnel.

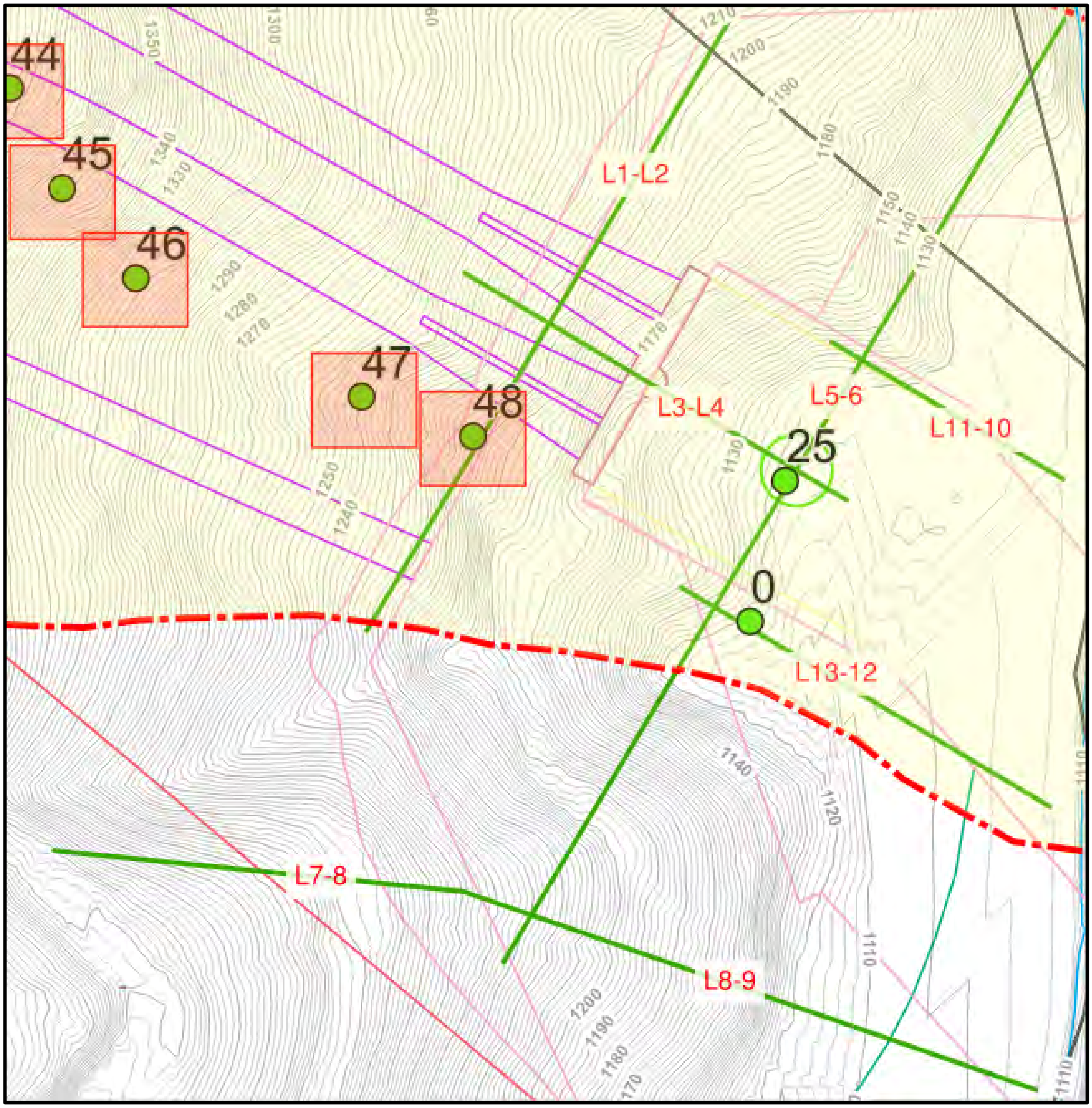


Figure 3: Landslide (yellow shading) at the lower reservoir inlet/outlet works and main access tunnel portal. Red dashed line – approximate contact of landslide with residual material, green-filled circles – mapping point, red-shaded boxes around circles – mapped landslide deposits or features. See figure 2 for actual extent of geophysical lines, primarily Line I5-6.

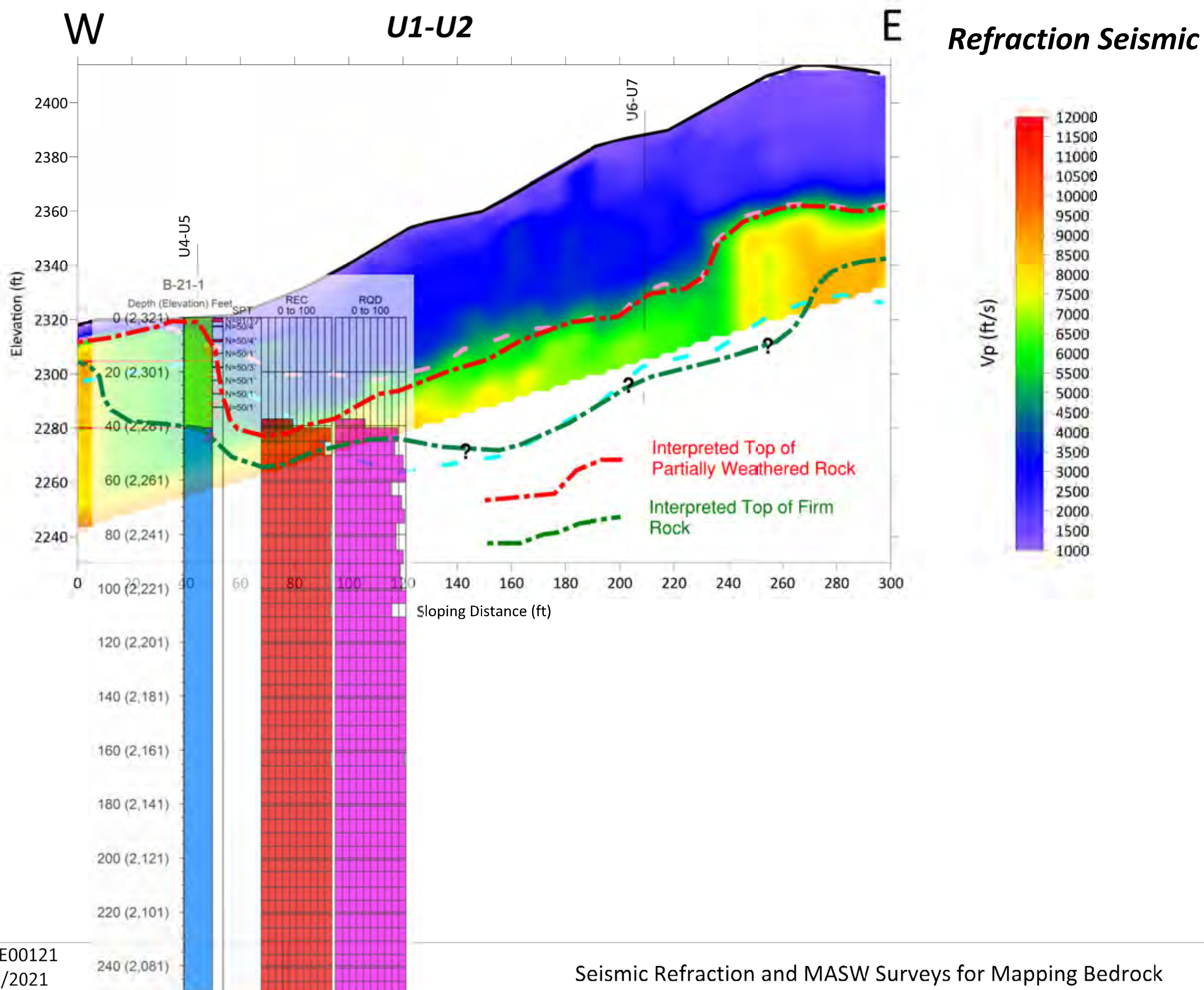
Photograph 1: Standing above the south scarp of the landslide/rockslide at the lower reservoir inlet/outlet works. Note the rock blocks within the slide proper.

Photograph 2: Within the landslide/rockslide above the lower reservoir inlet/outlet works. Note the rock blocks and various orientations of the blocks.

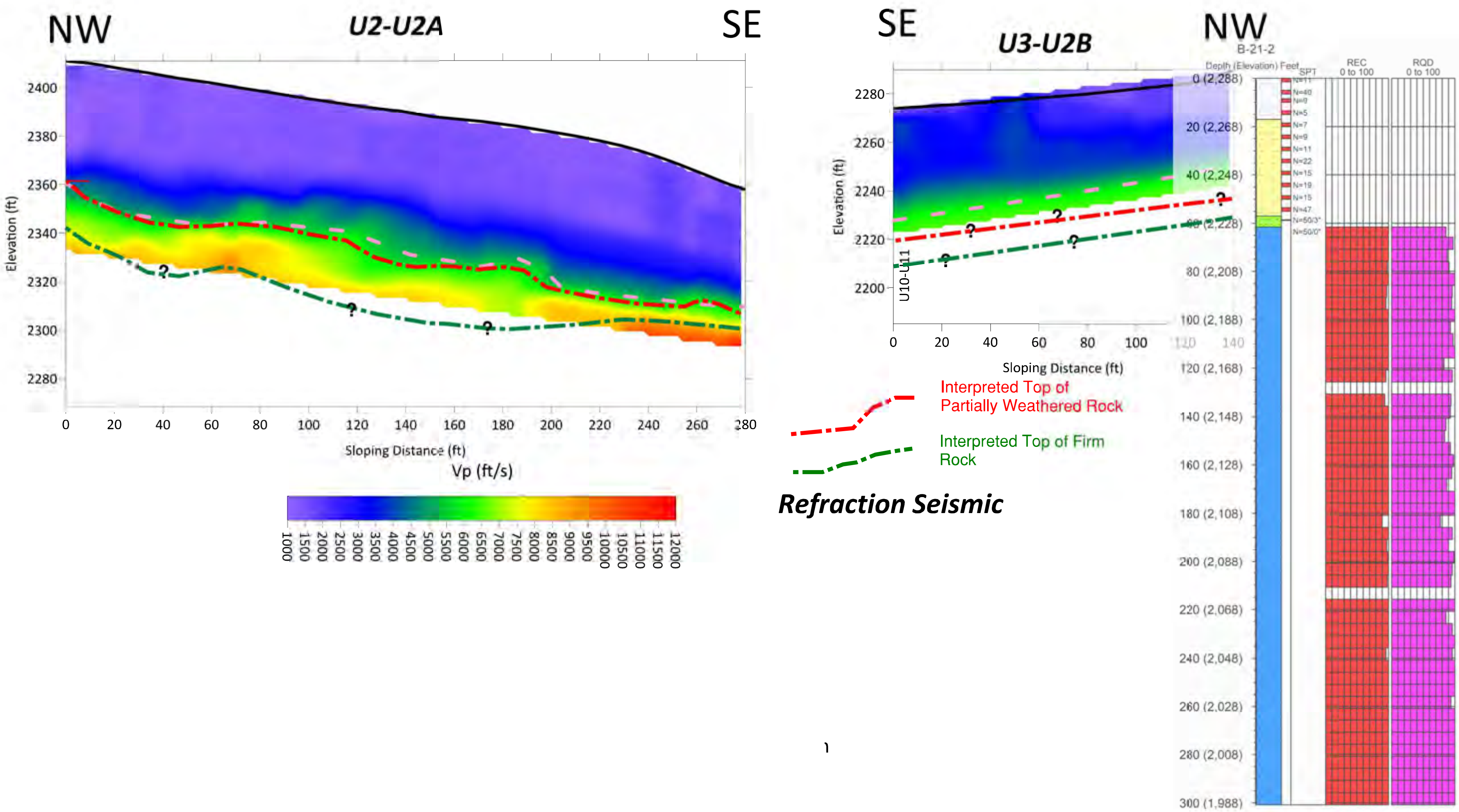
ATTACHMENT A

Upper Reservoir Inlet/Outlet Works

1) **Seismic Lines and Borehole Interpretations**
2) **Seismic Lines and Borehole Interpretations Superimposed on Preliminary Intake Structure, Tunnels, Gate Shafts, and Vertical Power Shafts**

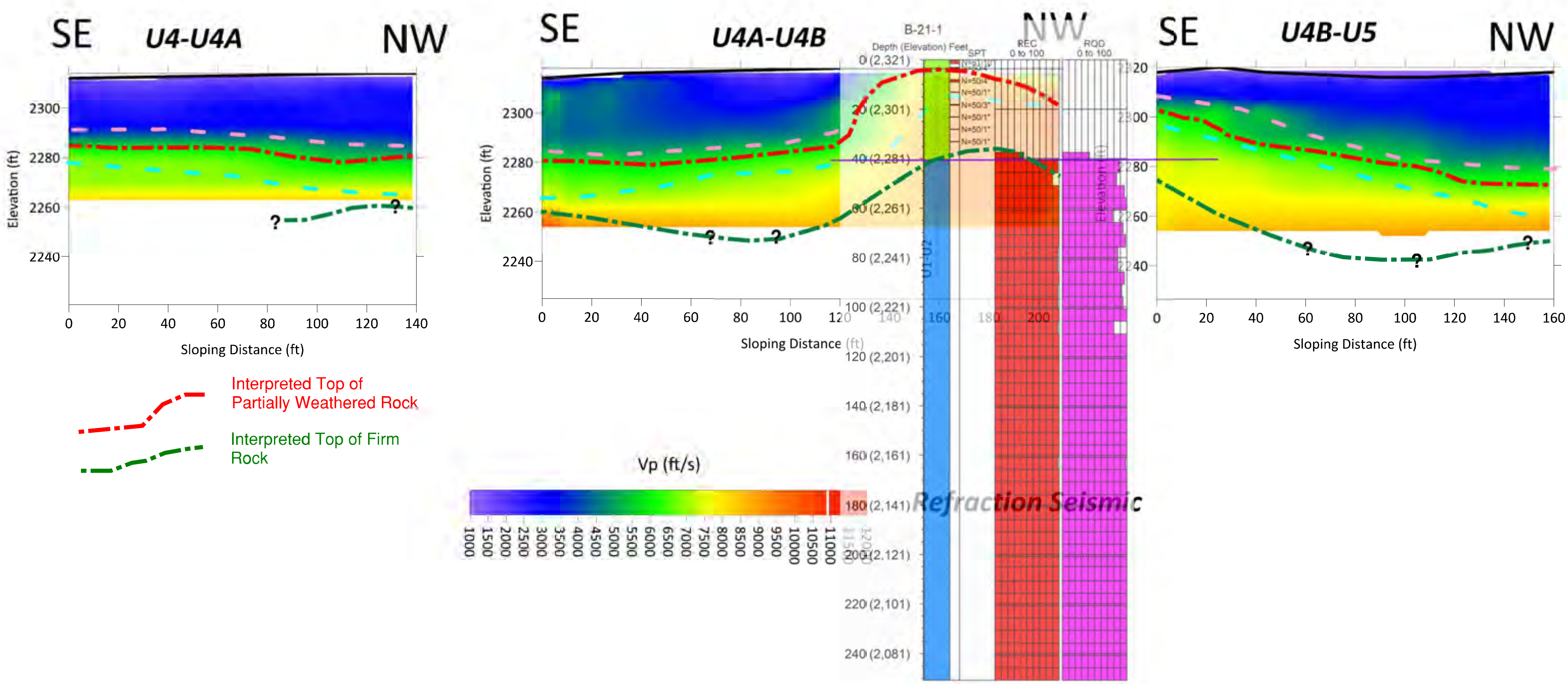


Seismic Refraction and MASW Surveys for Mapping Bedrock
Bad Creek II Pumped Storage Project, Salem, South Carolina



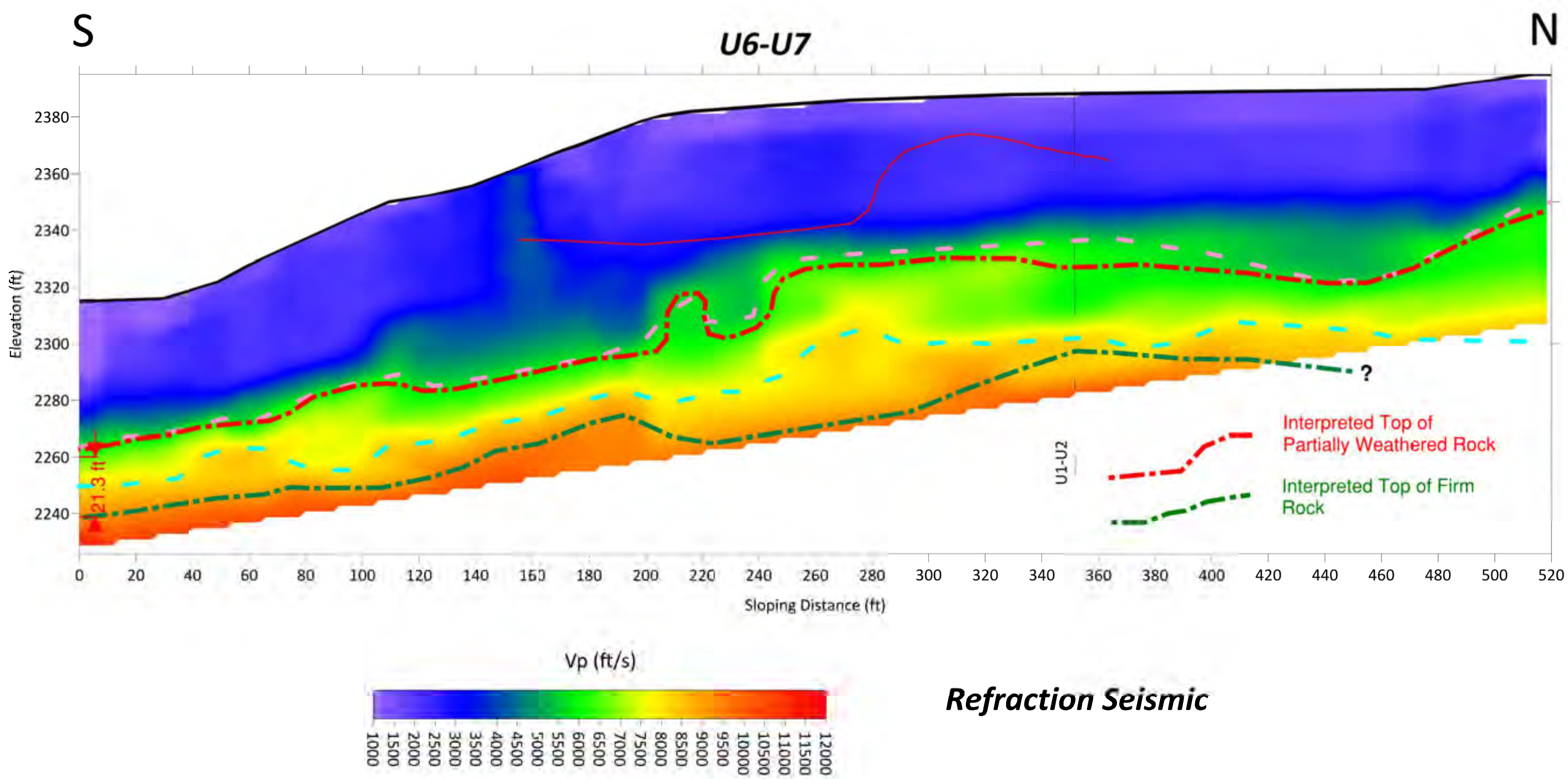
HDRE00121
3/22/2021

Seismic Refraction and MASW Surveys for Mapping Bedrock
Bad Creek II Pumped Storage Project, Salem, South Carolina

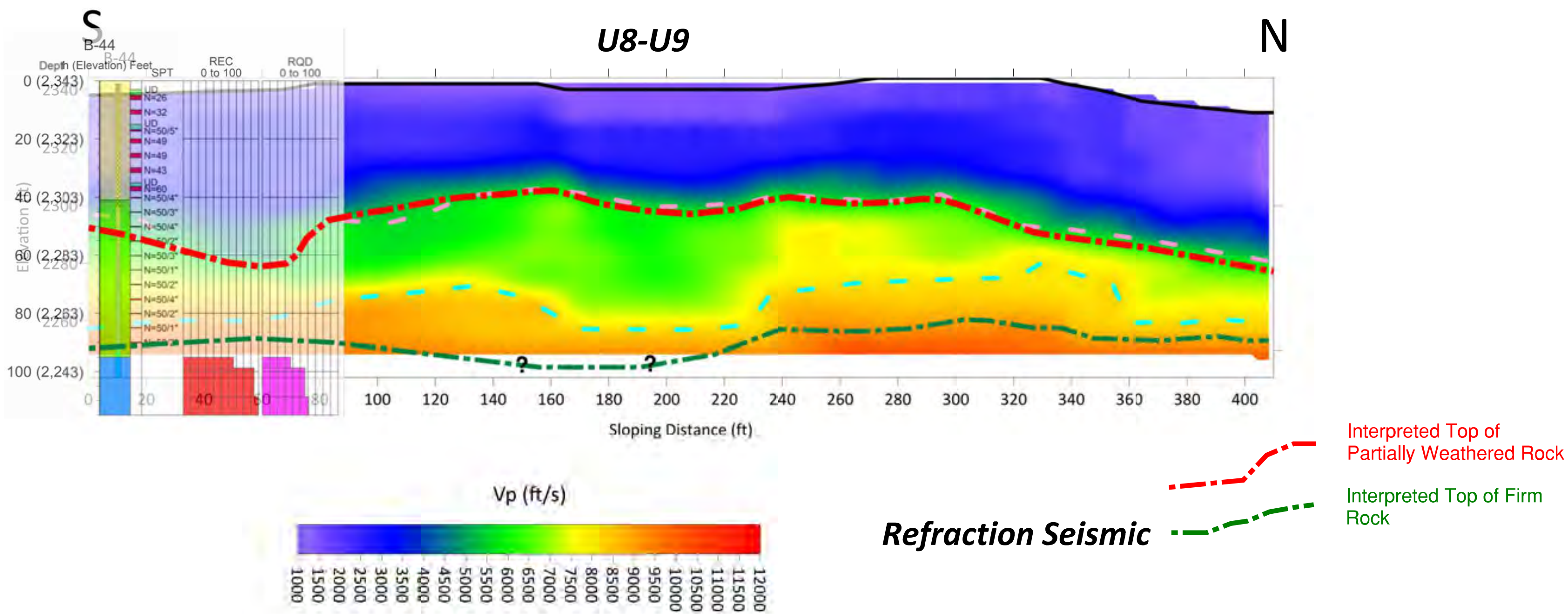


HDRE00121
3/22/2021

Seismic Refraction and MASW Surveys for Mapping Bedrock
Bad Creek II Pumped Storage Project, Salem, South Carolina

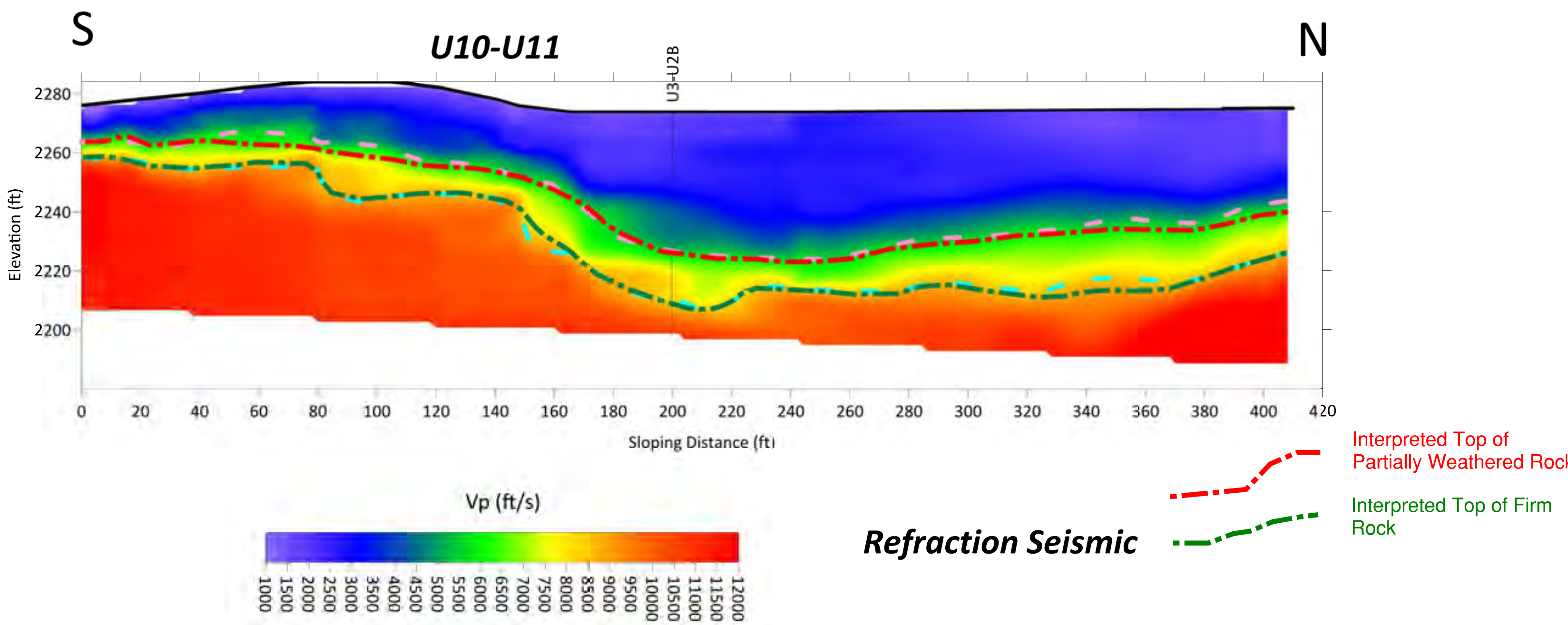


HDRE00121 3/22/2021	Seismic Refraction and MASW Surveys for Mapping Bedrock Bad Creek II Pumped Storage Project, Salem, South Carolina	



HDRE00121
3/22/2021

Seismic Refraction and MASW Surveys for Mapping Bedrock
Bad Creek II Pumped Storage Project, Salem, South Carolina



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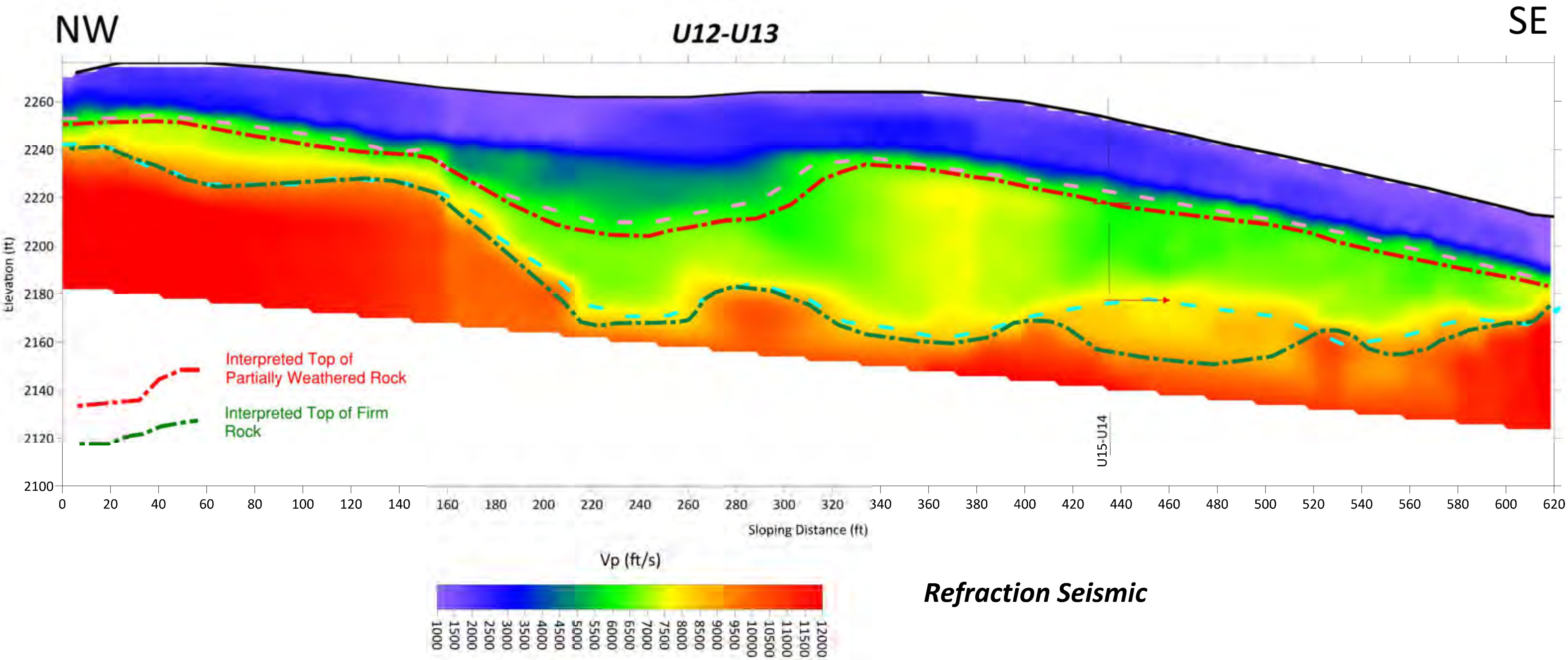

Refraction Seismic

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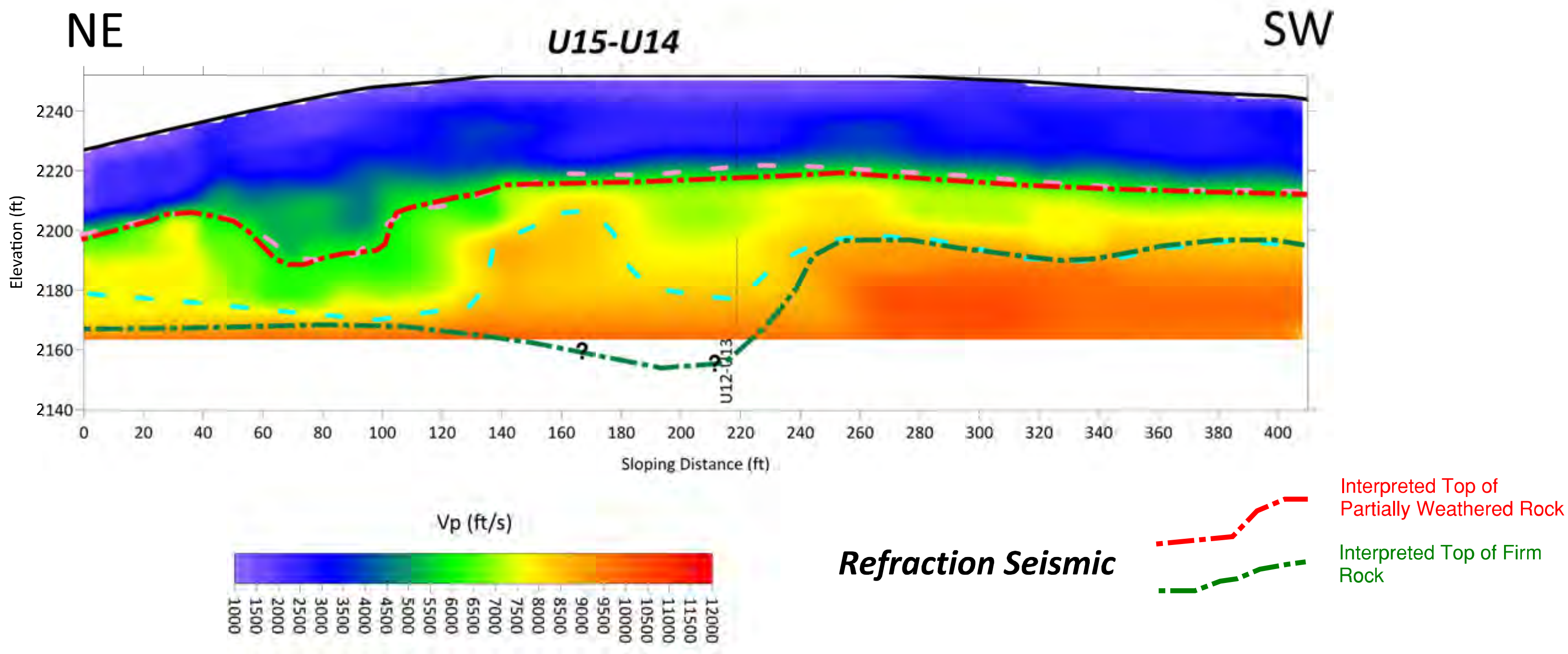

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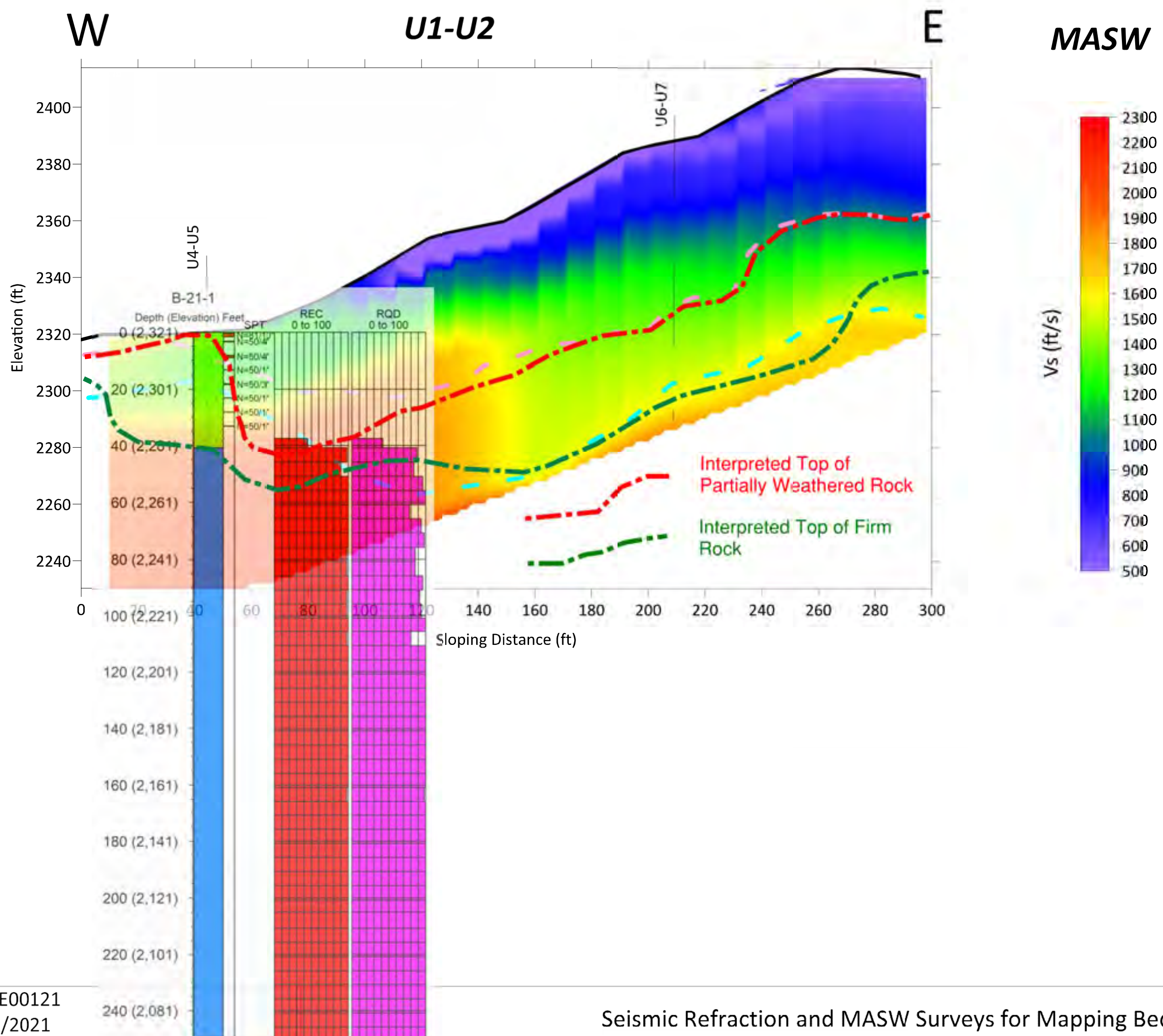

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3/22/2021

Seismic Refraction and MASW Surveys for Mapping Bedrock
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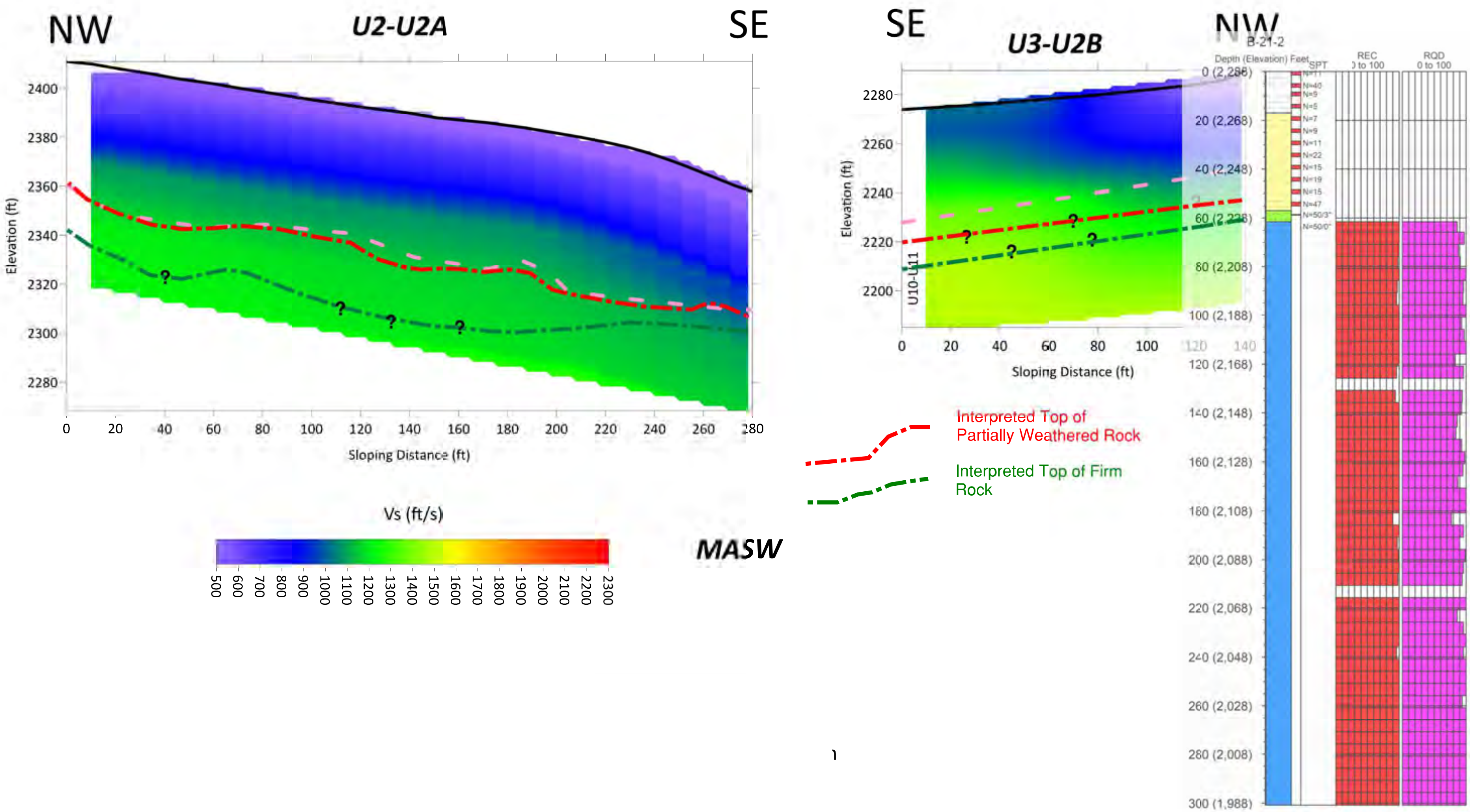

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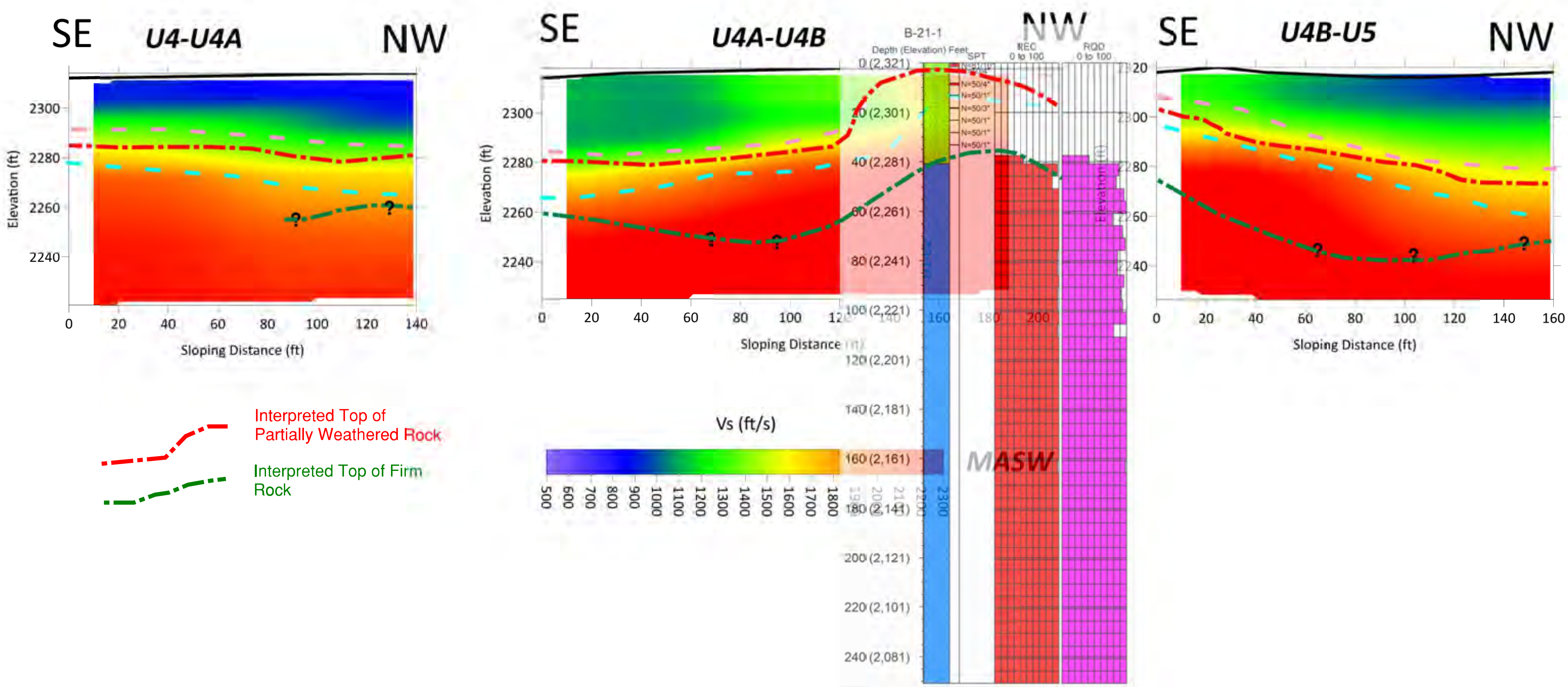

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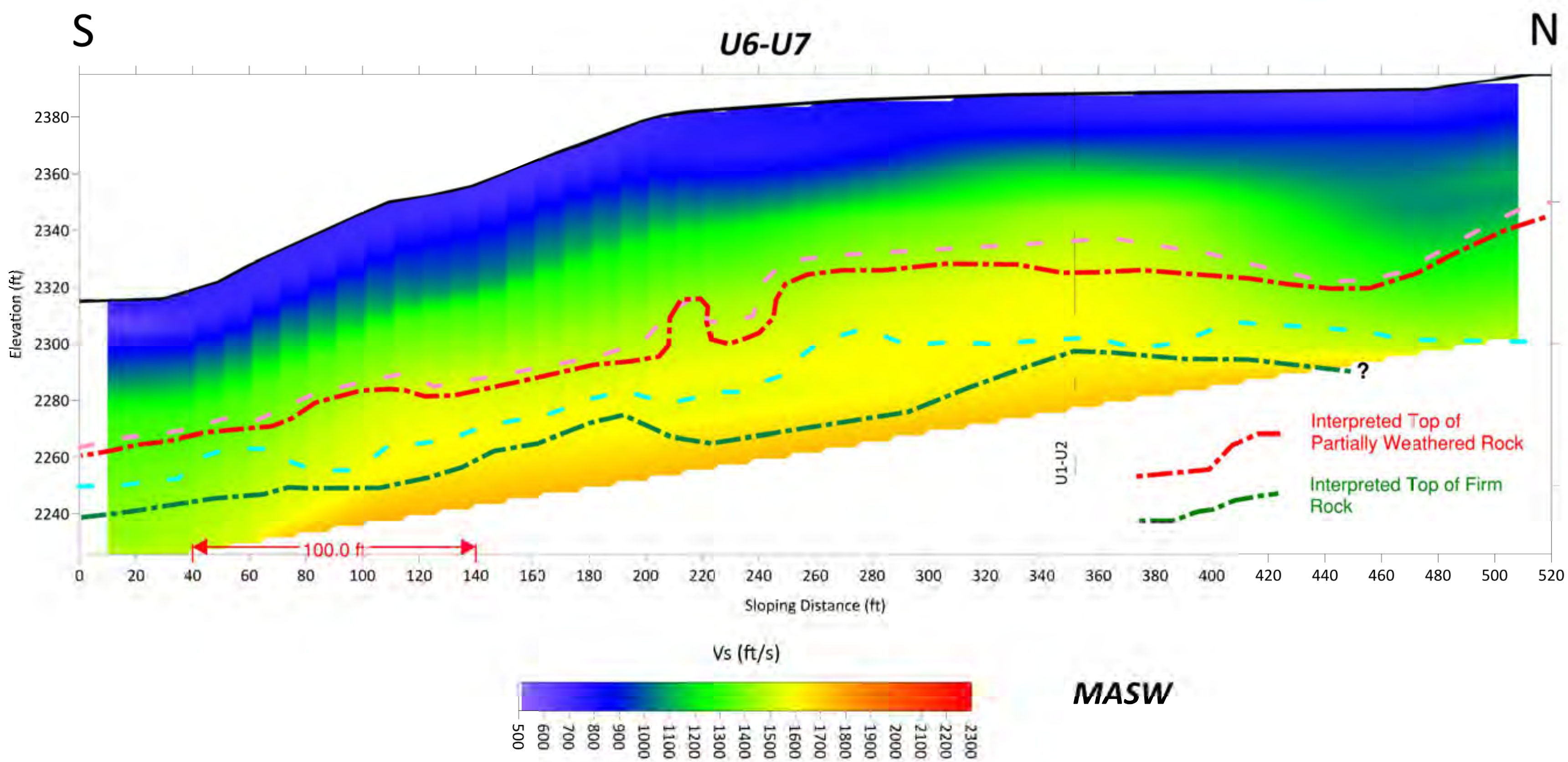
3/22/2021

Seismic Refraction and MASW Surveys for Mapping Bedrock
Bad Creek II Pumped Storage Project, Salem, South Carolina



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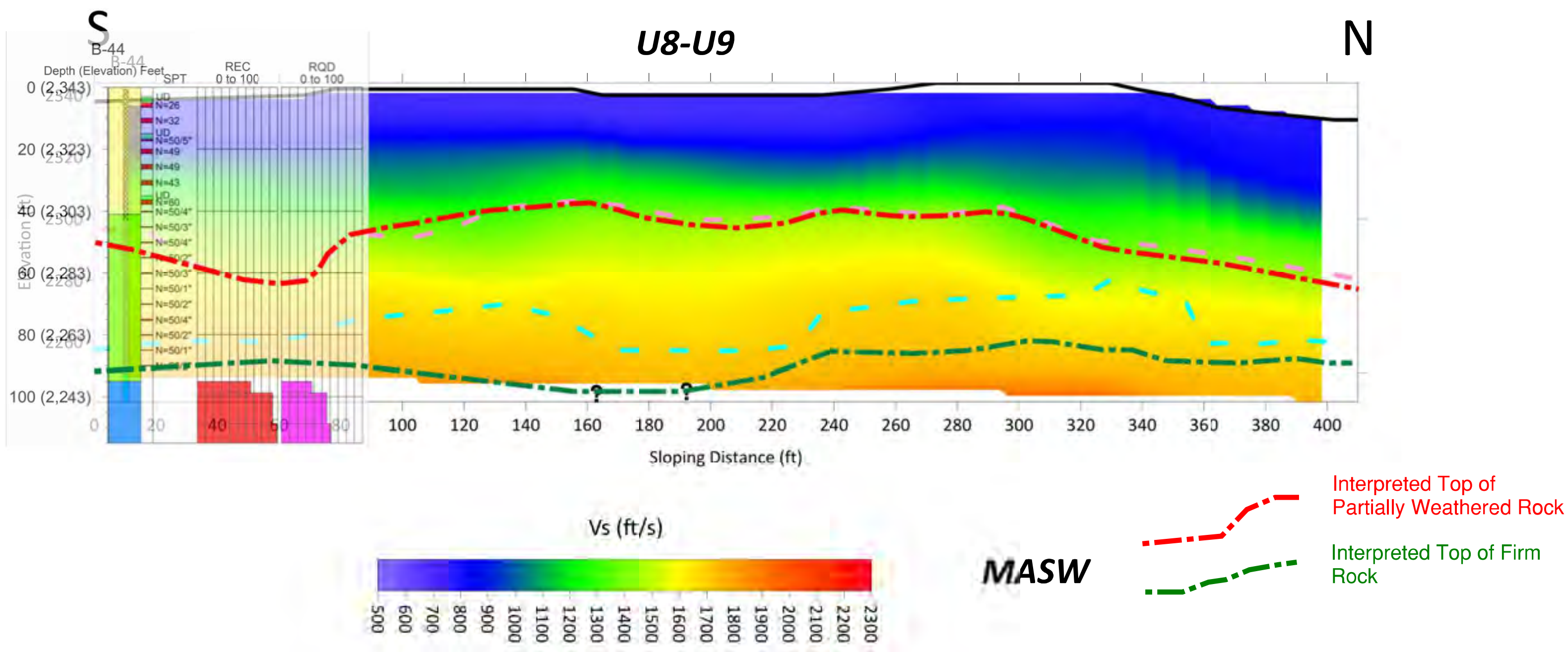

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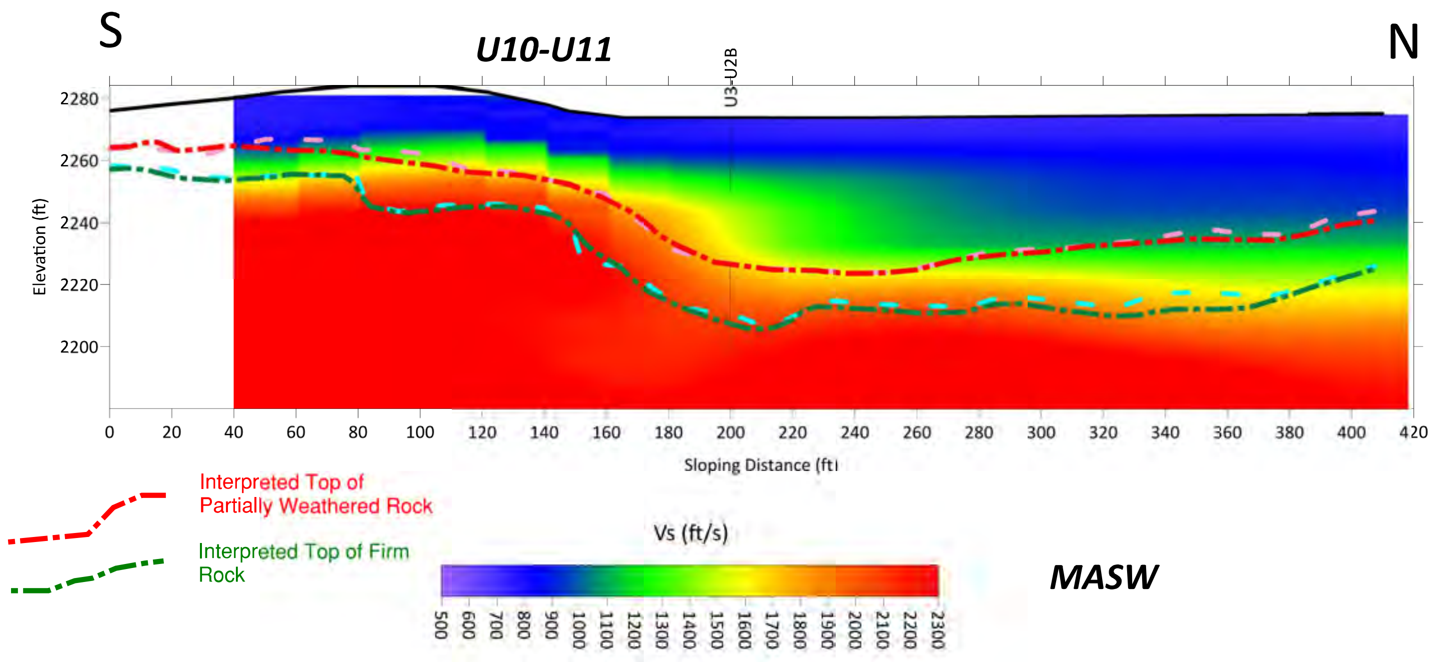

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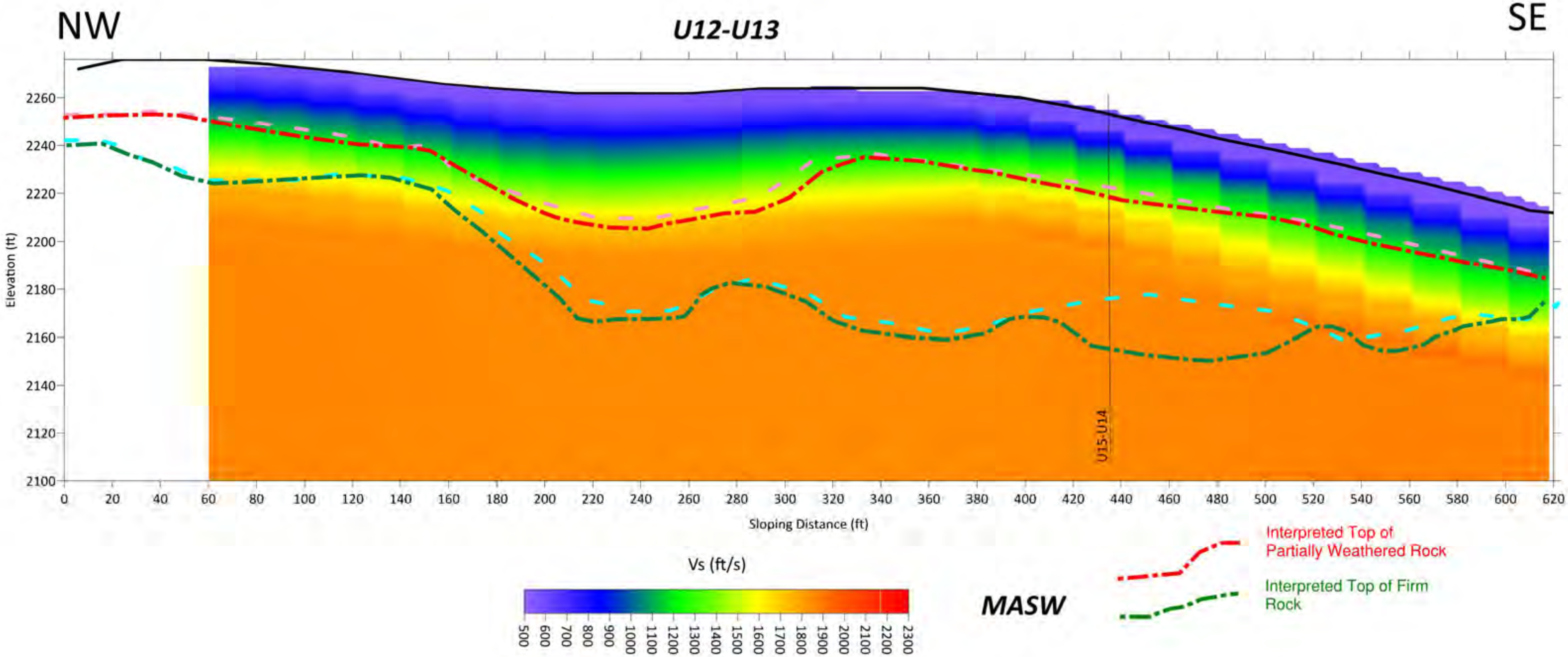
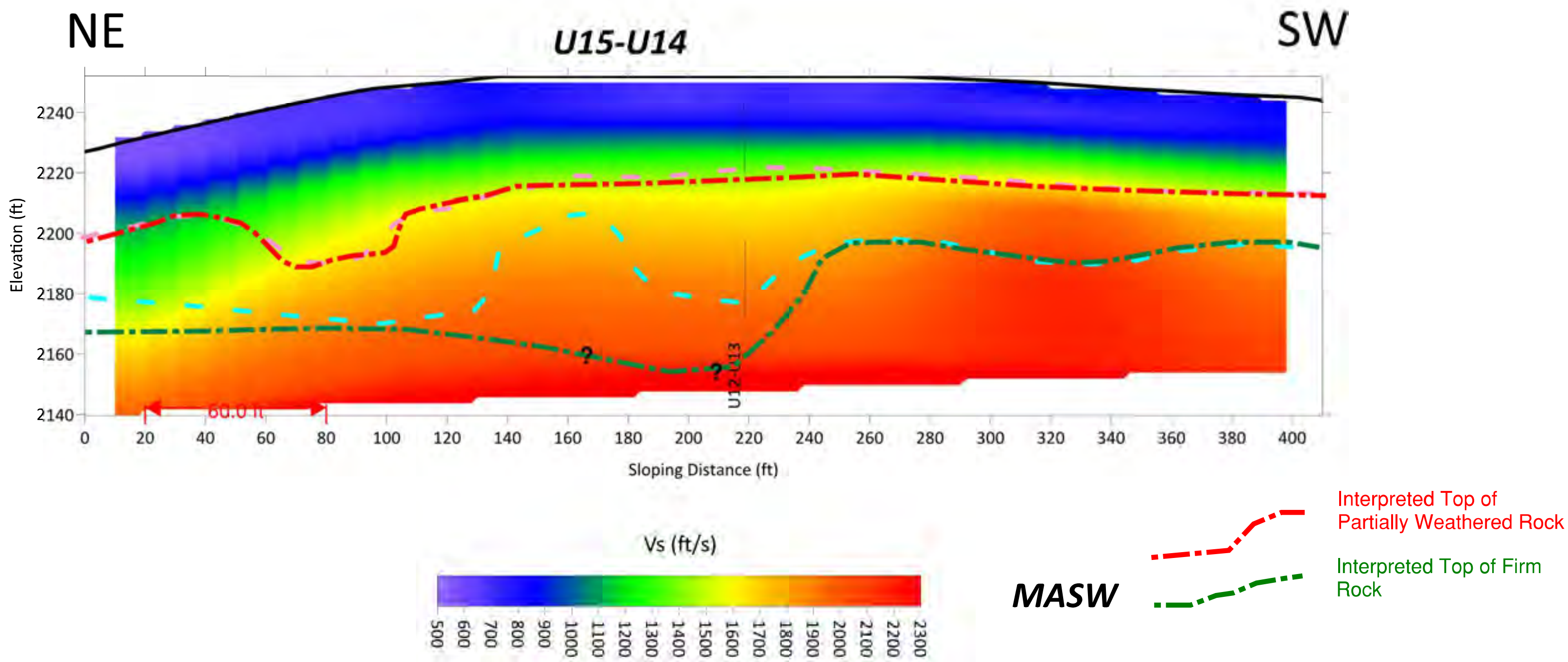


NW
U12-U13
SE
Elevation (ft)
2260
2240
2220
2200
2180
2160
2140
2120
2100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
U15-U14
Sloping Distance (ft)
Vs (ft/s)
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
MASW
Interpreted Top of Partially Weathered Rock
Interpreted Top of Firm Rock



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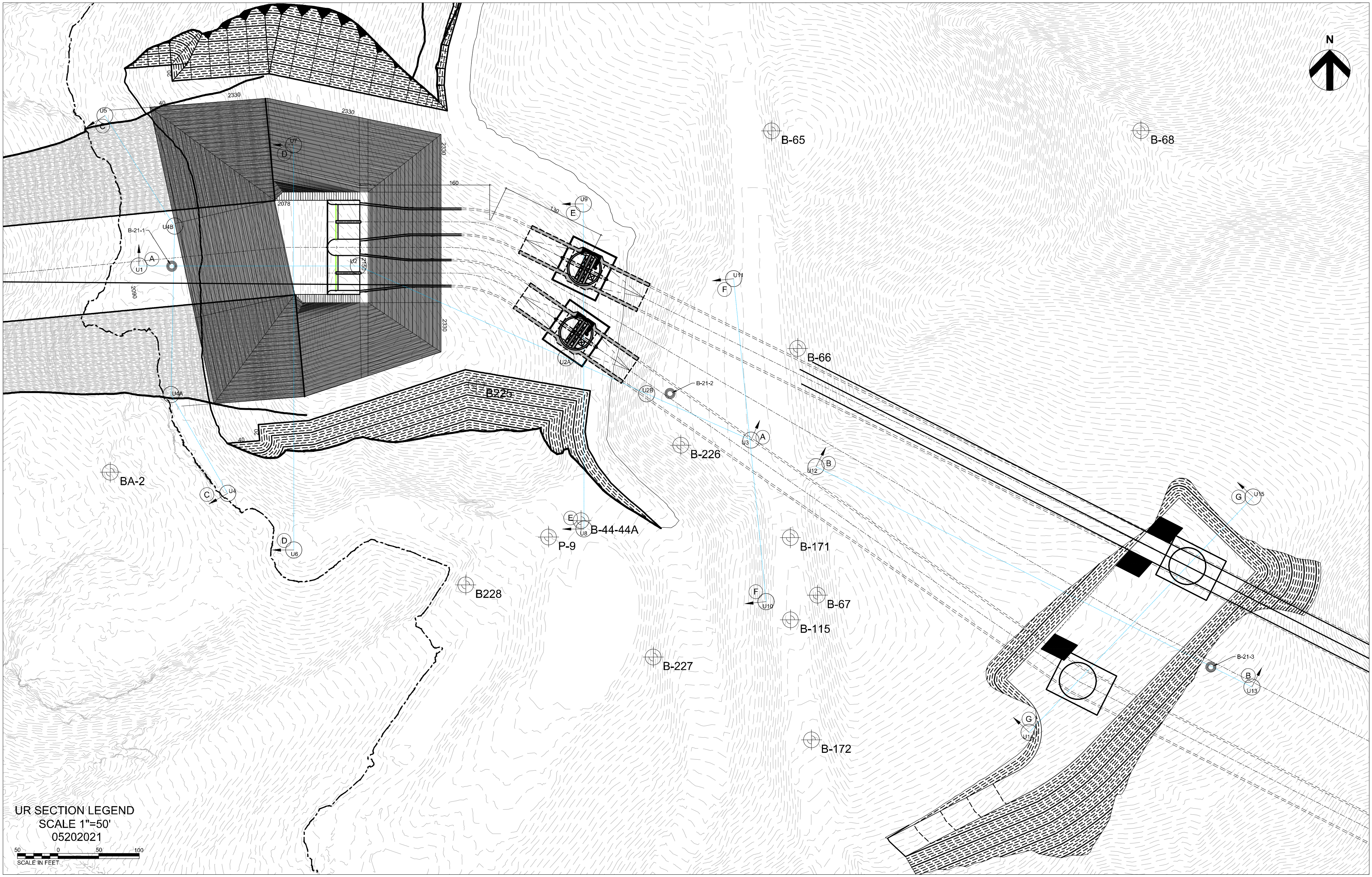
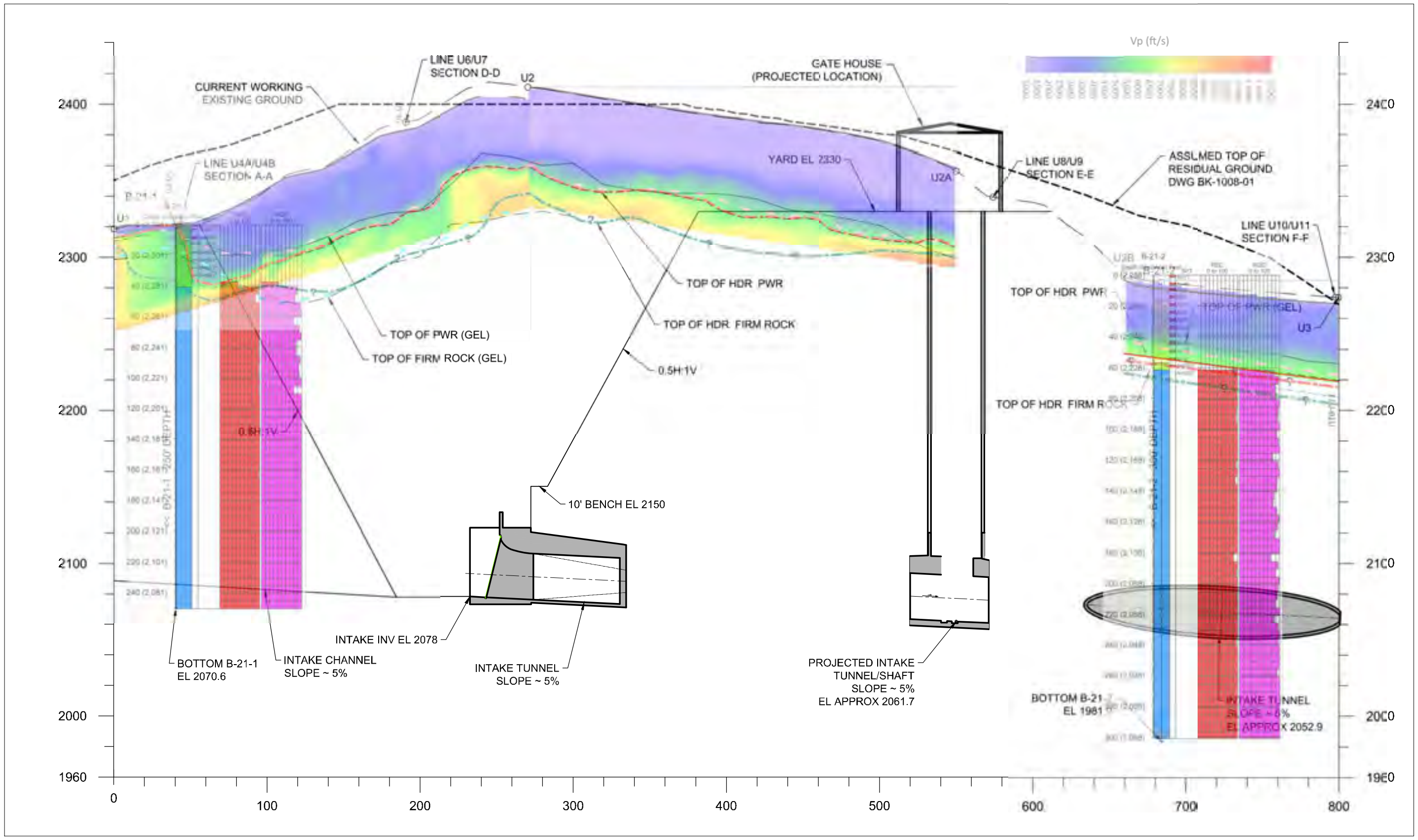
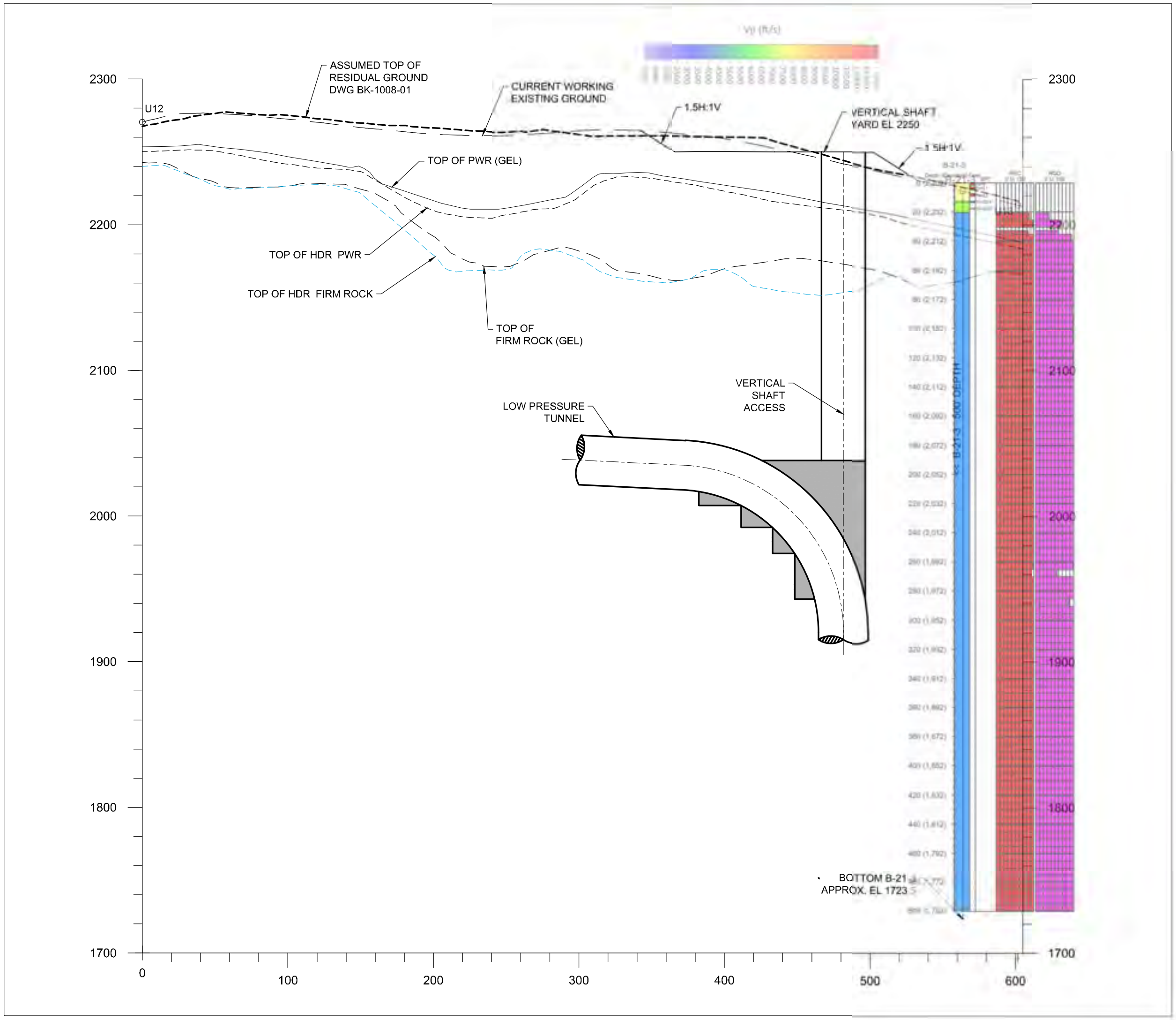

N
B-65
B-68
B-66
B-21-1
B-21-2
B-21-3
B-226
B-227
BA-2
B-44-44A
P-9
B-171
B-67
B-115
B-172
B228
B225
2330
2078
2150
2090
160
130
40
UR SECTION LEGEND
SCALE 1"=50'
05202021
SCALE IN FEET

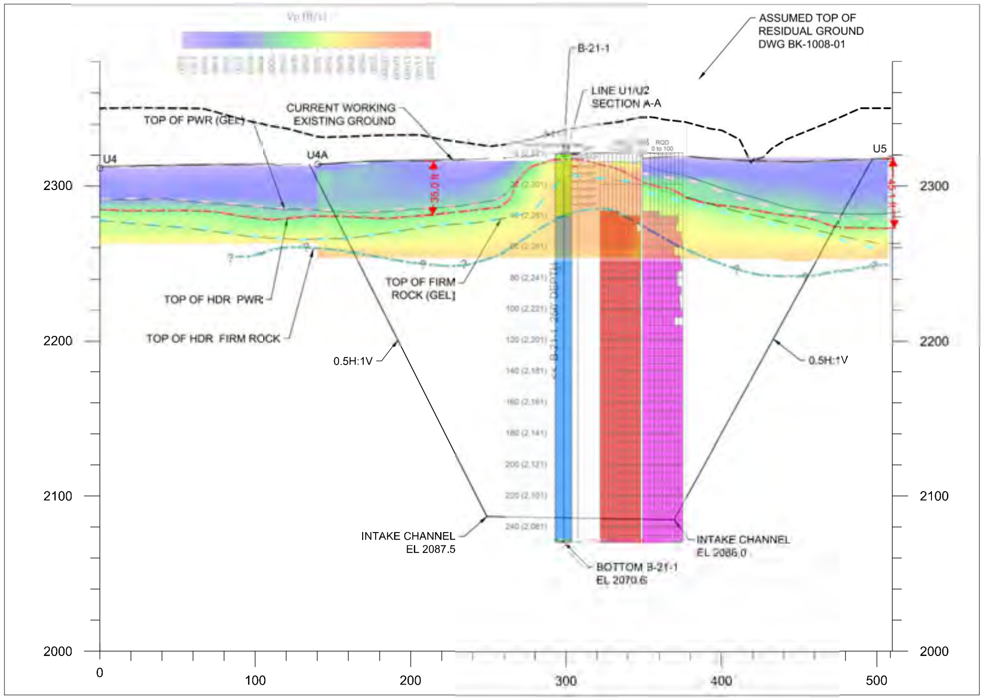


SECTION A-A
GEL DATA POINTS U1-U2-U2A-U2B-U3
SCALE 1"=40'

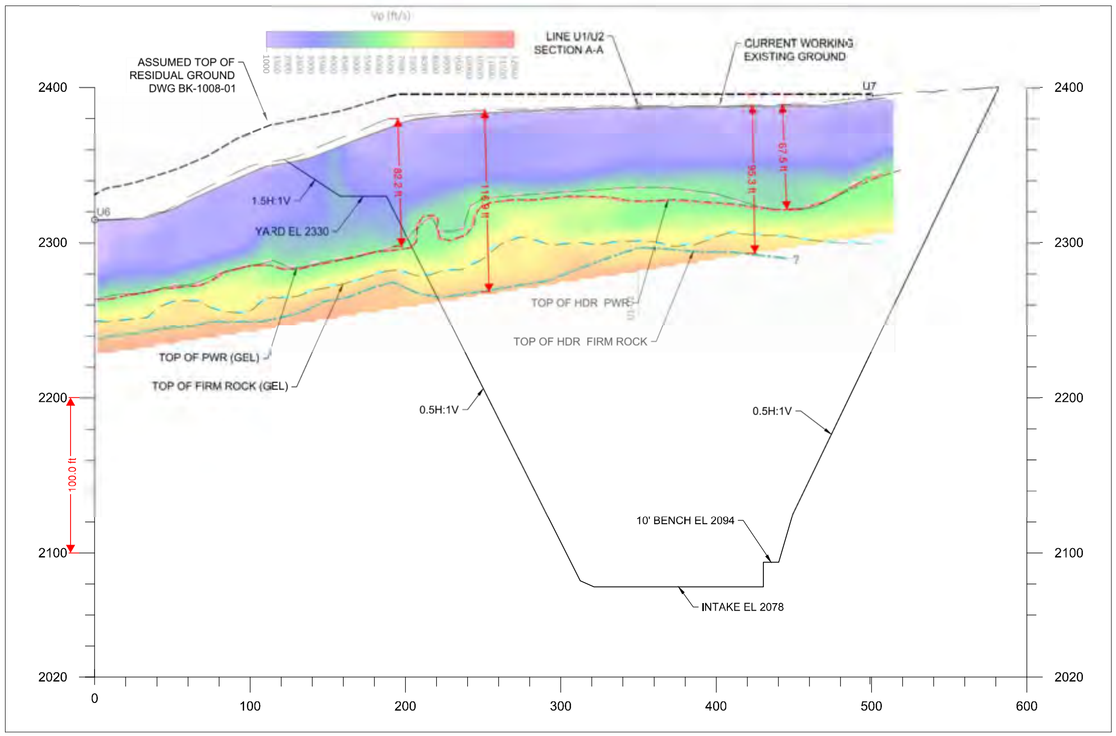


SECTION B-B
GEL DATA POINTS U12-U13
1"=40'

40 0 40 80
SCALE IN FEET

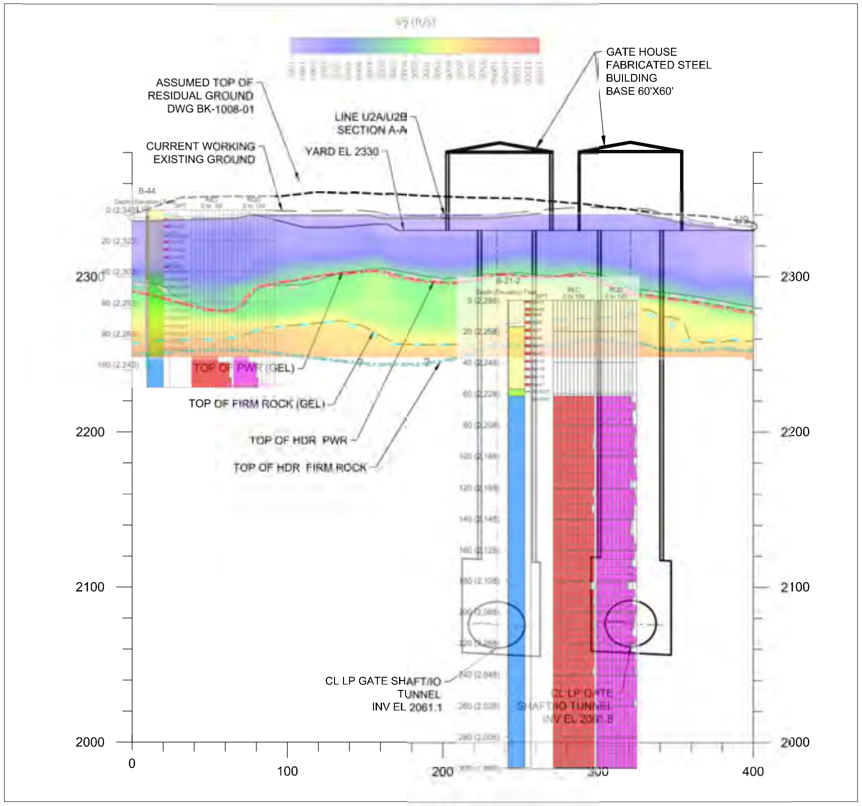


SECTION C-C
GEL DATA POINTS U4-U4A-U4B-U5
SCALE 1"=40'



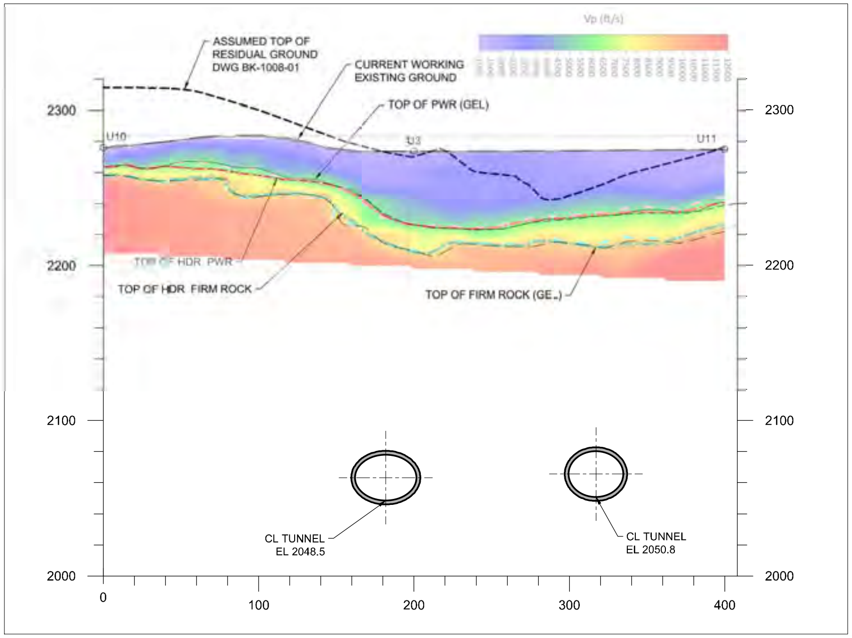
SECTION D-D
GEL DATA POINTS U6-U7
SCALE 1"=40'

40 0 40 80
SCALE IN FEET

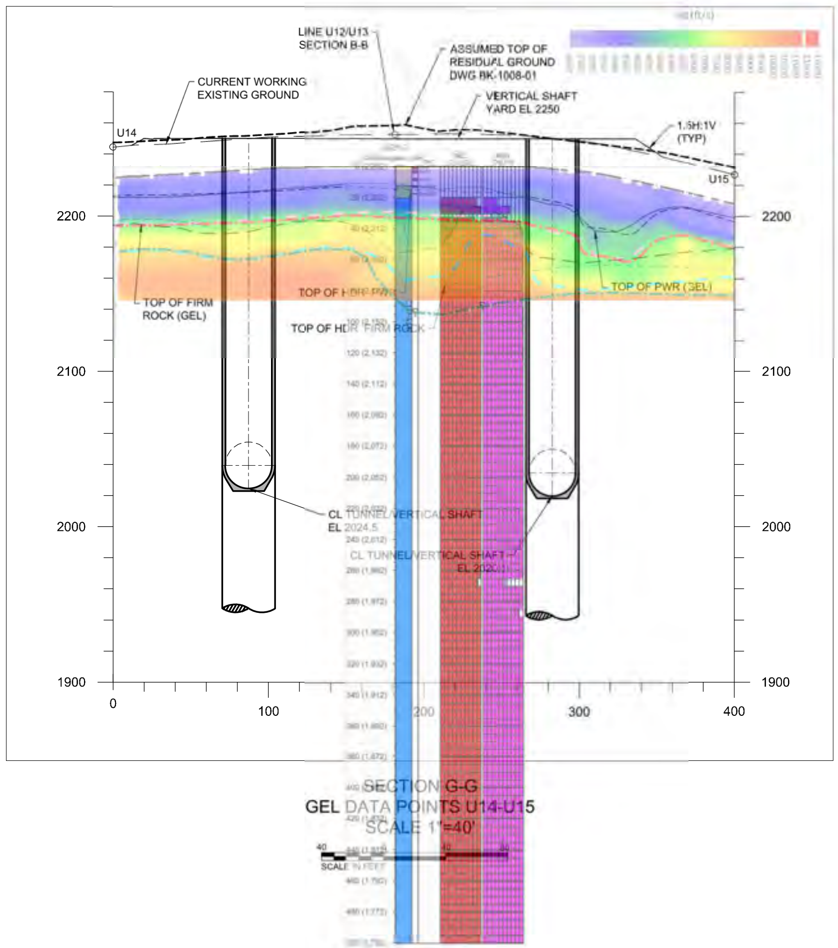


B-21-2 located approximately 170 ft downstream. of the gate structures

SECTION E-E
GEL DATA POINTS U8-U9
SCALE 1"=40'



SECTION F-F
GEL DATA POINTS U10-U11
SCALE 1"=40'



SECTION G-G
GEL DATA POINTS U14-U15
SCALE 1"=40'

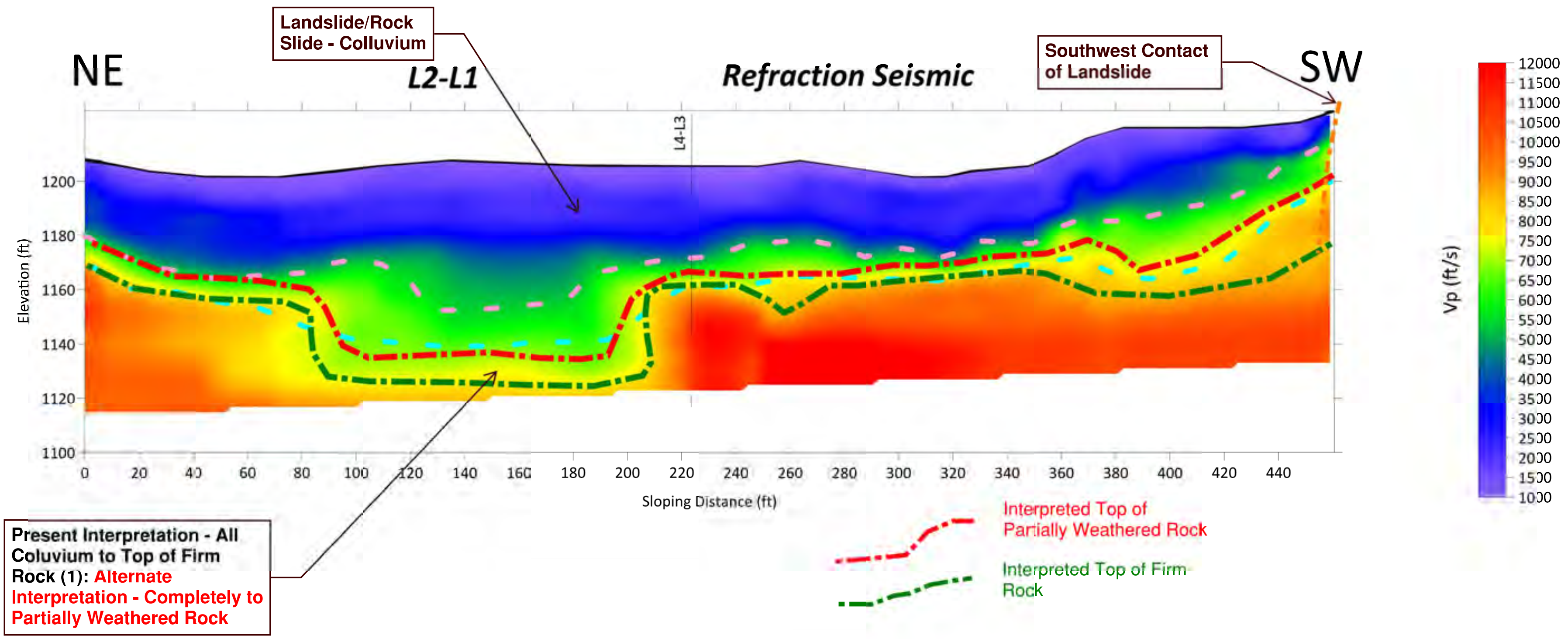
B-21-3 located approximately 150 ft downstream of the vertical power shafts.

ATTACHMENT B

Lower Reservoir Inlet/Outlet Works

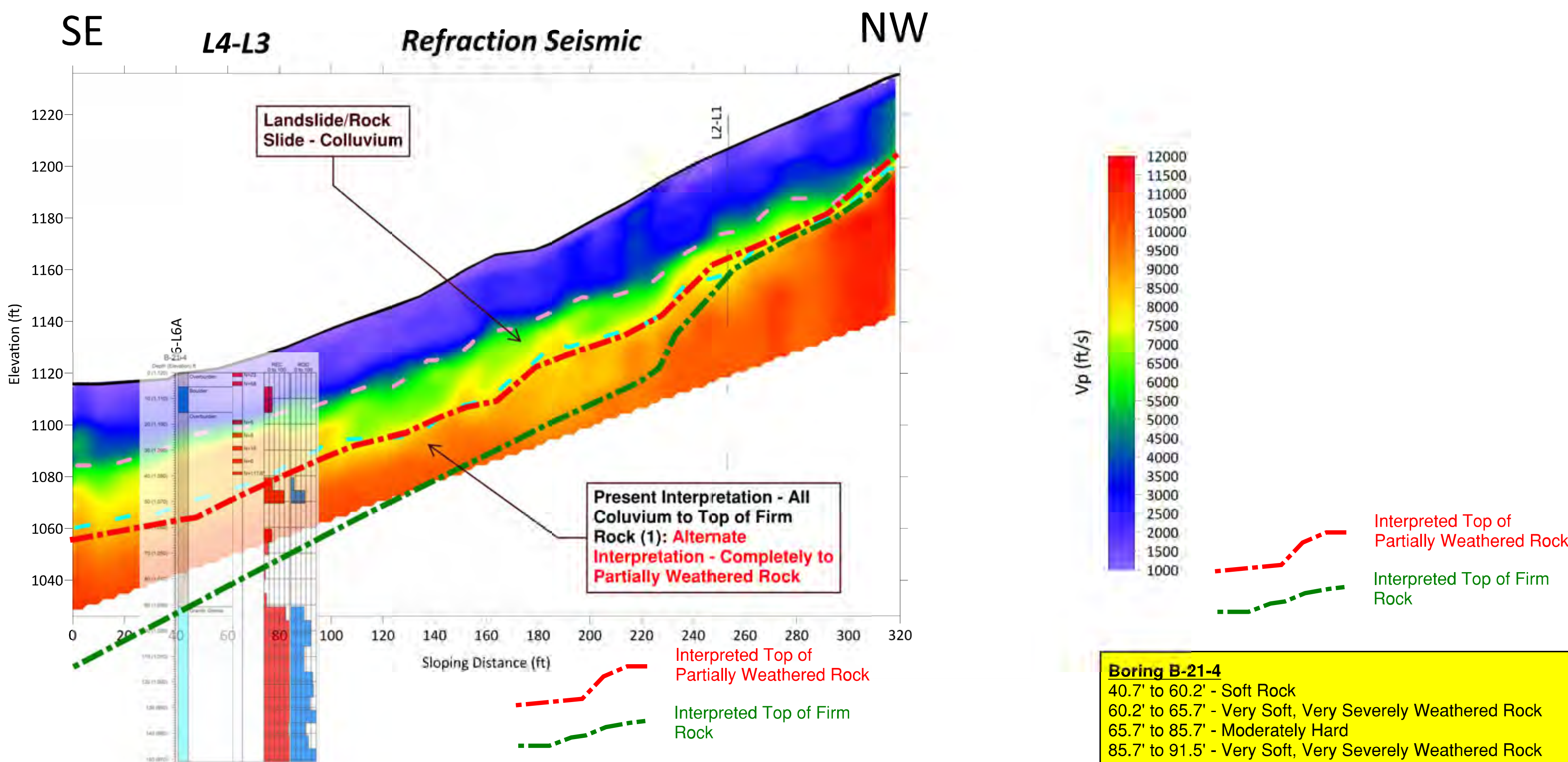
3) Seismic Lines and Borehole Interpretations

4) Seismic Lines and Borehole Interpretations Superimposed on Lower Reservoir Excavation Cross Sections



(1) Present interpretation based on Borehole B-21-4 and the characteristics of the Landslide/Rock Slide at the existing Bad Creek Lower Reservoir Inlet/Outlet Work.

HDRE00121 3/22/2021	Seismic Refraction and MASW Surveys for Mapping Bedrock Bad Creek II Pumped Storage Project, Salem, South Carolina	



Boring B-21-4
40.7' to 60.2' - Soft Rock
60.2' to 65.7' - Very Soft, Very Severely Weathered Rock
65.7' to 85.7' - Moderately Hard
85.7' to 91.5' - Very Soft, Very Severely Weathered Rock
91.5' to 93.0' - Moderately Hard Rock
93.0' to 96.5' - Hard Rock
Mostly hard with some moderately hard and one soft layer to 151.0'.

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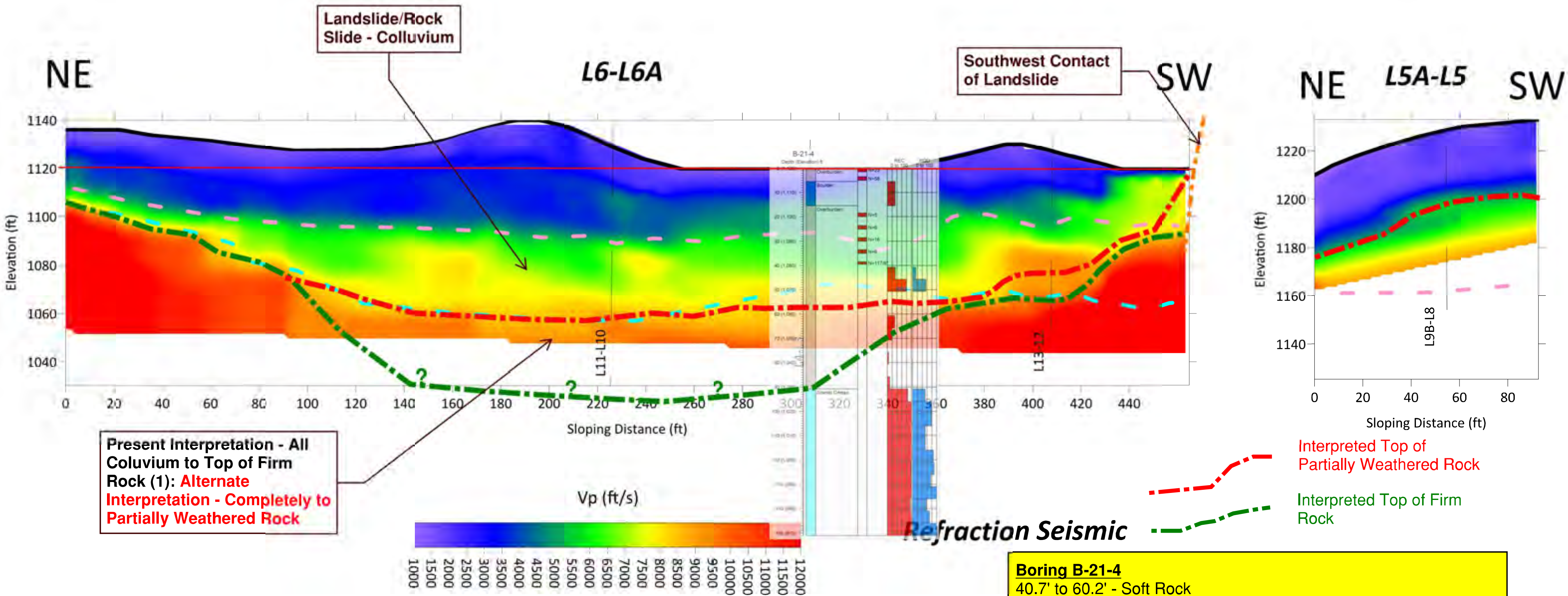

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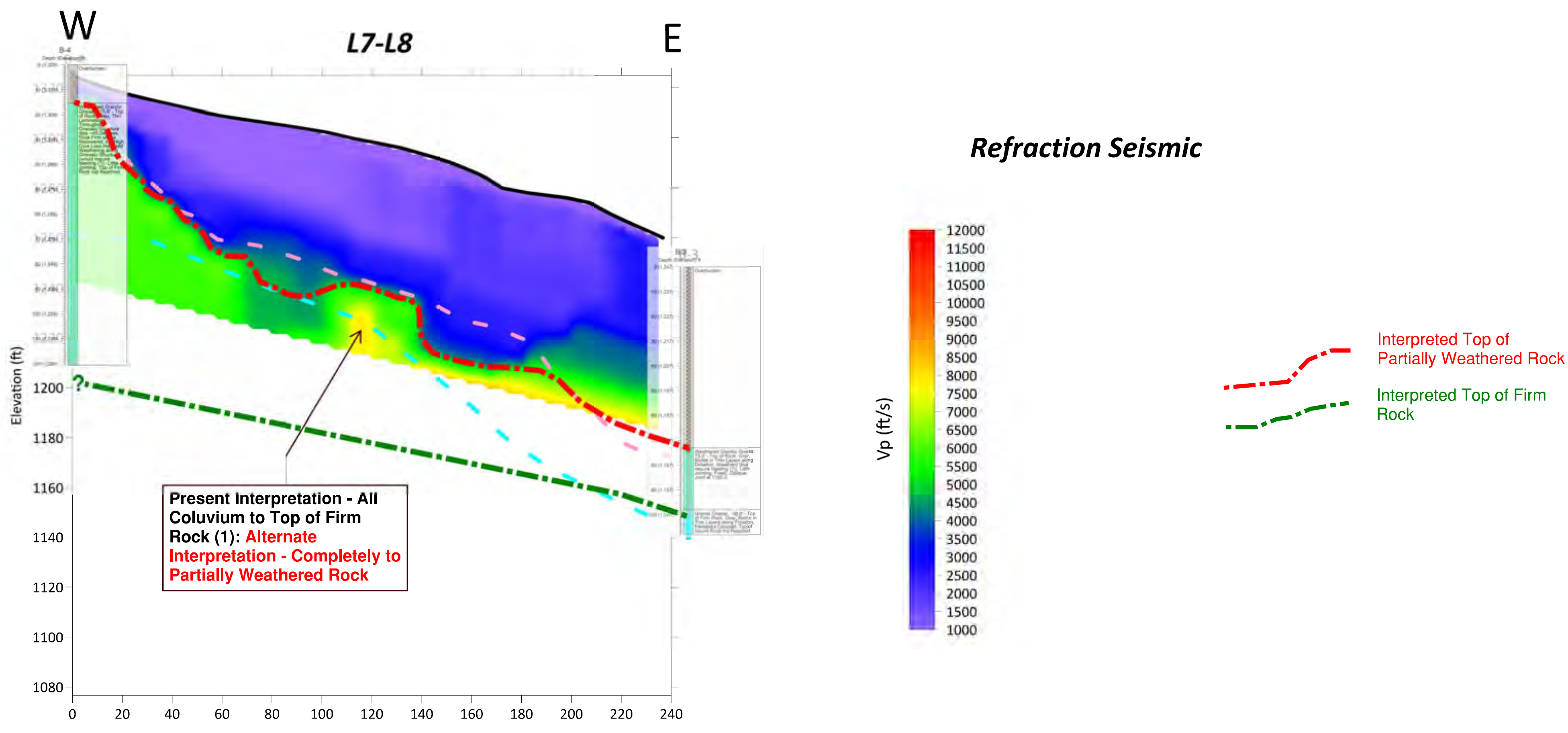
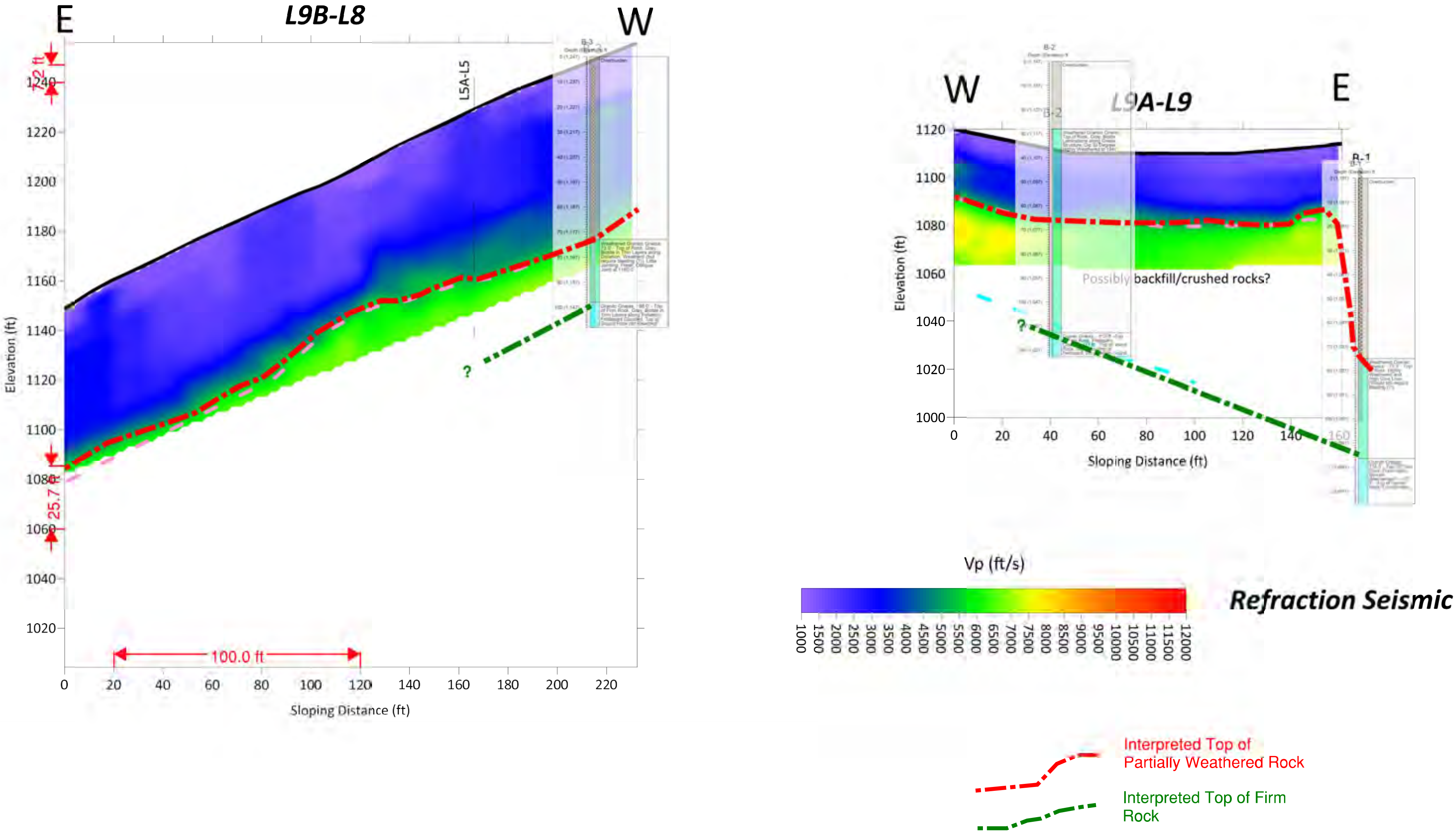


HDRE00121
3/22/2021

Seismic Refraction and MASW Surveys for Mapping Bedrock
Bad Creek II Pumped Storage Project, Salem, South Carolina



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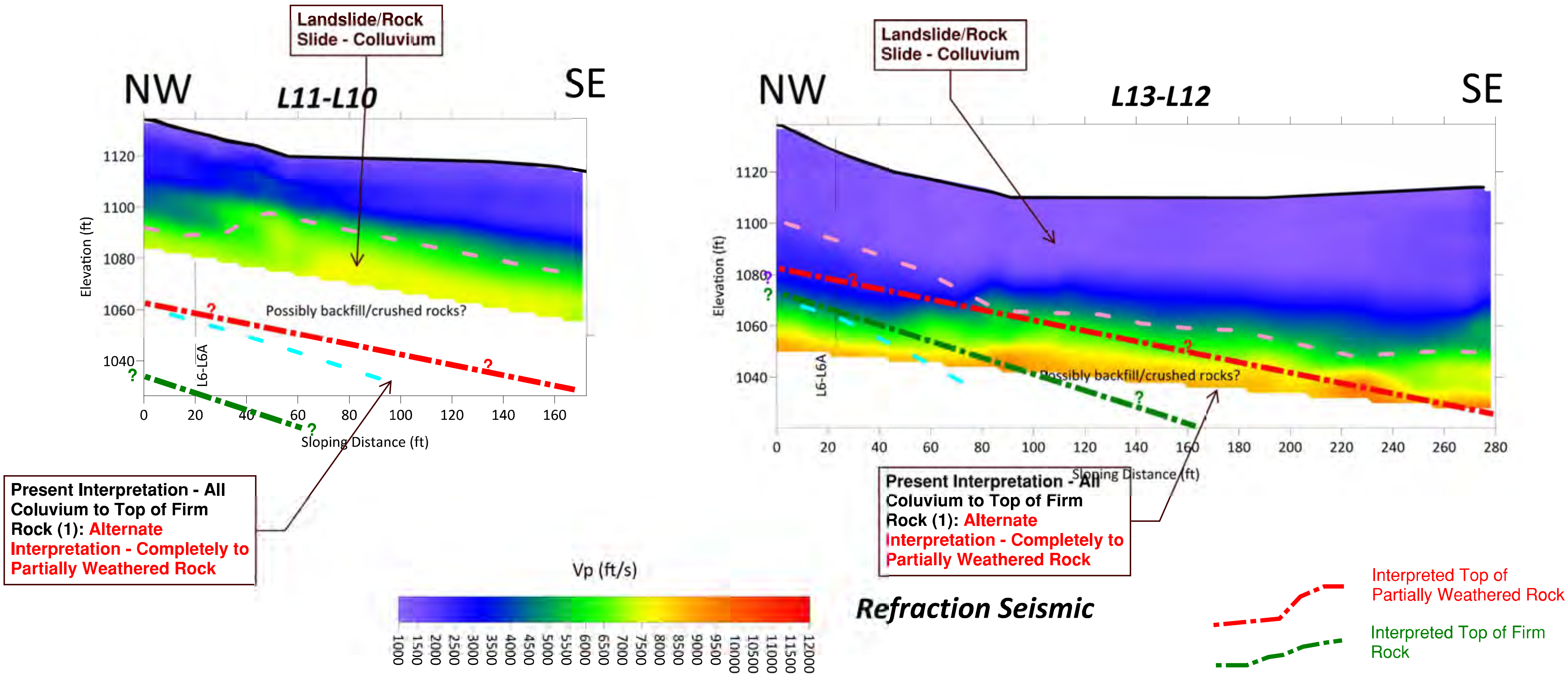

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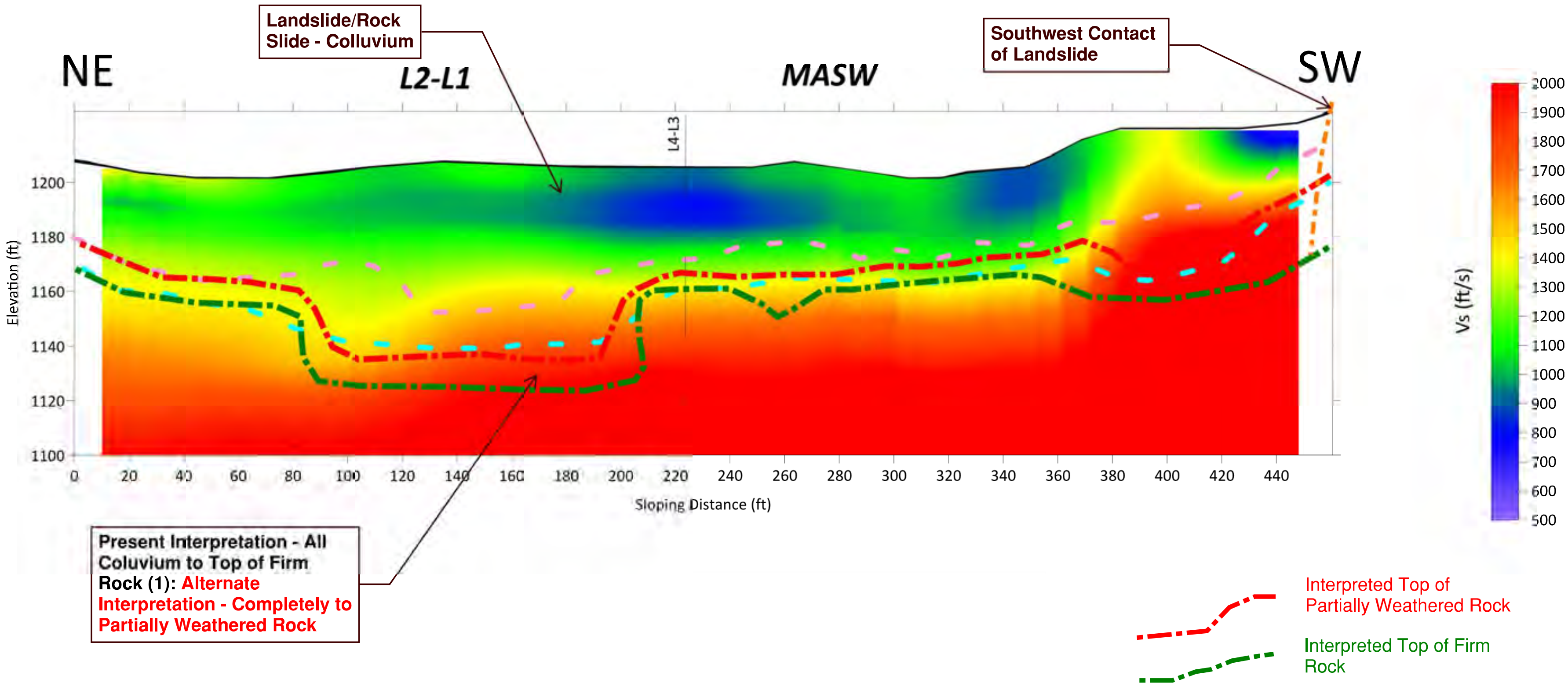

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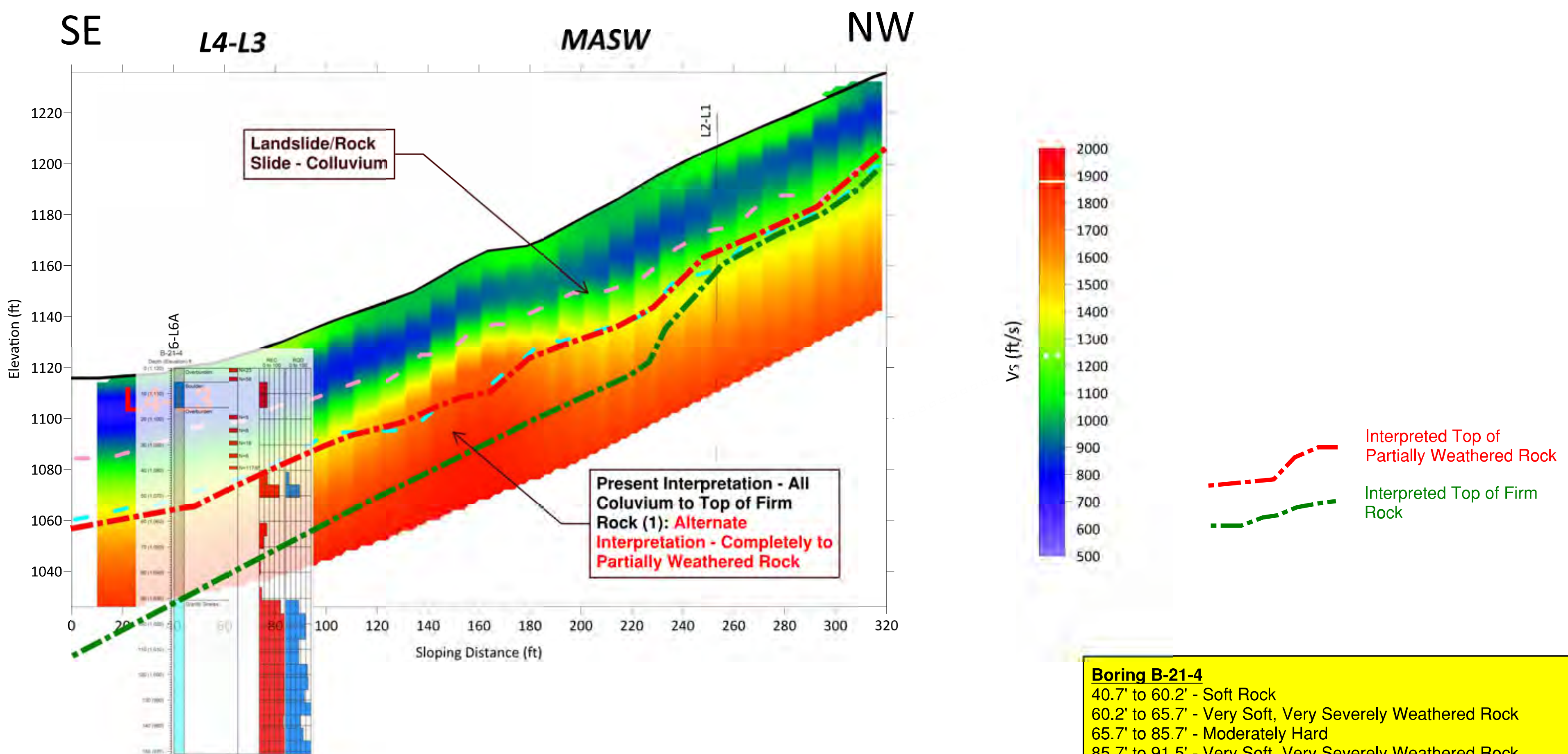

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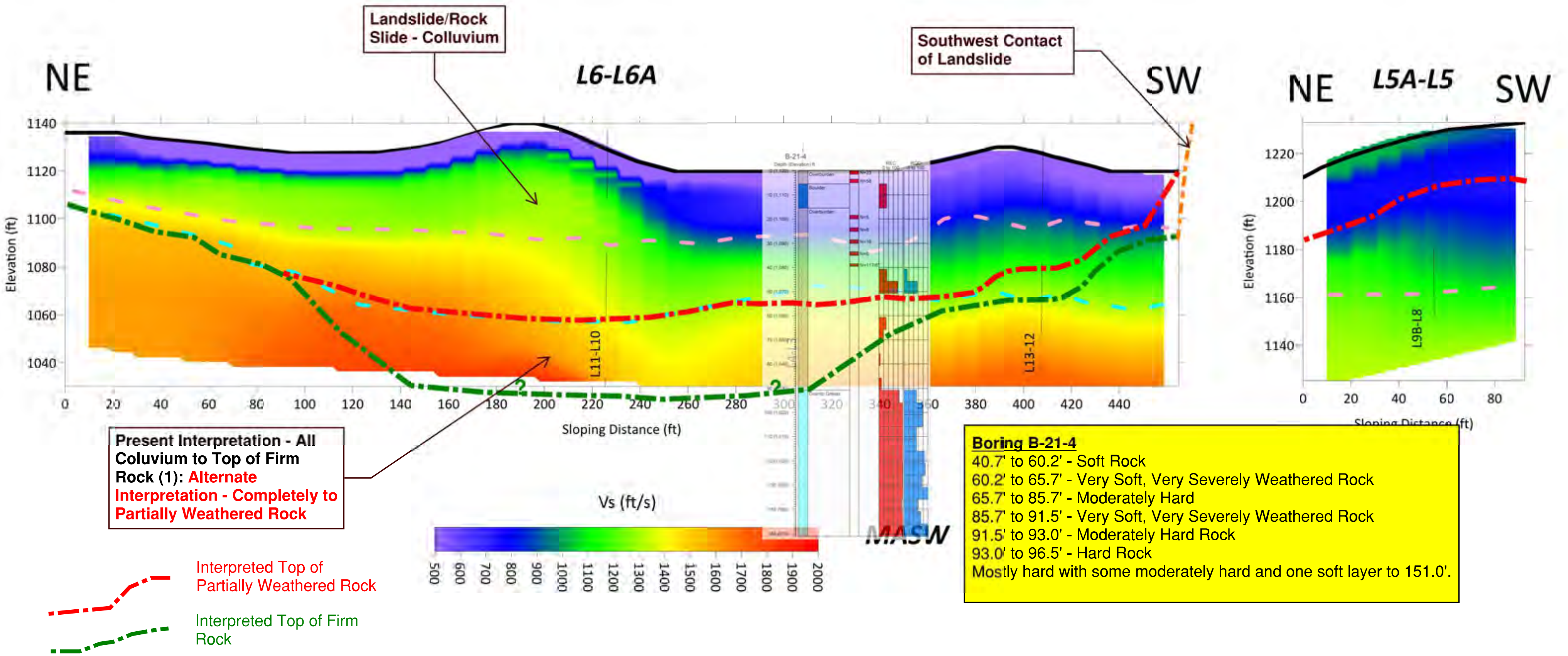

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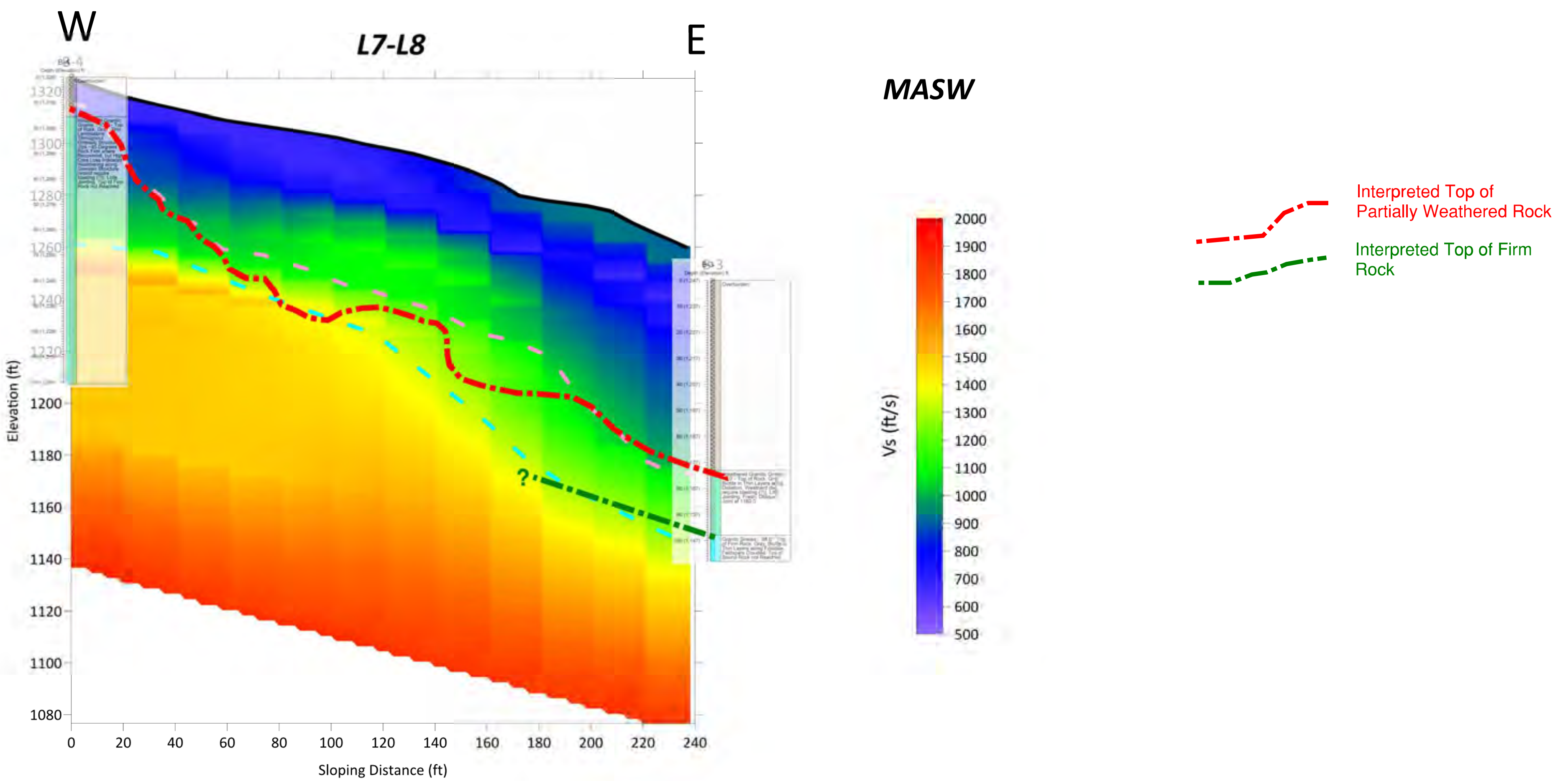

HDRE00121
3/22/2021

Seismic Refraction and MASW Surveys for Mapping Bedrock
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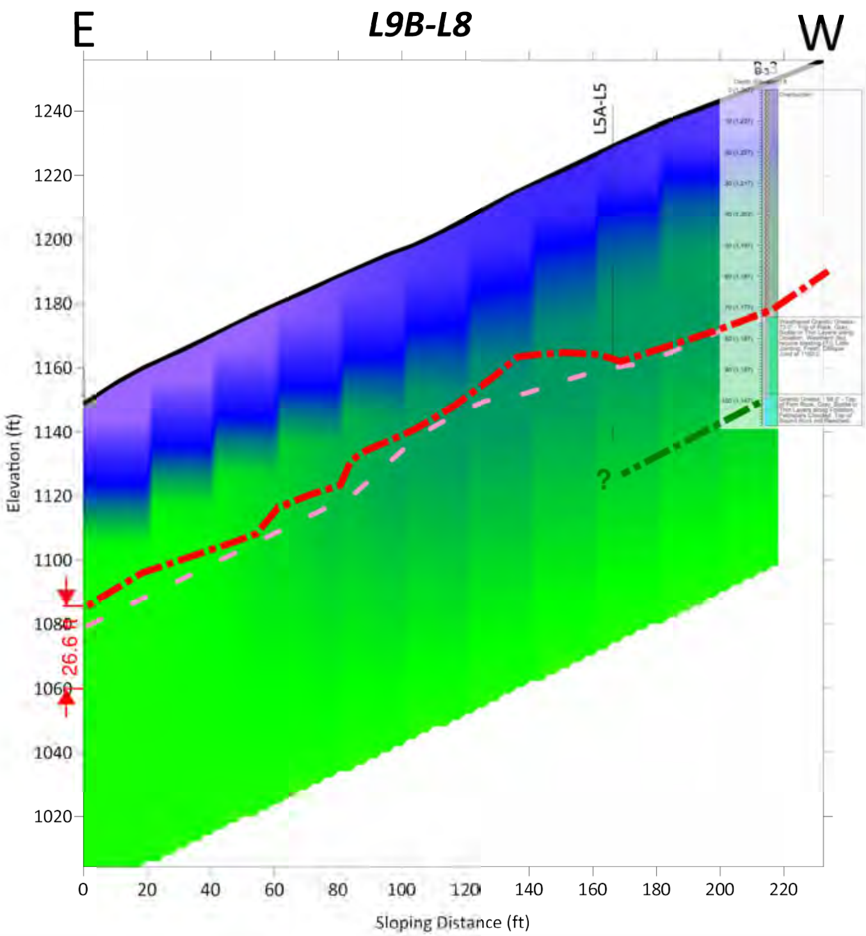

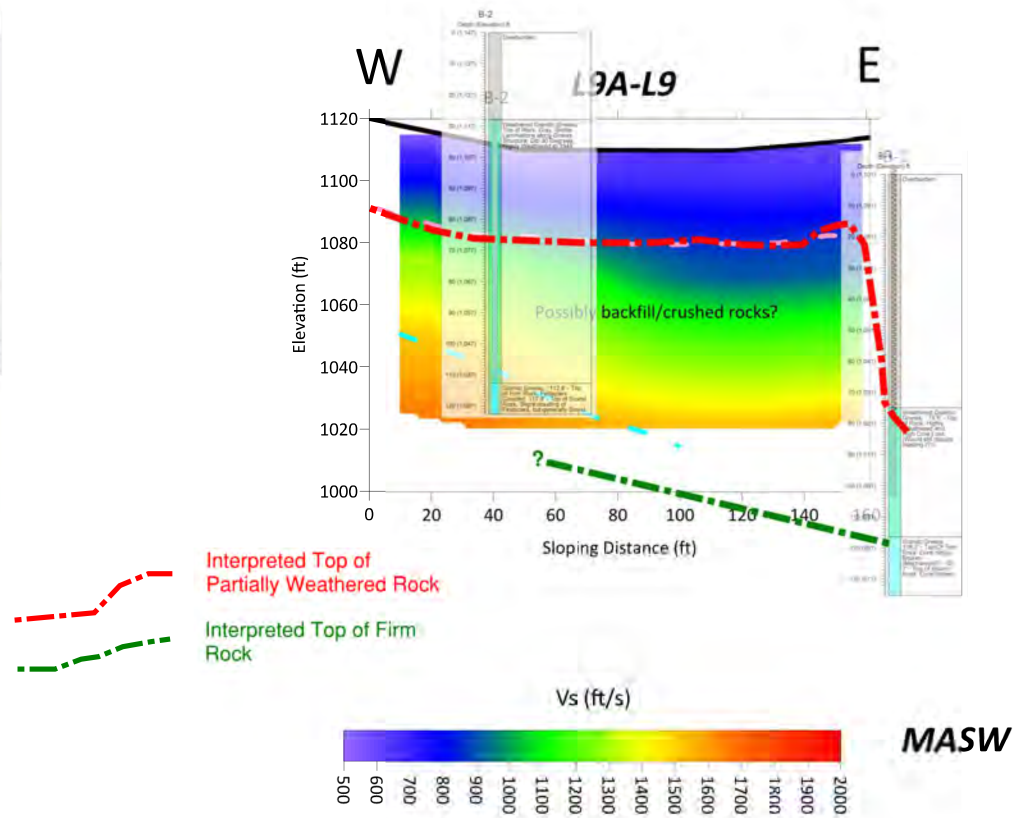

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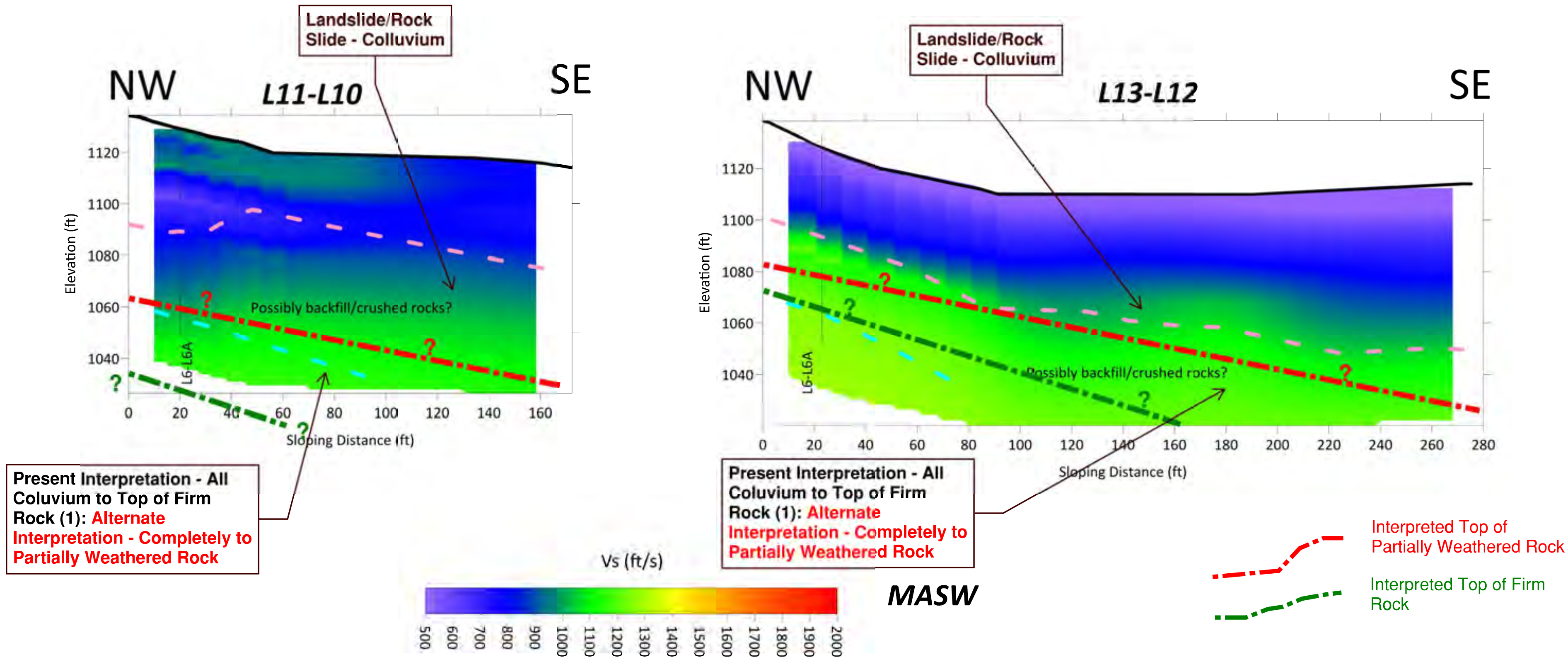

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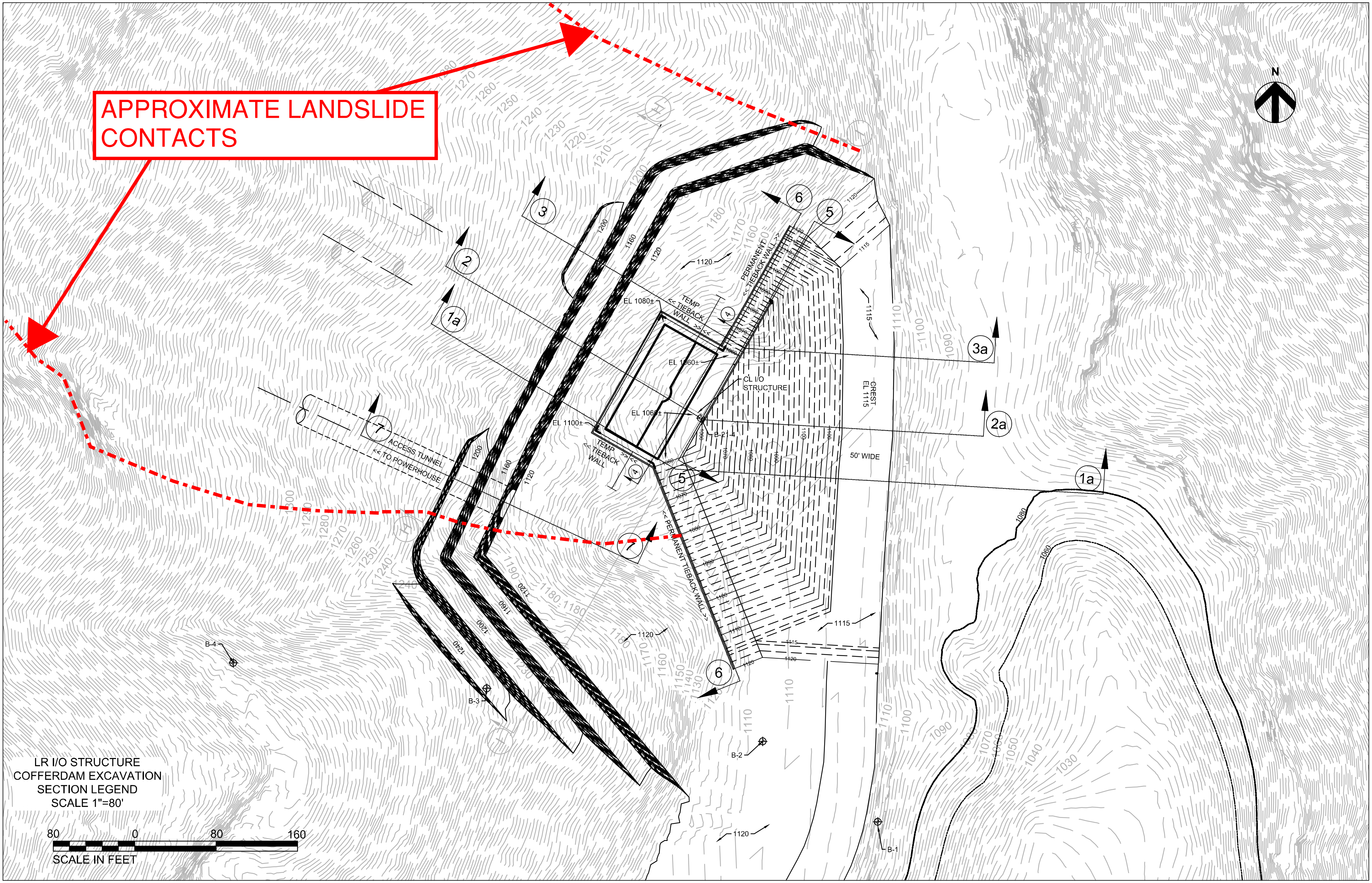
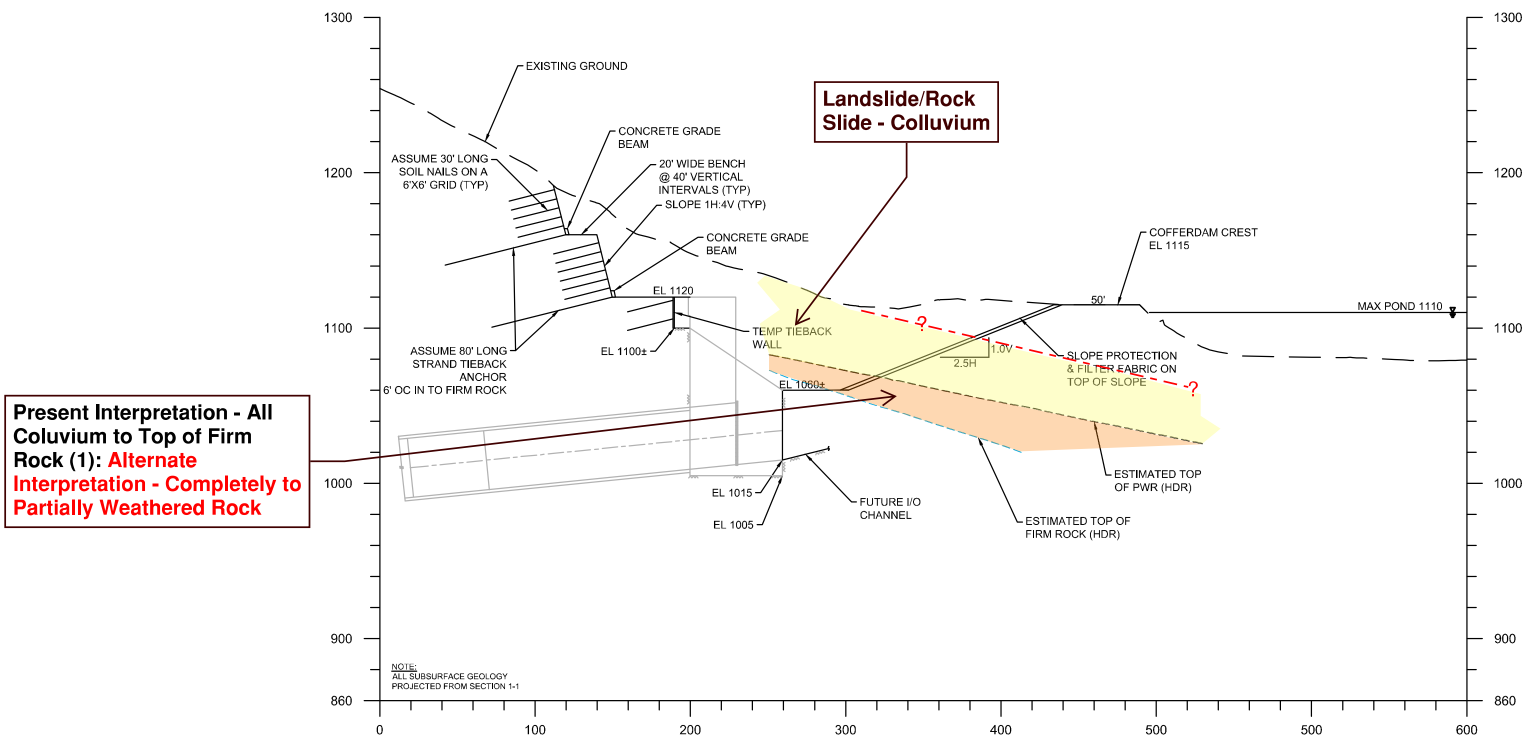
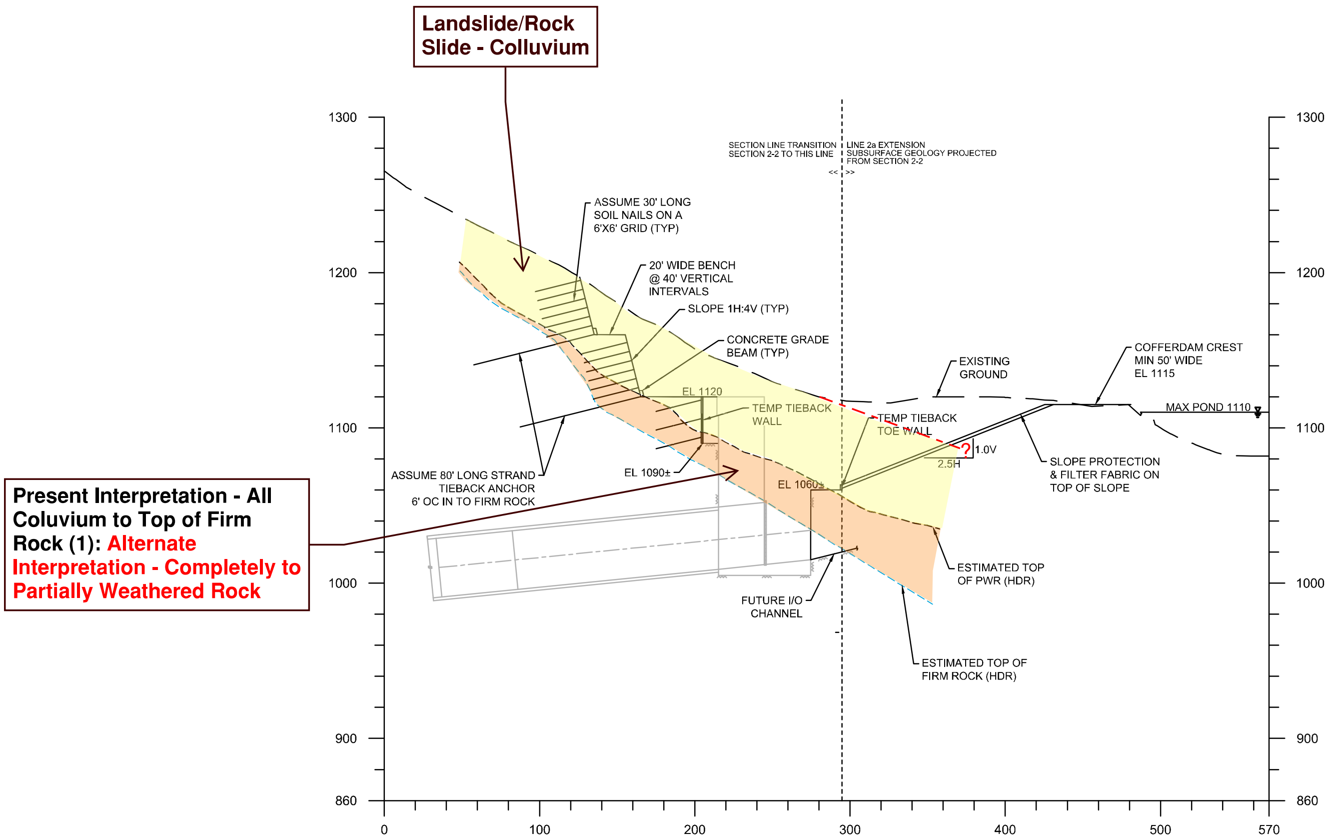


APPROXIMATE LANDSLIDE CONTACTS
N
ACCESS TUNNEL
<< TO POWERHOUSE
PERMANENT TIEBACK WALL
TEMP TIEBACK WALL
EL 1080±
EL 1060±
EL 1100±
CL I/O STRUCTURE
CREST EL 1115
50' WIDE
B-1
B-2
B-3
B-4
LR I/O STRUCTURE
COFFERDAM EXCAVATION
SECTION LEGEND
SCALE 1"=80'
80 0 80 160
SCALE IN FEET



I/O STRUCTURE EXCAVATION AND COFFERDAM
SECTION 1a-1a
SCALE: 1"=80'

80 0 80 160
SCALE IN FEET



I/O STRUCTURE EXCAVATION AND COFFERDAM
SECTION 2-2a
SCALE: 1"=80'

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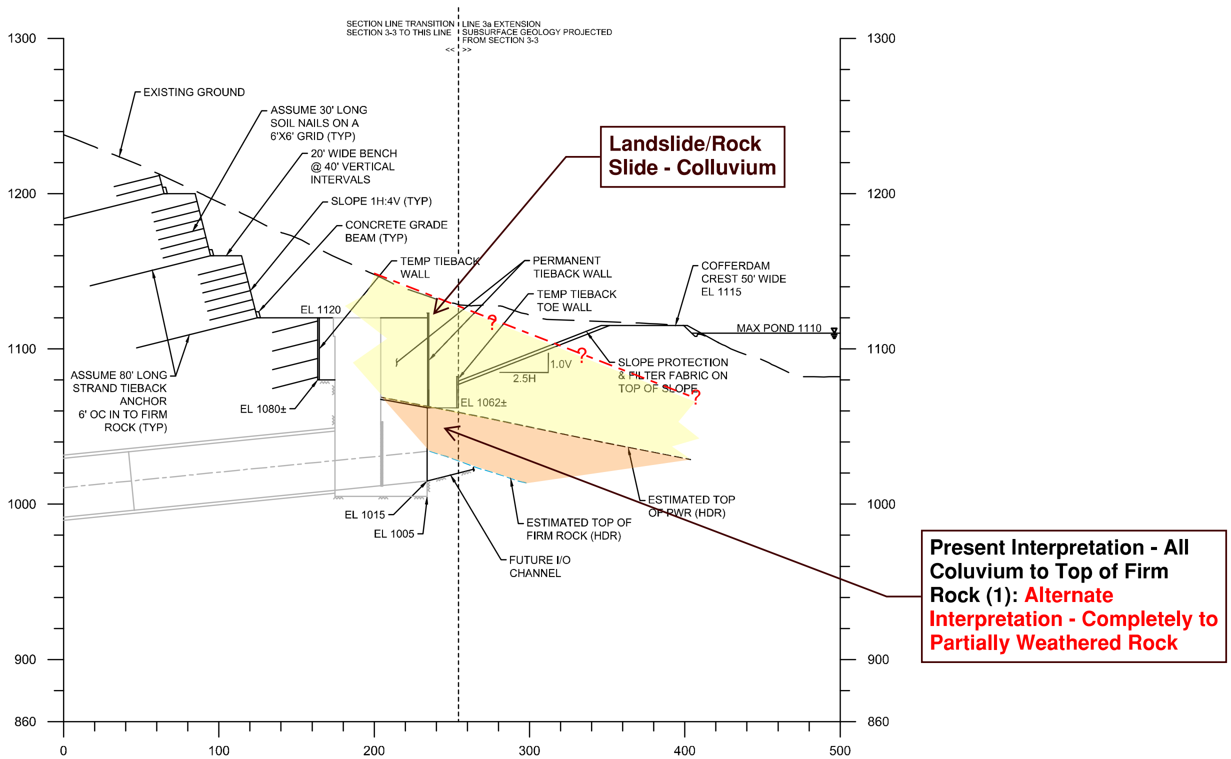
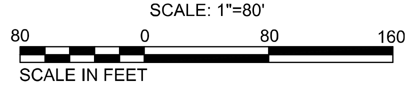
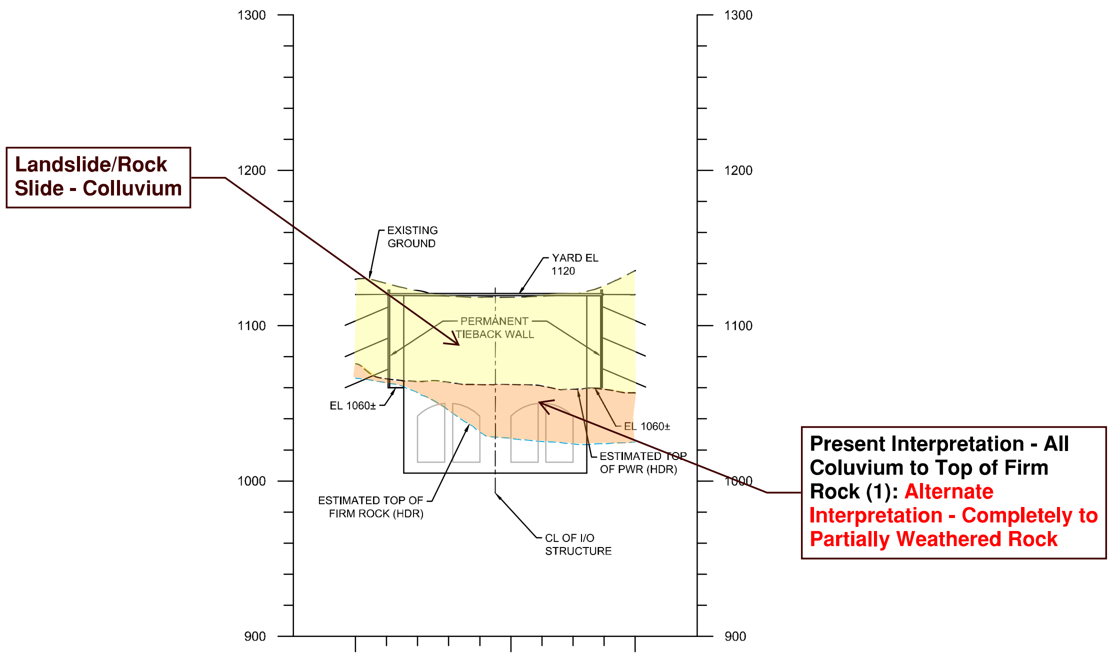
SCALE IN FEET



I/O STRUCTURE EXCAVATION AND COFFERDAM
SECTION 3-3a
SCALE: 1"=80'





I/O STRUCTURE EXCAVATION
SECTION 4-4
SCALE: 1"=80'

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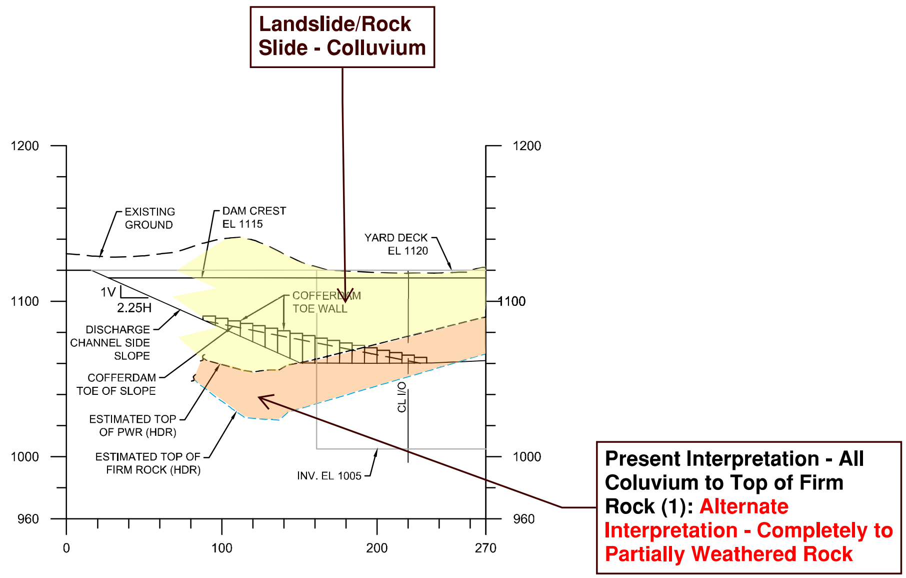
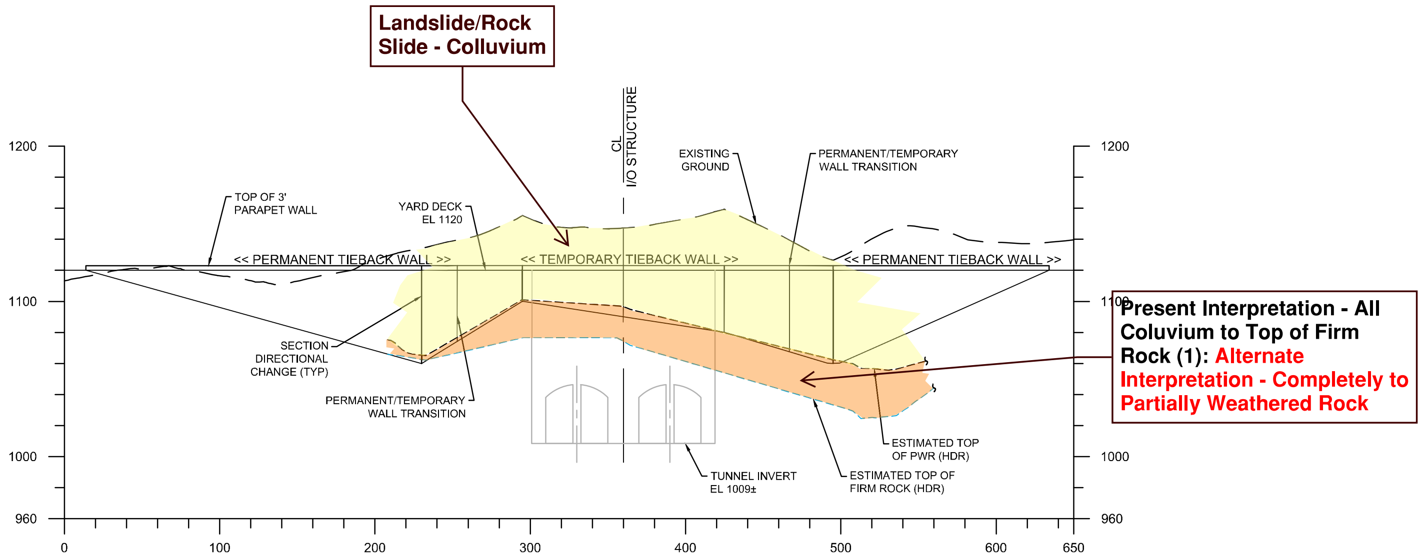
SCALE IN FEET



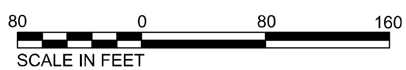
COFFERDAM TEMPORARY TIEBACK TOE WALL
SECTION 5-5
SCALE: 1"=80'

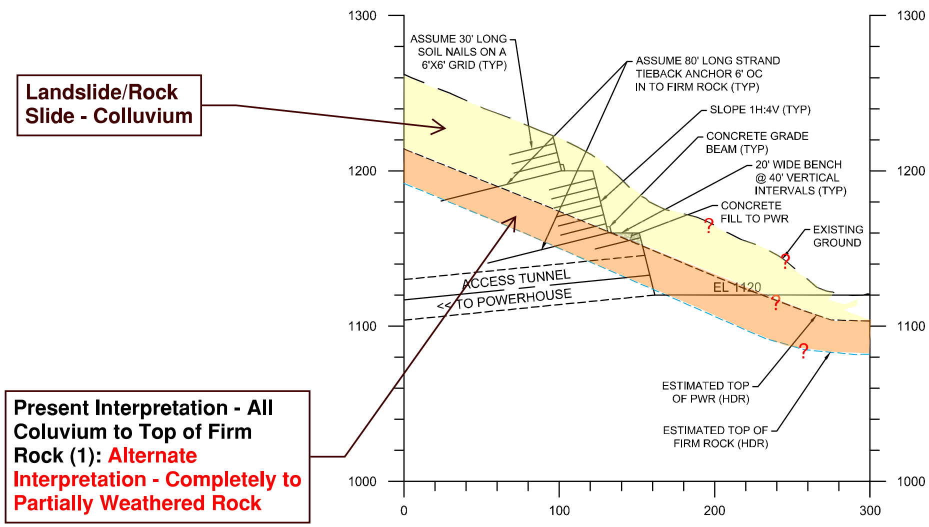
80 0 80 160

SCALE IN FEET



TEMPORARY AND PERMANENT TIEBACK WALLS
SECTION 6-6
SCALE: 1"=80'





LOWER RESERVOIR I/O YARD TIEBACK WALL
AND POWERHOUSE ACCESS TUNNEL
SECTION 7-7
SCALE: 1"=80'

80 0 80 160
SCALE IN FEET

Attachment 2

Attachment 2 – Geotechnical Studies Report

Bad Creek II Power Complex Feasibility Study

Volume 8: Geotechnical Studies

Salem, South Carolina
September 1, 2022

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Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

acre-ft	acre-feet
ASTM	ASTM International (formerly American Society for Testing and Materials)
Bad Creek II or Project	Bad Creek II Power Complex
cm	centimeters
Duke Energy	Duke Energy Carolinas, LLC
EM	elastic modulus
ft	feet/foot
HDR	HDR Engineering, Inc.
I/O	Intake/Outlet
k	hydraulic conductivity
MASW	multi-channel assessment of surface waves
psi	pounds per square inch
pcf	pounds per cubic feet
PWR	partially weathered rock
RQD	rock quality designation
sec	second
Standard Penetration Test	SPT
S&ME, Inc.	S&ME
TFF	Tallulah Falls Formation
TFR	Top of Firm Rock
TGn	Toxaway Gneiss
UWR	unweathered rock
UCS	unconfined compressive strength
V_p	P-wave: compressional wave velocity
V_s	S-wave: shear wave velocity
Water pressure	WP

1 Introduction

As part of the Bad Creek II Power Complex (Bad Creek II or Project) feasibility study being performed by HDR Engineering, Inc. of the Carolinas (HDR) in coordination with Duke Energy of the Carolinas, LLC (Duke Energy), a geotechnical field exploration program was carried out at the site of the existing Bad Creek Pumped Storage Station near Salem, SC from February 2021 through June 2021. Geotechnical site investigation efforts were organized and implemented by HDR and various subcontractors with logistical and site access support provided by Duke Energy. The Bad Creek II Geotechnical Investigation was performed to support the feasibility study of the Bad Creek II water conveyance tunnels and shafts, access tunnels and shafts, and underground powerhouse, and appurtenant structures including the proposed Upper Reservoir Intake/Outlet works (Upper Reservoir I/O) and Lower Reservoir Intake/Outlet works (Lower Reservoir I/O).

Five borings were drilled at the Project site and included downhole logging, packer testing, and water level monitoring wells in two of the borings. Four of the five borings (B-21-1, B-21-2, B-21-3, and B-21-4) were drilled at locations along the proposed water conveyance alignment. B-21-1 is located at the Upper Reservoir I/O, Boring B-21-2 in the area of the low pressure headrace tunnels just downstream of the low pressure headrace gates, Boring B-21-3 downstream of the vertical intake shaft, and Boring B-21-4 at the Lower Reservoir I/O. Boring B-21-5 was completed to investigate the Upper Reservoir I/O area, verify surface geophysical profiles, and to determine the location in the subsurface of a previously mapped shear zone in the Bad Creek Upper Reservoir. Boring locations are shown on drawings P-58, P-59, and P-61 in Appendix A.

The borings were drilled to obtain geotechnical data including soil properties, depth to top of weathered rock, depth to top of competent rock, lithology and rock hardness, rock recovery, and Rock Quality Designation (RQD), depth and thickness of shear zones, and rock permeability data water pressure (i.e., packer tests). Downhole geophysical logging of the borings was performed to assess rock mass fractures, foliation/banding, and other rock mass discontinuities. The borings were drilled vertically to depths ranging from 120.3 to 500.3 feet (ft) below existing grade. Sampling methods included Standard Penetration Test (SPT) sampling and HQ coring methods.

Surface geophysical investigations including seismic refraction surveys to establish compressional wave velocities (V_p) and multi-channel assessment of surface waves (MASW) to establish shear wave velocities (V_s) of subsurface materials that are utilized in the interpretation of subsurface materials (overburden, weathered rock, firm/sound rock). Drawings P-59 and P-61 in Appendix A show the locations of the geophysical lines.

Geologic investigations were conducted by HDR in tandem with the geotechnical investigation as part of an overall geological and geotechnical assessment the site. The investigations have been used to develop a geologic model of the proposed Bad Creek II tunnel alignment. The results of the assessments are presented in Volume 7 (Geology and Seismology Report) of the feasibility report.

2 Regional Physiography and Geology

2.1 Regional Physiography

The proposed Project site is situated in the Blue Ridge physiographic province, a mountainous zone that extends northeast-southwest from southern Pennsylvania to central Alabama and varies in width from less than 15 miles up to 70 miles. It is characterized by rugged terrain with valleys ranging in elevation from 1,000 ft in the south to greater than 1,500 ft in the north. Several mountain peaks have elevations greater than 6,000 ft with relief of up to 3,500 ft. In South and North Carolina. Massive and resistant basement gneiss, metaigneous, and metasedimentary rocks underlie most of the province with the valleys tending to follow weaker-rock outcrops (e.g., schist or minor carbonate rocks) and fracture or shear zones. The underlying geologic structure has a strong influence on local topography. Drainage is generally to the west; however, the slopes separating the Blue Ridge from the Piedmont physiographic province are typically steep and provide the initial run-off (headwaters) for some of the largest streams of the Piedmont, which drain to the east and southeast. The Project site is northwest of the Blue Ridge escarpment, which forms the southeastern boundary of the Blue Ridge physiographic province, with the Piedmont physiographic province to the south and southeast.

2.2 Regional Geology

The crystalline rocks of the southern Appalachians occur in northeast-trending parallel geologic terranes. The Project is within the Tugaloo terrane, which includes rocks of the eastern Blue Ridge province northwest of the Brevard zone (Hatcher 2002; Hatcher et al. 2007). The Blue Ridge province is a complex crystalline terrane consisting of Precambrian gneissic basement structurally overlain by a vast thickness of metasedimentary and metavolcanic rocks of Precambrian to lower Paleozoic age (Hatcher 1978a, 1978b). Numerous igneous bodies of mafic to felsic composition intrude into the basement core and into the overlying metasedimentary and metavolcanic sequences. The structure of the Blue Ridge is controlled by major thrust faults, associated complex polyphase folding, and subsequent brittle faulting (Hatcher 1978a; Clendenin and Garihan 2007a; 2007b).

The principal rock units of the western Tugaloo terrane (eastern Blue Ridge belt) at the Project site are the Tallulah Falls Formation (TFF) and the Toxaway Gneiss (TGn). The TFF consists of biotite gneiss (metagraywacke), pelitic schist, mafic volcanic rocks, and quartzite; the rocks of the TFF are migmatitic[1] in places. These rocks are intruded by Paleozoic granitoid rocks and overlie 1,150 to 1,200 million years ago (Ma) Precambrian Grenville basement rocks in the Toxaway Dome. The regional and site geology are discussed in detail in Volume 7 (Geology and Seismology Report) of the feasibility report.

[1] Migmatite – Rock consisting of alternating layers or lenses of granitic material in gneisses and schists; related to partial melting of the rock during deformation and metamorphism and then re-crystallization of the melt during the waning stages of metamorphism.

3 Site Investigation Program

The field program included five borings drilled by sub-contractor S&ME, Inc. and logged by HDR geologists. Packer testing was performed in all five borings after they were drilled to the required depths. The results are discussed in Section 4. Soil and rock samples obtained from the borings for testing were shipped to S&ME and GeoTesting Express, respectively.

The five borings were left open to the surface after drilling was completed to allow for downhole optical and acoustic televiewer logging to the maximum depth achievable by GEL Solutions before grouting them to the surface or monitoring well installation Borings B-21-2and B-21-5 had cloudy water that prevented complete optical televiewer surveys. The results of the televiewer data are discussed in Section 4.1.3.

After completion of the downhole logging, the casing through the overburden was pulled from borings B-21-1, B-21-4, and B-21-5 and boreholes backfilled with grout. Borings B-21-2 and B-21-3 were backfilled with grout to depths of 70 and 90 ft respectively before installation of monitoring wells.

Boring logs include lithology descriptions, packer testing intervals, and laboratory testing results. The logs and photographs of rock core and soil SPT samples are included in Appendix B. A boring summary is provided in Table 1.

Table 1. Boring Summary

Boring	Total Depth (ft)	Inclination	Azimuth	Soil Depth (ft)	Number of Water Pressure Tests	Well screen depths (ft)[1]	Acoustic and Optical Televiewer
B-21-1	250.8	90	NA	4.0	5	NA	Yes
B-21-2	300.8	90	NA	4.0	11	50-70	Yes
B-21-3	500.4	90	NA	6.4	7	70-90	Yes
B-21-4	150.4	90	NA	29.9	-	NA	Yes
B-21-5	120.3	90	NA	46.6	2	NA	Acoustic only

[1] Well screens are 2-inch diameter PVC

In addition to drilling and testing, surface geophysics including seismic refraction and MASW line surveys were completed by GEL Solutions. Geophysical surface investigations were carried out to better understand the subsurface conditions at the proposed locations of the Upper Reservoir I/O structure, the Lower Reservoir I/O structure, the low-pressure gate shafts and tunnels and the vertical water intake shafts.

3.1 Site Access and Restoration

All work related to the Bad Creek II Geotechnical Investigation was performed on land owned by Duke Energy. The Project site was accessed daily from HWY 130 and Bad Creek Road. Daily safety and pre-job briefings were held each morning in Duke Energy’s gated warehouse area where S&ME maintained a laydown area for equipment and supplies. All drilling and surface geophysical survey locations were within fenced areas and accessed through Duke Energy gates. Keys and automatic gate operators were provided to S&ME and HDR staff to facilitate efficient access and execution of work. GEL Solutions was accompanied by HDR staff for gate access to geophysical survey line locations. One of the drilling locations (Boring B-21-4) did not require any road improvement or drill pad construction. Boring B-21-2 required installation of a steel plate across the Bad Creek Road ditch and application of gravel for a limited distance off Bad Creek Road to prevent rutting of the soil due to daily support vehicle and water truck traffic. Borings B-21-1 and B-21-5 required some grading and clearing on the existing gravel road adjacent to the Upper Reservoir to facilitate drill rig set up and daily support vehicle and water truck access. Boring B-21-3 required construction of a new road and drill pad to provide drill rig, water truck, and support vehicle access on the southeast facing slope east of Bad Creek Road. Sumps to collect drill water and cuttings were constructed at borings B-21-1, B-21-2, B-21-3, and B-21-5. Duke Energy staff completed all site access improvements.

After completion of drilling, Duke Energy backfilled the sump areas and graded the ground surface. S&ME's subcontractor (Strickland, Inc.) completed drill site restoration including spreading and grading of any ruts and drill cuttings and application of seeding and straw to restore grass cover over the soil. Figure 1 shows the general site configuration.

Figure 1. Bad Creek II Geotechnical Investigation General Site Features Geotechnical Drilling

Borings were advanced vertically using either a track-mounted Burley D50 or ATV CME 550. Drilling through overburden/soil was accomplished using a 2 and 7/8-inch wash rotary bit with SPT at 5-ft intervals. Upon refusal at top of rock, the borings were reamed using a 4 and 7/8-inch-diameter wash rotary bit then HW casing installed into bedrock. Drilling in bedrock was achieved using HQ triple tube wireline coring with advancement of HW casing using a tri-cone bit at the casing shoe when needed to stabilize potentially unstable zones encountered during rock coring.

3.1.1 Standard Penetration Test (SPT) Sampling Method

Samples were collected from each borehole for purposes of geologic evaluation and geotechnical testing. SPTs were performed in general accordance with ASTM International (formerly American Society for Testing and Materials; ASTM) D1586-11, Test Method for Penetration Test and Split-Barrel Sampling of Soils. An 18-inch-long, 2-inch-outside-diameter, 1.375-inch-inside-diameter, split-spoon sampler was driven with an automatic 140-pound hammer, falling from a height of 30 inches. The number of blows required to achieve each of three, 6-inch increments of sampler penetration was recorded. The number of blows required to cause the last 12 inches of penetration is termed the Standard Penetration Resistance (N-value). When penetration resistances exceeded 50 blows for 6 inches or less of penetration, the test was generally terminated and the number of blows, along with the penetration distance, was recorded on the borehole log. All recovered SPT samples were transported to S&ME for laboratory testing as described in Section 3.5. Thirty-three of the samples recovered sufficient soil material for laboratory testing.

3.1.2 HQ-3 Triple-Tube Rock Coring

Rock core samples were obtained using a 5-ft-long, HQ-size, triple-tube core barrel. The triple-tube core barrel consists of inner and outer barrels and a split inner core tube. The outer barrel rotates while the inner barrel and inner split tube remain stationary. This system protects the core from the drilling fluid and reduces the torsional forces transmitted to the core. In addition, the split inner tube allows for detailed visual analysis of the relatively undisturbed core sample once it is extracted from the borehole. Most core runs were 5 ft long, although runs as short as 0.3 ft were made to improve recovery where low-rock-quality material was encountered. Cuttings were removed from the borehole circulating water through the drill steel and casing. The water used for drilling was obtained from the fire protection pond located in the former construction yard where Duke Energy has a warehouse, office, and maintenance facilities.

The drilling performed throughout the geotechnical investigation was high quality. Core drilling in 5-ft runs with an HQ triple barrel resulted in high recovery. There were few instances of core damage/loss from the drilling. When bedrock was severely weathered, there were indications of wash out and core loss. Careful extraction of the inner barrel using water pressure to push the inner barrel allowed extraction of the core without mechanical disturbance. In some cases, HWT casing was advanced into the bedrock to case through potentially unstable zones and prevent borehole collapse.

Rock core was logged and placed into wooden core boxes. In each core box, rock core was arranged in descending sequence beginning at the upper left end of the core box partition and continuing in the other partitions from left to right. Each core run was separated from the preceding run by blocks labeled with the depth. Each rock core box was photographed in the field after it was completely filled and the box properly labeled. On completion of drilling, core boxes were delivered by HDR personnel to the core shed located within the Duke Energy facilities area. Select core samples were designated for laboratory testing after a detailed core review. Rock core samples were wrapped with pipe insulation and duct tape and shipped to the selected laboratory GeoTesting Express of Acton, MA for the specified testing.

3.1.3 Water Pressure (Packer) Testing

Water pressure (WP) tests were performed in each borehole in bedrock to estimate in-situ hydraulic conductivity (k). WP tests were performed after drilling to final depth using a double packer system test apparatus, a water pump, and clean water obtained from the Duke Energy fire pond water supply. The rock core was evaluated as it was recovered and later transported to the storage facility where zones for WP testing were evaluated. Fractures in the bedrock were the main contributing factor to rock mass hydraulic conductivity. For borehole intervals where there were few or no fractures, the rock mass had an extremely low hydraulic conductivity (no water take at the maximum test pressure).

The Longyear Wireline Packer Type II system was used for packer testing at intervals specified by HDR geologists in the field. The packer system used a double packer with the stem length between packers at 5.5 ft. The HQ Wireline Packer has a deflated outer diameter of 2.13 inches (Gland) and inflated outer diameter of 4.6-inches which provided for successful packer seal in the nominal 3.8-inch HQ core hole. Packers were connected to a nitrogen gas source at the ground surface and expanded once in place at the proper depth. The nitrogen tanks were provided by S&ME and had readout pressure gauges mounted on the tank assembly lines. A Moyno™ pump bolted to the side of the drill rig was used to inject water at pressures specified by HDR into the rock at the packer test zone. A water flow meter and readout gauge were monitored by the HDR geologist to record the water inflow and pressure. The water pressure remained relatively constant during the WP tests with a few exceptions where test pressure could not be obtained in the test zone.

Testing was performed using the procedure outlined in the U.S. Bureau of Reclamation (1995) manual, which is a variation of Houlsby's (1976) method. As per of the USBR (1995) procedure using a series of stages, the test pressure was stepped up to a maximum pressure, calculated based on the estimated overburden pressure and the hydrostatic water level at the time of the testing, and then stepped back up and down over five stages with the third stage being the maximum. Houlsby's (1976) interpretative procedure was used to characterize the type of flow in the subsurface fractures. The pressure and flowmeter readings were taken at regular intervals and were used in the calculation of the k value. Results of the WP testing are presented in Appendix C and Table 5 and are discussed in Section 4.1.2.

3.2 Monitoring Wells

To monitor groundwater elevations, monitoring wells were installed in borings B-21-2 and B-21-3. Two-inch-inner diameter PVC screen and two-inch inner diameter PVC riser was used to construct the wells. Monitoring well construction details are presented in Appendix D.

3.3 Surface Geophysical Surveys

To investigate the subsurface conditions at the proposed locations of the Upper Reservoir I/O structure, the Lower Reservoir I/O structure, the proposed low pressure headrace tunnels and gate shafts, and the vertical water intake shafts area, seismic refraction and MASW line surveys were carried out by GEL Solutions. Twenty-three transects totaling approximately 6,000 linear ft were surveyed. The objective of the surface geophysical investigations was to produce profiles along the transects allowing the interpretation of the top of partially weathered rock (PWR) and top of unweathered rock (UWR) in conjunction with the boring and downhole logging data. The work was conducted from February 23, 2021, through March 5, 2021.

Prior to collecting seismic data, the transects were located with a Trimble 6 RTK/GPS and vegetation was cleared using hand tools as needed. GEL Solutions utilized an existing LiDAR topographic survey of the site to adjust the profiles for surface elevation variations.

Seismic refraction surveys were conducted using 10-hertz geophones spaced 10 ft apart and using a16 pound sledgehammer striking a plate (energy source) space every 30 ft along the line. MASW surveys were conducted using 10-hertz geophones spaced 10 ft apart with 16-pound sledgehammer strikes at 10 ft spacing along the transect. GEL Solutions collected and processed data using SeisImager software by Geometrics. Seismic refraction surveys provide two-dimensional V_p profiles and MASW surveys provide two-dimensional V_s profiles

The locations of the surface geophysical survey lines are presented on Project Drawings P-58, P-59, and P-61 presented in Appendix A. The GEL Solutions surface geophysical survey report is included in Appendix E.

3.4 Downhole Geophysical (Optical and Acoustic) Logging

Downhole optical and acoustic televiewer and three-arm caliper logs were completed by GEL Solutions and used to log each boring as far as the probes were able to go. Each borehole was flushed prior to downhole logging to provide the clearest possible borehole image. First, the optical image televiewer was used for the entire boring and the results were examined. In portions of the boring where water was present, an acoustic probe was used to survey the borehole in addition to optical logging. For zones where water within the borehole became cloudy even after flushing, the acoustic televiewer image was relied on to provide borehole information. Three-armed caliper logging was completed in each boring to measure the borehole diameter and its variations that are used to assess zones of poor recovery and specific features such as weathered zones observed in the rock core.

During post-processing, the optical and acoustical images are unwrapped, analyzed, and displayed. The displays show an image that simulates an intact core sample, which can be compared to the extracted sample. These images were analyzed for foliation, natural fractures and joints, fracture openness or width, and shear zones and provide orientation (dip and dip direction) of each feature. When compared with the actual core samples obtained from the boreholes, intervals of core loss and where core damage occurred were identified and the downhole images used to update information missing from the core logs. The GEL Solutions downhole geophysical report is presented in Appendix V.

3.5 Laboratory Testing

Soil and rock sample selection for testing was carried out by HDR from June 28 through July 2, 2021.

3.5.1 Soil Testing

Soil samples from SPT sampling were stored in sample jars and labelled at the time of drilling for laboratory testing and subsequently shipped to S&ME for testing (see Appendix G). Of the 43 SPT's completed, 33 of the soil samples recovered enough material for laboratory analysis to characterize the properties for the residual soil bedrock overburden and the soil portion of the landslide deposit at the Lower Reservoir I/O. In addition, one sample of soil material from rock core (RC-1) was obtained in B-21-4 and shipped to S&ME for testing. The laboratory testing summary for all soil samples is shown in Table 2 and the results are discussed in Section 5.1.

Table 2. Soil Sample Laboratory Testing

Laboratory	Test Method Name	ASTM Test Designation	Number of Tests
S&ME, Greenville, SC	Gradation without Hydrometer	D6913	34
	Atterberg Limits	D4318	34
	Natural Moisture		34

ASTM: American Society for Testing and Materials

3.5.2 Rock Testing

Rock core samples were selected to characterize the splitting tensile strength, unconfined compressive strength (UCS), and intact rock modulus of the major lithologies of the TGn discussed in Section 2. The rock core samples were selected at the time of detailed core review after completion of the drilling program, packaged to prevent breakage, and shipped to GeoTesting Express for testing (see Appendix H).

The laboratory testing summary for rock samples is shown in Table 3 and the results are discussed in Section 5.2.

Table 3. Rock Core Laboratory Testing

Laboratory	Test Method Name	ASTM Test Designation	Number of Tests
Geotesting Express, Acton, MA	Unconfined Compression Strength with Modulus	D7012-D	15
	Unconfined Compression Strength	D7012-C	20
	Splitting Tensile Strength	ASTM D3967	20

4 Field Investigation Results

4.1 Subsurface Data Evaluation Process

Site investigation data was derived from several different methods (e.g., borehole drilling, downhole geophysical logging, surface geophysical surveys, WP testing, laboratory testing, engineering evaluation). All exploration methods and associated data may not have been obtained in some or all portions of each boring (for example, packer tests were performed at selected intervals based on review of the rock core).

Boring logs present data from each borehole (with the exception of downhole geophysical data that is presented in Appendix F). The borehole depth is the first column on the left side of the log. The next column to the right provides the sample type and number including soil or rock core. The sample type is either an SPT as described in Section 3.1.1 or rock core run as described in Section 3.1.2. The next column to the right provides the number of blow counts in the SPT sampling process followed by the number of inches of soil recovery in the SPT sampler. The following columns provide rock core recovery and RQD. The material descriptions in each log represent a standardized field method of describing soil and rock developed by an HDR Senior Engineering Geologist based on a synthesis of published logging procedures. Material descriptions provide detailed information about the soil and/or rock unit encountered and contains information on soil/rock type, grain size, color, strength, weathering, plasticity (soil), and fracture spacing. Material descriptions are important for gaining an overall understanding of the rock or soil. Additional details such as drilling methods and conditions, casing depth, laboratory test results, WP test intervals, water level measurements, loss drilling fluid circulation, and any other pertinent information are detailed in the “Remarks” column on the right of the boring log sheets.

Rock cores were placed in core boxes, described in the field, then photographed and transported to the Duke Energy warehouse for storage, final core logging and subsequent review, and laboratory testing sample selection.

4.1.1 Standard Penetration Test, Recovery, and Rock-Quality Designation

As described in Section 3.1.1, SPT was performed within the overburden soils and the resulting N-values in blows/foot reported in parentheses on the boring logs. Fifty or more blows per 6 inches was considered refusal. This is represented with a notation showing the penetration in inches after 50 blows on the logs. For example, 50/2", is read as 50 blows for 2 inches of split-spoon penetration.

At the soil rock interface, the data collection method transitioned from SPT to rock coring where recovery and RQD were measured for each core run. Recovery represents the portion (reported as a percent) of the total core run length (typically 5 ft) that remains in the triple tube barrel when extracted from the boring. High recovery is desirable for understanding and interpreting the bedrock. Most of the core runs resulted in 100 percent recovery and recoveries less than 90 percent were limited to the upper 15 ft of rock when severely weathered rock with very close joint spacing was encountered in Boring B-21-1 and B-21-3. RQD is an approximate measure of rock quality and the jointing or fracturing of the rock mass. RQD is defined as the percentage of the length of intact core pieces longer than 100 millimeters (4 inches) divided by total length of the core run.

Based on the borings completed for this Phase II Geotechnical Study RQD increases with depth. Some exceptions across the site emerge when the RQD data is parsed into depth intervals and location as shown in Table 4. Boring B-21-1, B-21-3, and B-21-4 all have lower RQD values in the upper 50 ft indicating a more fractured and weathered rock mass. Boring B-21-2 and B-21-5 do not show the same trend. In addition, the RQD value of 56 percent in Boring B-21-3 occurs at a weathered shear zone at depth of 266.2 to 269.2 ft. There are borings from previous investigations near the proposed water conveyance alignment that are not included in this general assessment of RQD.

Table 4. RQD Variations in the Borings

Borings	Depth Interval Below Refusal (ft)	Minimum	Average	Maximum
B-21-1	37.5-87.5	42	85.8	100
	87.5-137.5	80	96.2	100
	137.5-250.8	98	99.9	100
B-21-2	61.5-111.5	86	94.3	100
	111.5-161.5	83	91.7	100
	161.5-300.8	77	96.4	100
B-21-3	20.5-70.5	0	77.4	100
	70.5-120.5	96	99.6	100
	120.5-500.4	56	99.2	100
B-21-4	90.5-140.5	52	79.7	92
	140.7-151.0	70	85	100
B-21-5	59.2-109.2	91	99.1	100
	109.2-120.3	100	100	100

4.1.2 Water Pressure Test Results

WP tests were performed in the borings after drilling was completed to evaluate the in-situ hydraulic conductivity as described in Section 3.1.3. WP tests were performed at selected intervals designated by HDR based on the anticipated potential for fractures or fracture systems to conduct water. The data from the WP testing were entered into a spreadsheet for processing and analysis. These spreadsheets are included with this report in Appendix C.

- Twenty-five WP tests were performed. Seven were performed in Boring B-21-1, eleven in Boring B-21-2, seven in Boring B-21-3, and two in Boring B-21-5.

Table 5 shows the results of all WP tests with the red text highlighting values that may be caused by leakage of the packer system for four tests in Boring B-21-2. The similarity of these values at 1.3 to 2.7E-06 centimeters/second (cm/sec) raised suspicion of a system leak. In three tests, pressure could not be built due to high permeability zones. These zones were:

- B-21-1: 45.2 to 50.7 ft. (8.3 ft below auger refusal). Bypass of upper packer due to fractured rock. Core logged as having moderate to severe weathering, close to very close joint spacing, and two open joints.
- B-21-3: 265.0 to 270.5 ft. Weathered shear zone from 266.2 to 269.2 ft.
- B-21-3: 75.0 to 80.5 ft (54.3 ft below auger refusal). Open joints at 79.2 and 79.3 ft with iron staining. One test in Boring B-21-3 from 68.5 to 74.0 ft (47.8 ft below auger refusal) had an open iron-stained fracture logged at 69.5 ft and resulted in K=1.1E-04 cm/sec.

Five tests resulted in no measured water take at injection pressures of 60 to 70 pounds per square inch (psi). These zones were selected for WP due to the presence of at least one fracture. These zones were:

- B-21-3: 286.1 to 291.6 ft (70 psi)
- B-21-3: 250.0 to 255.5 ft (70 psi)

- B-21-3: 244.5 to 250.0 ft (70 psi)
- B-21-3: 92.0 to 97.5 ft (70 psi)
- B-21-5: 67.5 to 73.0 ft (60 psi)

The remaining thirteen WP tests resulted in k values ranging from 5.7E-06 to 9.3E-05 cm/sec. The tests resulting in values higher than the 5.7E-06 to 9.3E-05 cm/sec range occurred at depths less than 55 ft below refusal (interpreted as TWR) with the exception of the shear zone encountered in Boring B-21-3 at a depth range of 266.2 to 269.2 ft below ground surface. The WP test data show that rock mass permeability is highest within an upper weathered zone generally within 50 ft below TWR and along a weathered shear zone at greater depths. Outside of these upper weathered and the weathered shear zone, the rock mass permeability is within the range of k 5.7E-06 to 9.3E-05 cm/sec due to fracture flow. Unfractured rock has no measurable permeability within the parameters of the water pressure injection test procedures.

Table 5. Water Pressure Test Results

Borehole	Test No.	Top of Borehole (Elevation - Feet)	Depth (ft)			Elevation (ft)			Depth of Hole (ft)	Water Level (ft)	Hydraulic Conductivity, k (cm/sec)	Remarks - Test Interval Description	Test Interpretation
B-21-1	Test 1	2320.5	91.4	to	96.9	2229.1	to	2223.6	250.8	22.4	2.4E-05	GRANITIC GNEISS, very hard, medium- to coarse-grained, fractures close to moderately close, very slight weathering to fresh.	Laminar flow. Decrease in flow with step-down pressures likely due to infilling/clogging of fractures during the test.
	Test 2	2320.5	75.2	to	80.7	2245.3	to	2239.8	250.8	25.6	7.3E-05	GRANITIC GNEISS, very hard, medium- to coarse-grained, fractures close to moderately close, very slight weathering to fresh.	Laminar flow. Decrease in flow with step-down pressures likely due to infilling/clogging of fractures during the test.
	Test 3	2320.5	60.2	to	65.7	2260.3	to	2254.8	250.8	25.6	5.4E-05	GRANITIC GNEISS, very hard, medium- to coarse-grained, fractures close to moderately close, very slight weathering to fresh.	Laminar flow in low permeability zone. Some removal of material in the fractures shown by the increase in flow rate during the step-down pressures.
	Test 4	2320.5	45.2	to	50.7	2275.3	to	2269.8	250.8	25.6	_	GRANTIC GNEISS, very hard, medium- to coarse-grained, fractures close to moderately close, slight to very slight weathering.	High permeability zone - Not able to build pressure due to leakage around the upper packer at maximum pump capacity. k in 10^{-1} to 10^{-2} cm/sec range.
	Test 5	2320.5	39.9	to	45.4	2280.6	to	2275.1	250.8	25.6	3.1E-05	GRANITIC GNEISS, very hard, medium- to coarse-grained, fractures close to moderately close, slight to very slight weathering.	Laminar flow in low permeability rock fracture zone.
B-21-2	Test 1	2283.1	187.5	to	193.0	2095.6	to	2090.1	300.8	36.4	9.2E-06	GRANITIC GNEISS, very hard, medium- to coarse-grained, moderate weathering to fresh, fractures tight to open at 10-to-45-degree dips, iron-staining present.	Practically Impermeable - Minimal Intake with an overall decrease in permeability with pressure and time indicating incomplete blockage of fractures by transported material.
	Test 2	2283.1	179.5	to	185.0	2103.6	to	2098.1	300.8	31.9	6.5E-05	GRANITIC GNEISS, very hard, medium- to coarse-grained, fresh joints, tight to open, 180.0' to 181.2' - highly fractured, Mn- and iron-staining present.	Low permeability with some washing out of material from the fractures increasing the permeability over Steps 4 and 5.
	Test 3	2283.1	167.0	to	172.5	2116.1	to	2110.6	300.8	33.2	6.4E-05	GRANITIC GNEISS, very hard, medium- to coarse-grained, moderately severe weathering, very close joints (168.5'-169.3' - highly fractured), tight to open, iron-staining.	Flow is laminar without removal of material or on clean fractures, discharge proportional to pressure head.
	Test 4	2283.1	161.5	to	167.0	2121.6	to	2116.1	300.8	26.4	2.8E-05	GRANITIC GNEISS, very hard, medium- to coarse-grained, fresh, hornblende augen, tight fractures at 20-to-50-degree dips, minor iron-staining.	Laminar flow, low permeability with some washing out of material from the fractures increasing the permeability during the duration of the test.
	Test 5a	2283.1	166.5	to	172.0	2116.6	to	2111.1	300.8	20.5	8.7E-05	GRANITIC GNEISS, hard, moderately severe weathering, very close joints, tight to open, with some iron-staining.	Laminar flow with low permeability and slight washing out of fractures.
	Test 5	2283.1	123.4	to	128.9	2159.7	to	2154.2	300.8	38.8	2.7E-06	GRANITIC GNEISS, very hard, medium- to coarse-grained, unweathered, and unfractured.	Low permeability zone; irregular flow that did not stabilize during pressure stages of the test. Estimated permeability k = 2.7E-06 cm/sec. Estimated value is questionable; could be due to leakage in the system and not water intake into rock fractures.
	Test 6	2283.1	115.5	to	121.0	2167.6	to	2162.1	300.8	33.1	1.5E-06	GRANITIC GNEISS, very hard, medium- to coarse-grained, fresh.	First run of test leakage around upper packer at 95 psi at start of Stage 3. Second run = Low permeability zone; irregular flow that did not stabilize during pressure stages of the test. Estimated permeability k = 1.5E-06/ cm/sec. Estimated value is questionable; could be due to leakage in the packer system and not water intake into rock fractures.
	Test 7	2283.1	99.5	to	105.0	2183.6	to	2178.1	300.8	37.7	1.7E-06	GRANITIC GNEISS, soft, moderate weathering, close to very close iron-stained joints, highly fractured zone.	Low permeability zone; irregular flow that did not stabilize during pressure stages of the test. Estimated permeability k = 1.7E-06 cm/sec Estimated value is questionable; could be due to leakage in the packer system and not water intake into rock fractures.
	Test 8	2283.1	85.5	to	91.0	2197.6	to	2192.1	300.8	26.5	1.2E-04	GRANITIC GNEISS, light gray, hard, thickly banded, very slight weathering, single open joint with iron-staining.	Water flow back up drill steel when reducing pressure from Stage 3 to 4 and Stage 4 to 5. Water table at end of test at 16.90 feet indicating leakage above the upper packer. Estimated permeability, k = 1.2E-04 cm/sec, is suspect and questionable because of water backflow and upper packer leakage; could be due to leakage in the packer system and not water intake into rock fractures.

Borehole	Test No.	Top of Borehole (Elevation - Feet)	Depth (ft)			Elevation (ft)			Depth of Hole (ft)	Water Level (ft)	Hydraulic Conductivity, k (cm/sec)	Remarks - Test Interval Description	Test Interpretation
	Test 9	2283.1	70.5	to	76.0	2212.6	to	2207.1	300.8	21.3	1.2E-05	GRANITIC GNEISS, medium- to coarse-grained, thinly to thickly banded with thin quartz bands, joints spaced close, 72.2' - 74.4' - 10- to 30-degree dip, close to open foliation joints, iron-staining.	Relatively low permeability, laminar flow with minor washing out of material from fractures.
	Test 10	2283.1	64.5	to	70.0	2218.6	to	2213.1	300.8	34.6	3.8E-05	GRANITIC GNEISS, medium- to coarse-grained, thinly to thickly banded with thin quartz bands, moderately weathered, joints spaced close, open foliation joints 10- to 40-degree dips, iron-staining.	Relatively low permeability, laminar flow with deceasing permeability due to incomplete blocking of fractures be transported materials.
B-21-3	Test 1	2230.1	286.1	to	291.6	1944.0	to	1938.5	500.4	149.0	-	GRANITIC GNEISS, very hard, medium- to coarse-grained, fresh (rock), fractures, iron- and Feldspar staining present, 288.7' to 289.9', fault zone 50º to 70º dip.	No take at 70 psi.
B-21-3	Test 2	2230.1	265.0	to	270.5	1965.1	to	1959.6	500.4	149.0	-	GRANITIC GNEISS, moderately hard to hard, moderate to slight weathering, shear zone from 265.4' to 269.2' consisting of numerous low angle open fractures with iron-staining.	Pumped ~200 gallons at 26 gpm; interval did not build pressure; high permeability related to the shear zone that crosses the test interval.
B-21-3	Test 3	2230.1	250.0	to	255.5	1980.1	to	1974.6	500.4	149.0	-	QUARTZ FELDSPAR GNEISS, very hard, medium- to very coarse-grained, very hard; at 253.4' contact with GRANITIC GNEISS hard to very hard, fine- to coarse-grained, slight weathering to fresh, fractures at 21.2', 30º dip, chlorite mineralization, 254.0', 30º dip, partially open, 254.0' 30º dip, iron-staining, trace clay.	No take at 70 psi.
B-21-3	Test 4	2230.1	244.5	to	250.0	1985.6	to	1980.1	500.4	144.4	-	GRANITIC GNEISS, very hard, fine-grained, thinly to thickly laminated, at 249.2' contact with QUARTZ FELDSPAR GNEISS, very hard, medium- to very coarse-grained, fractures at 248.3', 60º dip, tight, chlorite mineralization, 278.2', 20º dip, tight, chlorite mineralization.	No take at 70 psi.
B-21-3	Test 5	2230.1	92.0	to	97.5	2138.1	to	2132.6	500.4	145.6	-	GRANITIC GNEISS, very hard, medium-grained, thinly to thickly laminated, fresh weathering, open fracture at 94.8', 15º dip.	No take at 70 psi.
B-21-3	Test 6	2230.1	75.0	to	80.5	2155.1	to	2149.6	500.4	155.7	-	GRANITIC GNEISS, very hard, medium-grained, foliated, thinly to thickly laminated, fresh weathering, open fractures at 79.2' - 20º dip; 79.3' - 30º dip.	Flow rate at 24.5 gpm at 5 psi. Flow too high for a complete test. High permeability zone.
B-21-3	Test 7	2230.1	68.5	to	74.0	2161.6	to	2156.1	500.4	150.2	1.1E-04	GRANITIC GNEISS, very hard, medium-grained, very slight weathering to fresh, fractures at 69.5', 25º dip, tight, minor iron-staining, 72.9', 20º dip, biotite (?).	Flow is laminar without removal of material or on clean fractures, discharge proportional to pressure head.
B-21-5	Test 1	2314.0	67.5	to	73.0	2246.5	to	2241.0	120.3	21.4	-	GRANITIC GNEISS, with fractures along foliation, slight iron-staining.	No take at 60 psi.
B-21-5	Test 2	2314.0	62.5	to	68.0	2251.5	to	2246.0	120.3	16.3	5.5E-06	GRANITIC GNEISS, with fractures along foliation with minor iron-staining.	Low permeability zone: irregular flow that did not stabilize during pressure stages of the test. Estimated permeability k = 5.7E-06 cm/sec (Stage 5 pressure excluded due to no take).

4.1.3 Downhole Optical and Acoustic Televiewer Data

Optical televiewer logging was performed below any installed casing and acoustic televiewer logging was performed below the water level in the borings at the time of logging as described in Section 3.5.

The results of the televiewer data are presented in Appendix F and include:

- **Unwrapped Televiewer Image:** The walls of the boreholes unwrapped to a flat surface. The 360-degree unwrapped image begins with the zero degree representing magnetic north (azimuth).
- **Structure:** Discontinuity structure data is presented as dip direction, dip, and structure type on a tadpole plot. The dip direction is indicated by the orientation of the tick on each tadpole with up being 0/360 degrees. The dip is indicated by the x-axis location on the graphic column ranging from 0 (horizontal) to 90 (vertical) degrees.
- **Stereonet Plots:** Rose diagram plots developed by GEL Solutions and lower hemisphere stereonet plots developed by HDR (Appendix I) present the sources of identification of foliation and prominent joint/fracture sets.

The televiewer data were analyzed to identify rock type, joint structure, and other defects and characteristics that may influence hydraulic conductivity, excavation methods, stability, and treatment/stabilization requirements. Rock structure types identified from the televiewer data are presented in Table 6.

Table 6. Rock Structure Types

Designation	Rock Structure Type
S-F	Fracture/Joint Along Foliation
F	Joint
S	Foliation
Sh-F	Shear Plane
Flt	Fault Plane

Review of the televiewer data and other structural characteristics indicated a limited range of discontinuity orientations throughout the site subsurface. Foliation generally dips to the southeast with dip ranging from 19 degrees in Boring B-21-4 at the proposed Lower Reservoir I/O location to 36 degrees at the proposed Upper Reservoir I/O structure. Table 7 presents the statistical maximum of foliation at each boring location based on stereonet plots of the downhole data utilizing DIPS Version 8.008 software. The downhole data used was generated by GEL Solutions through downhole televiewer analysis wherein foliation was identified and measured approximately every 10 ft for each borehole. The stereonets for each boring presenting foliation and joint sets based on the downhole structural data as interpreted by HDR are presented in Appendix I Downhole Data Stereonets.

Table 7. Foliation Orientations

Boring	Orientation
B-21-1	N34E, 36SE
B-21-2	N43E, 28SE
B-21-3	N27E, 23SE
B-21-4	N43E, 19SE
B-21-5	N40E,35SE

Most joints observed in the downhole televiewer data are joints along foliation. One additional discontinuity set strikes generally N70E and dips 60 to 65 degrees to the NW. An additional discontinuity set strikes N76E and dips 35 degrees to the NW. Table 8 presents the discontinuity sets identified in each boring from the downhole optical and acoustic televiewer data. The set number corresponds to the set identified on the stereonets presented in Appendix I.

Table 8. Major Discontinuity Fracture Sets

Boring	Set Number[1]	Orientation	Discontinuity type
B-21-1	1m	N36E;17SE	Foliation Joint (S-F)[2]
B-21-1	2m	N45E; 5NW	Joint (F)
B-21-2	1m	N48E; 25SE	Foliation Joint (S-F)
B-21-2	2m	N69E; 63NW	Fault/Joint (Flt & F)
B-21-2	3m	N76E; 35NW	Joint (F)
B-21-3	1m	N46E; 21SE	Foliation Joint (S-F)
B-21-4	1m	N28E;11SE	Foliation Joint (S-F)
B-21-5	1m	N60E; 30SE	Foliation Joint (S-F)
B-21-5	2m	N71E; 65NW	Foliation Joint

1. From Stereonets in Appendix I.
2. Abbreviation for Rock Structures used on the Stereonets in Appendix I.

A number of specific discontinuities comprised of faults and shear zones were identified during rock core inspection and then compared to the optical and acoustic televiewer logs. Some but not all of the faults and shear zones were discernible in the optical and acoustic logs. Table 9 presents the boring in which each feature was observed, the depth, strike, dip, and description. The shear zones are parallel to foliation/banding in the TGn consistent with previous observations and geologic mapping (Schaeffer 2016). Faults generally dip 55 to 70 degrees to the northwest.

Table 9. Shear Zones and Fault Features

Boring/Set Number	Strike	Dip	Description	Depth in Borehole
B-21-2	N78E;	56NW	Flt	167.6
	N72E	54NW	Flt	168.2
	N68E	62NW	Flt	168.5
	N67E	60NW	Flt	168.6
	N67E	63NW	Flt	180.4
	N88W	66S	Flt	180.5
	N65E	62NW	Flt	180.6
	N66E	65NW	Flt	180.8

Boring/Set Number	Strike	Dip	Description	Depth in Borehole
	N68E	61NW	Flt	214.5
B-21-3	N45E	24SE	Sh-F	253.0
	N47E	28SE	Sh-F	253.0
	N69E	27SE	Sh-F	253.1
	N66E	28SE	Sh-F	253.1
	N62E	26SE	Sh-F	253.2
	N59E	27SE	Sh-F	253.3
	N60E	32SE	Sh-F	253.3
	N77W	28SSE	Sh-F	253.7
	N64E	30SE	Sh-F	254.0
	N	11E	Sh-F	265.2
	N49E	16SE	Sh-F	266.4
	N15W	10ENE	Sh-F	266.5
	N22E	31SE	Sh-F	266.7
	N31E	32SE	Sh-F	266.8
	N59E	28SE	Sh-F	267.1
	N65E	21SE	Sh-F	267.2
	N66E	70NW	Flt	287.8
	N64E	62NW	Flt	287.9

4.1.4 Surface Geophysical Refraction and MASW Results

GEL Solutions collected seismic refraction and MASW data along 23 transects that varied in length from 31 to 602 ft each (see Table 10). The total length of transects completed along ground surface is 6,078 ft. Site conditions dictated that the transect locations varied somewhat from the planned locations. Three sections of the initially proposed transects were excluded due to areas of steep terrain that were not safely accessible and that presented technical challenges related to the reliability of data collection on steep slopes. Sections between U2A and U2B, L5A and L6A, and L9A and L9B were eliminated due to these limitations. Drawings P-58, P-59, and P-61 in Appendix A present the locations of the geophysical lines.

Table 10. Surface Geophysics Line Transects

Transect	Length (ft)
U1 to U2	270
U2 to U2A	280
U2A to U2B	109
U2B to U3	141
U4 to U4A	140
U4A to U4B	207
U4B to U5	161
U6 to U7	499
U8 to U9	400
U10 to U11	400
U12 to U13	602
U14 to U15	400
L1 to L2	453
L3 to L4	280
L5 to L5A	89
L5A to L6A	462
L6A to L6	462
L7 to L8	233
L8 to L9B	205
L9B to L9A	31
L9A to L9	161
L10 to L11	170
L12 to L13	270

The purpose of conducting the seismic refraction and MASW surveys is to develop reasonably accurate profiles of PWR and UWR that can be used by HDR in estimates of excavation requirements for the proposed Upper and Lower Reservoir I/O works and gate and vertical intake shafts yards. GEL Solutions used both the seismic refraction and MASW data to interpret top of PWR and top of UWR that are presented as dashed pink lines for PWR and dashed cyan lines for UWR on the seismic refraction and MASW profiles presented in Appendix F. Borings from the previous investigations for the Bad Creek 1 construction were provided to GEL Solutions to assist with calibration of interpretations with available drilling data. GEL Solutions interpretations of the PWR and UWR were reviewed and revised by HDR prior to developing preliminary excavation objectives. Using borehole data and knowledge of the characteristics of the granitic gneisses at the site (including V_p and V_s values in partially and un-weathered TGn) gained from previous site investigations that include drilling, surface geologic mapping, detailed mapping of the existing Bad Creek subsurface structures, and current geologic mapping of a landslide at the Lower Reservoir I/O. HDR reinterpreted the seismic data and those interpretations are discussed in Volume 7 – Appendix D.

4.1.5 Monitoring Wells

Table 11 lists the borings and monitoring well screened interval depths and measured static water level. The water levels reported in Table 11 were measured on June 26, 2021. Drilling was completed in Boring B-21-2 on May 13, 2021, and water pressure tests were completed on May 20, 2021. Drilling was completed on May 12, 2021, in Boring B-21-3 and water pressure tests completed on May 20, 2021. Due to the duration of time (36 days) between the completion of water pressure tests and the final water level measurement, the water levels reported in Table 11 are considered representative of static water levels free of the influence from drilling and water pressure testing. Boring B-21-3 was bailed on June 14, 2021, and the water levels measured before and after bailing of 75.3 ft and 75.5 ft indicate rapid recovery and that a reliable static water level has been measured.

Table 11. Monitoring Wells and Groundwater Levels

Borehole	Elevation	Screened Interval Depth (ft)			Screened Interval Elevation (ft)	Depth of Water (ft)	Water Level Elevation (ft)
B-21-2	2283.1	20.0	to	50.0	2263.1 to 2233.1	33.0	2250.1
B-21-3	2230.1	26	to	91	2204.1 to 2139.1	75.5	2154.6

4.2 Borehole Discussion

The drilling program consisted of five borings as shown on the Project Drawings in Appendix A. A brief discussion of the main findings from each boring is presented below.

4.2.1 Individual Boreholes

B-21-1: Boring B-21-1 was drilled at elevation 2320.5 ft above mean sea level to a depth of 250.8 ft below ground surface. Overburden consisted of silty gravel (fill) and residual soil/saprolite derived from the bedrock. SPT values ranged from 50/4” to 50/1”. Alternating soft and hard layers were encountered during drilling to refusal. Drilling, SPT, and HW casing was continued with the casing advanced to 37.5 ft. HQ coring began at 37.5 ft in slightly weathered, hard granitic gneiss. Joint spacing ranged from close to moderately close with limited zones of very close joint spacing to approximate depth of 109 ft. From 109 ft to the bottom of the boring at 250.8 ft, joint spacing was very wide and weathering fresh to slightly weathered. During drilling operations water level measurements in the open borehole ranged from 22.4 to 25.6 ft below ground surface. After drilling was complete and immediately prior to water pressure testing, groundwater was measured at 36 ft below ground surface. Significant intervals/features observed included:

- <u>46.8-47.5 ft</u>: Moderately severe weathering and very close joint spacing; core loss 47.0-47.5 ft, could not build pressure during water pressure test from 45.2 to 50.7 ft.
- <u>78.9-79.1 ft</u>: Fault healed with chlorite with 2-cm displacement.
- <u>184.6 ft</u>: Fault zone with brecciation; calcite and chlorite healing. NE strike; NW dip.
- <u>201.8-202.3 ft.</u>: Fault zone with brecciation; calcite and chlorite healing. NE strike; 70º NW dip.

B-21-2: Boring B-21-2 was drilled at elevation 2,283.1 ft above mean sea level to a depth of 300.8 ft below ground surface. Overburden consisted of 7.5 ft of silty gravel with cobbles and boulders (fill material) and sandy silt and silty sand saprolite derived from bedrock to 57.0 ft then sandy gravel with silt (PWR) to 61.8 ft. SPT N-values ranged from 5 to 50/5". HW casing was advanced to 61.4 ft and HQ coring began at 61.8 ft in moderately weathered, hard granitic gneiss to 66.5 ft then slightly weathered to fresh gneiss with limited zones of moderate weathering to the bottom of the borehole. Joint spacing ranged from close to very close to 66.5 ft then moderately close to close to 75.8 ft. From 75.8 ft to 250.8 ft, joint spacing was wide to very wide with limited zones of close joint spacing. After drilling was complete the water level in the borehole was measured at 34.7 ft below ground surface on April 19, 2021. Significant intervals/features observed included:

- 167.2 ft*:* Fault zone dipping 30 degrees, with brecciated quartz and feldspar in chlorite matrix.
- 215.3-215.8 ft: Fault zone with brecciation; calcite and chlorite healing; dipping 60 degrees.
- 293.9-294.5 ft: Fault zone, 75-degree dip, chlorite and calcite on fault planes, trace pyrite, 1-6 cm displacement, NE strike/NW dip.

B-21-3: Boring B-21-3 was drilled at elevation 2,230.1 ft above mean sea level to a depth of 500.4 ft below ground surface. Overburden consisted of micaceous clayey sand at the ground surface then silty sand and sand with trace gravel (saprolite) to 20.5 ft. SPT N-values ranged from 6 to 50/0" at refusal at 20.5 ft. HW casing was advanced to 20.5 ft. and HQ coring began at 20.5 ft in moderately to slightly weathered, moderately hard to hard granitic gneiss with zones of severe weathering and close to moderately close joint spacing. At a depth of 45.4 ft, there was a change to slightly weathered rock and joint spacing to wide with limited zones of close joint spacing and increased weathering. From 80.5 to 265.4 ft, drilling encountered fresh gneiss with wide to very wide joint spacing. A shear zone was encountered from 266.2-269.2 ft. From a depth of 270 ft. to the bottom of the boring at depth of 500.4 ft, bedrock was slightly weathered to fresh with wide to very wide joint spacing and limited zones of close joint spacing. During drilling on April 29, 2021, water level in the borehole was measured at 56.3 ft below ground surface. On May 11, 2021, water level was measured at 146.6 ft below ground surface. The significant drop in water elevation is related to the shear zone at 266.2 ft where drill water circulation was lost. Significant intervals/features observed in Boring B-21-3 included:

- 41.0 ft: Complete loss of drilling water.
- 61.4-61.5 ft*:* Very severely weathered, saprolitic material.
- 75.0-80.5 ft: Maximum pumping rate during a water pressure test could not build pressure; 20-degree dipping open joint with iron staining at 79.2 ft; likely cause of high flow.
- 253.8-254.1 ft: Shear zone dipping 30 degrees along foliation. Iron staining on shear plane with clay and sand infilling.
- 266.3-269.3 ft: Zone of sheared weathered rock; 100% loss of drill water; could not build pressure in water pressure test.
- 288.7-289.2 ft: Fault Zone, 50-degree dip, open, slickensides indicated oblique slip movement, iron staining, chlorite, clay infilling, NE strike/NW dip.
- 289.6-289.9 ft: Fault plane, 70-degree dip, open, slickensides indicate oblique slip movement, iron staining, clay infilling, NE strike/NW dip.

B-21-4: Boring B-21-4 was drilled at elevation 1,119.4 ft above mean sea level to a depth of 151.0 ft below ground surface. Overburden extended to a depth of 90.7 ft and consisted of large blocks of banded augen granitic gneiss (15 to 17-ft diameter) in a soil matrix of silty sand and clayey sand. Overburden is interpreted as landslide material. HW casing was advanced to 90.7 ft. HQ coring began at 90.7 ft in moderately to moderately to severely weathered banded augen granitic gneiss with closely to moderately closely spaced jointing and iron staining observed on most of the joints to a depth of 141 ft, then a reduction in iron staining from a depth of 141 ft to the boring termination depth of 151 ft. Significant intervals/features observed in Boring B-21-4 included.

- A zone of hard, sheared, mylonitic rock was observed from 126.1 ft to 126.9 ft below ground surface.

B-21-5: Boring B-21-5 was drilled at elevation 2,314.0 ft above mean sea level to a depth of 120.3 ft below ground surface. This boring was added to the original scope to investigate an anomalously low area in top of (PWR) and top of firm rock (TFR) along seismic line U4A-U4B and to investigate the presence, depth, orientation, and characteristics of a shear zone mapped immediately to the west in the Upper Reservoir. Overburden extended to a depth of 59.2 ft and consisted of silty sand (saprolite) with zones of PWR as defined by SPT blow counts of 50/0” to 50/3”. HW casing was advanced to 59.2 ft and HQ coring began at a depth of 59.2 ft and advanced to a final depth of 120.3 ft. Bedrock consisted of granitic gneiss with 0.4 to 0.6-ft thick zones of quartz-feldspar gneiss. The shear zone mapped in the Upper Reservoir to the west was not identified in the rock core during drilling. Based on possible variability in the dip and dip direction of the shear zone, it may have been drilled through in the saprolite or may be deeper than the boring termination depth.

5 Laboratory Testing Results

5.1 Soil Testing Results

As described in Section 3.5.1, index soil testing was performed at S&ME laboratories. Samples were placed in jars (labeled at the time of SPT sampling), boxed up, and shipped to the S&ME laboratory.

5.1.1 Laboratory Soil Testing

Within each of the five boreholes, 33 soil samples were taken from the SPT split-spoon during drilling of the five borings in the overburden materials that contained enough material for laboratory testing. In addition, one soil/saprolite sample from rock core (RC-1) in B-21-4 retrieved enough material for testing. The sample depths range from 0 to 60.7 ft across the five borings. The soil is predominantly silty sand with poorly-graded sand with silt and well-graded sand with silt in the upper 0 to 5 ft. The natural moisture content across the site where the borings were conducted ranges from 2.1 to 26.4 percent. The percent fines of the samples range from 1.4 to 46.8 percent. The soil is predominately non-plastic with the exception of ten samples that exhibited minor plasticity. The ranges for the Atterberg Limits for the plastic samples are as follows: The liquid limit range is from 27 to 33 percent and the plasticity index range is from 1 to 11 percent. A summary of soil sample results is included in Table 12 and complete laboratory test results are in Appendix G.

Table 12. Soil Sample Laboratory Test Results

Borehole	Sample ID	Sample Depth	USCS Symbol	SPT (N)	Natural Moisture (%)	Percent Finer #200	Atterberg Limits	
							LL (%)	PI (%)
B-21-1	SS-1	0.3	SP-SM	81	3.0	10.0	NP	NP
	SS-2	3.1	SP-SM	-	8.6	11.4	NP	NP
	SS-3	8.1	SM	50/6"	12.0	12.0	NP	NP
B-21-2	SS-1	0	SW-SM	23	2.9	10.8	NP	NP
	SS-2	5	SP-SM	40	4.3	8.6	NP	NP
	SS-3	8.5	SC	9	19.2	46.5	33	11
	SS-4	13.5	SM	5	16.7	33.3	30	5
	SS-5	18.5	SM	7	15.1	23.0	NP	NP
	SS-6	23.5	SM	9	20.9	35.8	32	5
	SS-7	28.5	SM	11	14.4	22.8	NP	NP
	SS-8	33.5	SM	22	22.5	20.7	NP	NP
	SS-11	48.5	SM	15	26.4	22.9	NP	NP
	SS-12	53.5	SM	42	20.4	25.6	NP	NP
	SS-13	58.5	SM	-	17.5	24.0	NP	NP
B-21-3	SS-1	0	SM	6	16.3	46.8	33	8
	SS-2	2.7	SM	21	13.6	22.3	NP	NP
	SS-3	7.7	SM	13	18.0	20.6	NP	NP
	SS-4	12.7	SM	50/6"	13.9	17.6	NP	NP
B-21-4	SS-1	0	SP-SM	23	3.9	9.3	NP	NP
	SS-2	3.5	SW	58	5.9	1.4	NP	NP
	SS-3	18.5	SM	5	23.4	30.5	28	2
	SS-4	23.5	SM	8	23.2	33.4	27	1
	SS-5	28.5	SM	16	16.6	19.2	NP	NP
	SS-6	33.5	SM	6	20.1	29.6	27	2
	RC-1	60.7	SM	-	2.1	27.9	NP	NP
B-21-5	SS-1	2.6	SM	-	14.5	20.1	NP	NP
	SS-2	7.6	SM	26	15.1	27.8	NP	NP
	SS-3	12.6	SM	62	13.7	24.3	NP	NP
	SS-4	17.6	SM	-	12.5	16.1	NP	NP
	SS-6	27.6	SM	-	21.3	27.3	NP	NP
	SS-10	47.6	SM	-	14.4	26.1	NP	NP
	SS-17	32.6	SM	50/6"	19.3	29.8	27	NP
	SS-18	37.6	SM	50/6"	18.7	29.7	27	NP
	SS-21	52.6	SC-SM	93	17.6	36.0	27	5

PI = plasticity index; LL = liquid limit; NP =non-plastic
SP = Poorly graded sands and gravelly sands, little or no fines; SM = silty sands, sand-silt mixtures; SC = Clayey sands, sand-clay mixtures; SW = Well-graded sands and gravelly sands, little or no fines; S = Sands

5.2 Rock Testing Results

The results of the rock testing program described in Section 4.1.3 are provided in Table 13 through Table 15 along with boring number, depth interval of sample, and sample lithology. Appendix H includes the GeoTesting Express rock testing summary and forms.

Table 13 presents the results of UCS test results on 34 rock core samples with the ASTM D7012C procedure. One sample from Boring B-21-3 (depth 278.7 ft) arrived at the laboratory broken and not tested. Unit weight in pounds per cubic foot (pcf) was calculated for each rock core specimens prior to testing. Twenty-five of the UCS tests were performed on granitic gneiss, one on quartz feldspar gneiss, three on biotite gneiss, and five on banded augen granitic gneiss.

Table 14 presents the results of uniaxial compression test with elastic modulus results on 15 rock core samples with the ASTM D7012D procedure. Eleven tests were performed on samples of granitic gneiss, three tests were performed on banded augen gneiss, and one test performed on biotite gneiss.

Table 13. Results of Unconfined Compressive Strength Tests (ASTM D7012-C and D7012-D)

Borehole	Sample Number	Depth Interval	Date Sample Tested	Testing	Field Lithology	Unit Weight (pcf)	UCS (psi)	Failure Type	Meets ASTM D4543	Meets ASTM D7012	Note(s)
B-21-1	B-21-1-2C	103.51-103.95	8/16/2021	UCS	Granitic Gneiss	166	17412	3	Yes		
	B-21-1-4C	125.03-125.47	8/16/2021	UCS	Granitic Gneiss	166	23733	1	Yes		
	B-21-1-6C	174.31-174.75	8/16/2021	UCS	Granitic Gneiss	168	17884	1	Yes		
	B-21-1-8C	212.34-212.78	8/16/2021	UCS	Granitic Gneiss	169	20886	1	Yes		
	B-21-1-5CM	146.28-146.72	8/30/2021	UCS w/ EM	Granitic Gneiss	168	20681	1		Yes	
	B-21-1-10CM	231.4-231.84	8/25/2021	UCS w/ EM	Granitic Gneiss	168	19967	1		Yes	
B-21-2	B-21-2-14C	295.1-295.54	8/16/2021	UCS	Granitic Gneiss	168	19903	1	No		2,*
	B-21-2-2C	106.28-106.72	8/16/2021	UCS	Granitic Gneiss	168	19973	3	Yes		
	B-21-2-5C	159.9-160.4	8/16/2021	UCS	Granitic Gneiss	167	18775	3	Yes		
	B-21-2-8C	219.9-220.34	8/16/2021	UCS	Granitic Gneiss	168	18747	3	Yes		
	B-21-2-10C	238.59-239.03	8/16/2021	UCS	Granitic Gneiss	166	22699	1	Yes		
	B-21-2-3CM	132.21-132.65	8/25/2021	UCS w/ EM	Granitic Gneiss	167	18760	1		Yes	
	B-21-2-6CM	166.29-166.73	8/25/2021	UCS w/ EM	Granitic Gneiss	168	18161	1		Yes	
	B-21-2-11CM	255.26-255.7	8/30/2021	UCS w/ EM	Granitic Gneiss	168	19552	1		Yes	
	B-21-2-12CM	267.15-267.65	8/25/2021	UCS w/ EM	Granitic Gneiss	169	20648	1		Yes	
	B-21-2-15CM	299.09-299.52	8/30/2021	UCS w/ EM	Granitic Gneiss	169	19803	1		Yes	
B-21-3	B-21-3-21C	481.77-482.21	8/16/2021	UCS	Granitic Gneiss	168	18086	3	Yes		
	B-21-3-2C	233.17-233.61	8/16/2021	UCS	Granitic Gneiss	167	18446	3	Yes		
	B-21-3-5C	250.68-251.12	8/16/2021	UCS	Quartz-Feldspar Gneiss	162	32661	1	Yes		
	B-21-3-9C	332.35-332.79	8/16/2021	UCS	Granitic Gneiss	168	21079	1	Yes		
	B-21-3-11C	364.7-365.2	8/16/2021	UCS	Granitic Gneiss	167	18777	1	Yes		
	B-21-3-13C	380.6-381.04	8/16/2021	UCS	Biotite Gneiss	169	19250	3	Yes		
	B-21-3-15C	285.5-286.24	8/16/2021	UCS	Biotite Gneiss	168	20357	1	Yes		
	B-21-3-18C	433.02-433.46	8/16/2021	UCS	Granitic Gneiss	168	22047	3	Yes		
	B-21-3-3CM	237.50-237.94	8/25/2021	UCS w/ EM	Granitic Gneiss	169	14789	1		Yes	
	B-21-3-10CM	356.21-356.65	8/30/2021	UCS w/ EM	Granitic Gneiss	168	19577	1		Yes	
	B-21-3-16CM	389.4-389.9	8/30/2021	UCS w/ EM	Biotite Gneiss	167	22228	1		Yes	
	B-21-3-19CM	434.59-435.03	8/30/2021	UCS w/ EM	Granitic Gneiss	169	20417	1		Yes	

Borehole	Sample Number	Depth Interval	Date Sample Tested	Testing	Field Lithology	Unit Weight (pcf)	UCS (psi)	Failure Type	Meets ASTM D4543	Meets ASTM D7012	Note(s)
	B-21-3-22CM	483.68-484.12	8/25/2021	UCS w/ EM	Granitic Gneiss	169	10642	1		Yes	
	B-21-3-7C	278.7		UCS	Granitic Gneiss						5
B-21-4	B-21-4-2C	122.06-122.50	8/16/2021	UCS	Banded Augen Granitic Gneiss	168	15546	1	Yes		
	B-21-4-5C	130.4-130.95	8/16/2021	UCS	Banded Augen Granitic Gneiss	168	16463	1	Yes		
	B-21-4-3CM	124.19-124.63	8/25/2021	UCS w/EM	Banded Augen Granitic Gneiss	168	12121	1		Yes	
	B-21-4-6CM	135.21-135.65	8/30/2021	UCS w/EM	Banded Augen Granitic Gneiss	168	20238	1		Yes	
	B-21-4-8CM	141.75-142.19	8/30/2021	UCS w/EM	Banded Augen Granitic Gneiss	168	15555	1		Yes	

Failure types: 1=Intact material failure; 3=Intact material failure and discontinuity failure. Notes: 2= The core (as-received by the lab) did not meet the ASTM side straightness tolerance due to irregularities in the sample as cored. 5= Sample received broken by lab and unfit for testing. *Because the indicated test specimens did not meet the ASTM D4543 standard tolerances, the results reported here may differ from those for a test specimen within tolerances. Notes: UCS = unconfined compressive strength; EM=elastic modulus

Table 14. Results of Uniaxial Compression Test with Elastic Modulus (ASTM D7012D)

Borehole	Sample Number	Depth Interval (ft)	Date Sample Tested	Testing	Field Lithology	Stress Range (psi)	Young's Modulus (psi)	Poisson's Ratio	Peak Compressive Strength (psi)	Unit Weight (pcf)
B-21-1	B-21-1-5CM	146.28-146.72	8/30/2021	UCS w/ EM	Granitic Gneiss	2100-7600 7600-13100 13100-18600	3.24E+06 3.98E+06 3.72E+06	0.21 0.34 0.49	20,681	168
	B-21-1-10CM	231.4-231.84	8/25/2021	UCS w/ EM	Granitic Gneiss	2000-7300 7300-12600 12600-18000	3.43E+06 4.43E+06 4.63E+06	0.24 0.40 ---	19.967	168
B-21-2	B-21-2-3CM	132.21-132.65	8/25/2021	UCS w/ EM	Granitic Gneiss	1900-6900 6900-11900 11900-16900	3.22E+06 4.13E+06 4.30E+06	0.28	18,760	167
	B-21-2-6CM	166.29-166.73	8/25/2021	UCS w/ EM	Granitic Gneiss	1800-6700 6700-11500 11500-16300	3.71E+06 5.17E+06 5.58E+06	0.21 0.33 0.42	18,161	168
	B-21-2-11CM	255.26-255.7	8/30/2021	UCS w/ EM	Granitic Gneiss	2000-7200 7200-12400 12400-17600	3.85E+06 4.54E+06 4.50E+06	0.20 0.30 0.44	19,552	168
	B-21-2-12CM	267.15-267.65	8/25/2021	UCS w/ EM	Granitic Gneiss	2100-7600 7600-13100 13100-18600	4.23E+06 5.01E+06 5.31E+06	0.18 0.30	20,648	169
	B-21-2-15CM	299.08-299.52	8/30/2021	UCS w/ EM	Granitic Gneiss	2000-7300 7300-12500	3.42E+06 4.51E+06	0.17 0.26	19,803	169

Borehole	Sample Number	Depth Interval (ft)	Date Sample Tested	Testing	Field Lithology	Stress Range (psi)	Young's Modulus (psi)	Poisson's Ratio	Peak Compressive Strength (psi)	Unit Weight (pcf)
						12500-17800	4.26E+06	0.32		
B-21-3	B-21-3-3CM	237.50-237.94	8/25/2021	UCS w/ EM	Granitic Gneiss	1500-5400 5400-9400 9400-13300	2.26E+06 3.59E+06 4.01E+06	0.15 0.30 0.38	14,789	169
	B-21-3-10CM	356.21-356.65	8/30/2021	UCS w/ EM	Granitic Gneiss	2000-7200 7200-12400 12400-17600	2.93E+06 4.21E+06 4.92E+06	0.27 --- ---	19,577	168
	B-21-3-16CM	389.4-389.9	8/30/2021	UCS w/ EM	Biotite Gneiss	2200-8200 8200-14100 14100-20000	3.25E+06 4.14E+06 3.85E+06	0.17 0.31	22,228	167
	B-21-3-19CM	434.59-435.03	8/30/2021	UCS w/ EM	Granitic Gneiss	2000-7500 7500-12900 12900-18400	3.74E+06 4.70E+06 4.62E+06	0.19 0.30 0.46	20,417	169
	B-21-3-22CM	483.68-484.12	8/25/2021	UCS w/ EM	Granitic Gneiss	1100-3900 3900-6700 6700-9600	3.54E+06 3.74E+06 4.77E+06	0.33	10,642	169
B-21-4	B-21-4-3CM	124.19-124.63	8/25/2021	UCS w/ EM	Banded Augen Granitic Gneiss	1200-4400 4400-7700 7700-10900	1.90E+06 2.87E+06 3.52E+06	0.21 0.30 0.38	12,121	168
	B-21-4-6CM	135.21-135.65	8/30/2021	UCS w/ EM	Banded Augen Granitic Gneiss	2000-7400 7400-12800 12800-18200	3.13E+06 4.21E+06 4.17E+06	0.16 0.29 0.39	20,238	168
	B-21-4-8CM	141.75-142.19	8/30/2021	UCS w/ EM	Banded Augen Granitic Gneiss	1600-5700 5700-9900 9900-14000	2.28E+06 2.95E+06 3.52E+06	0.13 0.27 ---	15,555	168

Note: UCS = unconfined compressive strength; EM=elastic modulus

Table 15 presents the results of the Splitting Tensile Strength Tests. Of the twenty rock samples, fourteen were granitic gneiss, three were samples banded augen granitic gneiss, two were biotite gneiss, and one sample was quartz feldspar gneiss. The granitic gneiss splitting tensile strength results ranged from 5,217 psi to 7,106 psi with a mean of 6,249 psi. The banded augen granitic gneiss results ranged from 5,220 psi to 3,834 psi. The biotite gneiss sample test results were 6,267 and 6,736 psi. The lone quartz feldspar gneiss sample splitting tensile strength result was 6,999 psi. All specimen failures were intact failures, meaning that discontinuities did not influence the failure.

Table 16 presents a statistical analysis of the unit weight, UCS, and splitting tensile strength. One quartz feldspar gneiss sample had the highest UCS of 32,661 psi with only one sample tested. As presented in Table 16, the granitic gneiss test values ranged from 10,642 to 23,733 psi. with a Mean value of 19,258 psi. Biotite gneiss results ranged from 19,250 to 22,258 psi with a Mean value of 20,611 psi. Banded augen gneiss results ranged from 12,121 to 20,238 psi. The mean value was 15,985 psi. There is not enough data to draw conclusions regarding the relative strength of the quartz feldspar gneiss when compared to the other tested rock types. Based on the data, biotite and granitic gneiss have similar UCS values. The banded augen granitic gneiss appears to be slightly lower in UCS when compared to the other lithologies but the fact that the samples were all from the upper 50 ft (TFR) makes any such conclusion premature. Unit weight ranged from 166 to 169 pcf with the mean value 167.8 pcf.

Table 15. Results of Splitting Tensile Strength Tests (ASTM D3967)

Borehole	Sample Number	Test No.	Depth Interval	Date Sample Tested	Testing	Field Lithology	Failure Load (lbs)	Splitting Tensile Strength (psi)	Failure Type
B-21-1	B-21-1-1T	ST-1	102.88-102.97	7/27/2021	Splitting Tensile	Granitic Gneiss	5,973	1,410	1
B-21-1	B-21-1-3T	ST-2	122.20-122.29	7/27/2021	Splitting Tensile	Granitic Gneiss	6,573	1,650	1
B-21-1	B-21-1-7T	ST-3	174.97-175.06	7/27/2021	Splitting Tensile	Granitic Gneiss	6,938	1,590	1
B-21-1	B-21-1-9T	ST-4	212.93-213.02	7/27/2021	Splitting Tensile	Granitic Gneiss	6,233	1,520	1
B-21-2	B-21-2-1T	ST-5	105.84-105.93	7/27/2021	Splitting Tensile	Granitic Gneiss	6,578	1,620	1
B-21-2	B-21-2-4T	ST-6	159.40-159.49	7/27/2021	Splitting Tensile	Granitic Gneiss	6,806	1,780	1
B-21-2	B-21-2-7T	ST-7	217.29-217.38	7/27/2021	Splitting Tensile	Granitic Gneiss	6,351	1,510	1
B-21-2	B-21-2-9T	ST-8	238.06-238.15	7/27/2021	Splitting Tensile	Granitic Gneiss	5,217	1,240	1
B-21-2	B-21-2-13T	ST-9	289.78-289.87	7/27/2021	Splitting Tensile	Granitic Gneiss	5,284	1,320	1
B-21-3	B-21-3-1T	ST-10	232.81-232.90	7/27/2021	Splitting Tensile	Granitic Gneiss	5,810	1,380	1
B-21-3	B-21-3-4T	ST-11	249.87-249.96	7/27/2021	Splitting Tensile	Quartz-Feldspar Gneiss	6,999	1,770	1
B-21-3	B-21-3-6T	ST-12	277.61-277.70	7/27/2021	Splitting Tensile	Granitic Gneiss	7,106	1,650	1
B-21-3	B-21-3-8T	ST-13	331.43-331.52	7/27/2021	Splitting Tensile	Granitic Gneiss	6,886	1,780	1
B-21-3	B-21-3-12T	ST-14	379.68-379.77	7/27/2021	Splitting Tensile	Biotite Gneiss	6,267	1,530	1
B-21-3	B-21-3-14T	ST-15	383.82-383.91	7/27/2021	Splitting Tensile	Biotite Gneiss	6,736	1,610	1
B-21-3	B-21-3-17T	ST-16	430.89-430.98	7/27/2021	Splitting Tensile	Granitic Gneiss	5,595	1,350	1
B-21-3	B-21-3-20T	ST-17	480.48-480.57	7/27/2021	Splitting Tensile	Granitic Gneiss	6,140	1,510	1
B-21-4	B-21-4-1T	ST-18	120.02-120.11	7/27/2021	Splitting Tensile	Banded Augen Granitic Gneiss	5,220	1,270	1
B-21-4	B-21-4-4T	ST-19	129.95-130.04	7/27/2021	Splitting Tensile	Banded Augen Granitic Gneiss	4,821	1,170	1
B-21-4	B-21-4-7T	ST-20	136.06-136.15	7/27/2021	Splitting Tensile	Banded Augen Granitic Gneiss	3,834	929	1

Note: Strain rate= 2.5%/min; Failure Type: 1= Intact Material Failure; lbs=pounds

Table 16. Statistical Analysis of Rock Core Laboratory Data

	Banded Augen Granitic Gneiss			Granitic Gneiss			Biotite Gneiss		
	UW (pcf)	UCS (psi)	STS (psi)	UW (pcf)	UCS (psi)	STS (psi)	UW (pcf)	UCS (psi)	STS (psi)
				168	18086	1,410			
				167	18446	1,650			
				168	21079	1,590			
				167	18777	1,520			
				168	22047	1,620			
				169	14789	1,780			
				168	19577	1,510			
				169	20417	1,240			
				169	10642	1,320			
				168	19903	1,380			
				168	19973	1,650			
				167	18775	1,780			
				168	18747	1,350			
				166	22699	1,510			
				167	18760				
				168	18161				
				168	19552				
				169	20648				
				169	19803				
				166	17412				
	168	15546		166	23733				
	168	16463		168	17884				
	168	12121	1,270	169	20886		167	22228	
	168	20238	1,170	168	20681		169	19250	1,530
	168	15555	929	168	19967		168	20357	1,610
Count=	5	5	3	25	25	14	3	3	2
Mean=	168	15984.6	1123.0	167.8	19257.8	1522.1	168.0	20611.7	1570.0
Median=	168	15555	1170	168	19577	1,515	168	20,357	
SD=	0	2593.2	143.1	0.9	2502.3	161.0	0.8	1229.0	
+1 SD	168.0	18577.8	1266.1	168.8	21760.1	1683.2	168.8	21840.7	
-1 SD	168.0	13391.4	979.9	166.9	16755.4	1361.1	167.2	19382.6	
Min=	168	12121	929	166	10,642	1320	167	19250	
Max=	168	20238	1,270	169	23,733	1780	169	22228	

Note: UW = Unit Weight; UCS = Unconfined Compressive Strength; STS = Splitting Tensile Strength

6 Geotechnical Conditions

6.1 Site Geotechnical Conditions

The proposed Bad Creek II tunnel alignment is located entirely within the TGn and all tunnels and shafts will be in constructed within sound, unweathered TGn except possibly a portion of the tailrace tunnels at the Lower Reservoir I/O. Partially weathered TGn, residual soil and saprolite derived from the TGn , colluvium, and minor amounts of fill material will require excavations to reach elevations for construction of the Upper Reservoir I/O, vertical shafts, and gate shafts. Excavation to achieve construction elevations for the Lower Reservoir I/O structure will be primarily in fill, silty sandy gravel with boulders (landslide/rockslide materials, partially weathered rock, and unweathered rock.

6.1.1 Overburden Soil

Overburden materials primarily consists of residual soil and/or saprolite classified primarily as non-plastic silty sand. Soils close to the bedrock interface contained PWR fragments. Residual soil consistency ranges from loose (N value of 5 to 10) to very dense with N values 50 or greater. More specifically soils in Boring B-21-2 are loose to medium dense to a depth of 52 ft and Boring B-21-3 soils are loose to medium dense to a depth of 10 ft then very dense to refusal at 17.7 ft. Soils in Boring B-21-1 and B-21-5 are dense to very dense.

Soil sampled in Boring B-21-4 is colluvium/landslide material and was primarily loose however, Standard Penetration Resistance values or N-values were not assessed past 35 ft below ground surface as the drilling operations switched to HQ coring due to the presence of a boulder. The material is identified as landslide/colluvium due to the presence of large, rotated blocks of TGn in a soil matrix that was identified in the borehole and during field mapping. Results of field mapping are presented in Volume 7 - Geology and Seismology Report. Table 17 presents soil thickness and basic descriptions using the Unified Soil Classification System (USCS) (ASTM 2020) as determined from laboratory tests of overburden soils.

Table 17. Soil Thickness and Description

Boring	Soil Thickness (ft)	Classification (in order of prevalence)
B-21-1	36.9	SP-SM, SM (Residual/Saprolite)
B-21-2	61.8	SM, SC, SP-SM, SW-SM (classifications SP-SM and SW-SM are fill)
B-21-3	20.5	SM
B-21-4	90.7	SW, SM (fine fraction of colluvium)
B-21-5	59.2	SC-S

Note: SP = Poorly graded sands and gravelly sands, little or no fines; SM = silty sands, sand-silt mixtures; SC = Clayey sands, sand-clay mixtures; SW = Well-graded sands and gravelly sands, little or no fines; S = Sands

6.1.2 Bedrock

The proposed tunnel alignment is located entirely within the TGn. A total of 1,054 ft of TGn was cored during this phase of geotechnical investigations. Detailed geologic mapping of the underground excavations during construction of the existing Bad Creek Project resulted in subdivision of ten rock types within the TGn. Of those ten identified rock types, six were encountered during the current investigation as follows:

(1) **Granitic Gneiss**, medium light gray to light gray, medium to coarse-grained, gneiss consisting of layers of light-colored quartz feldspar bands and darker biotite quartz feldspar bands, distinctly/well foliated; comprises over 90 percent of the total cored rock.

(2) **Quartz-Feldspar Gneiss**, light gray to white, coarse to very coarse-grained, distinctly foliated, trace biotite and hornblende, occurs predominantly in 0.3- to 1.0 ft-thick zones along foliation with thicker zones of 1.5 ft. Encountered in borings B-21-1, (5.0 ft), B-21-2-(1.1 ft), B-21-3, (16.2 ft), B-21-5, (5.3 ft). Comprises approximately 2.6 percent of the total cored rock.

(3) **Banded Augen Granitic Gneiss**, medium light gray, medium to coarse-grained gneiss consisting of foliated (banded) augen 0.2 to 2.5 centimeters (cm). Only encountered in Boring B-21-4, 59.5 ft of the 60.3 ft cored. Comprises approximately 5.7 percent of the total cored rock.

(4) **Biotite Gneiss**, medium dark gray to dark gray, hard fine to medium-grained, thinly foliated with interlayered quartz-feldspar veins. Encountered 11 ft of this rock type in Boring B-21-3. Comprises approximately 1 percent of the total cored rock.

(5) **Weathered sheared rock**, encountered in Boring B-21-3 (3.0 ft), and comprises less than 1 percent of total cored rock.

(6) **Hard sheared rock**, encountered in Boring B-21-4 (0.8 ft) and B-21-5 (1.9 ft)

The TGn is typically massive with few joints in slightly weathered to fresh rock (Schaeffer et al. 1979; Schaeffer 2016). Jointing decreases with depth and the majority of the cored bedrock is very slightly fractured. Based on data collected during Bad Creek II Geotechnical Investigation, the most prominent discontinuity set consists of joints developed along foliation. The orientation of foliation dipping to the southeast is significant in that it aligns with the slope topography along portions of the proposed Bad Creek II tunnel alignment. Discontinuity sets are discussed in more detail in Section 4.1.3. Detailed soil and rock descriptions are presented on the boring logs in Appendix B.

6.1.3 Landslide/Rockslide Material

B-21-4 was drilled in a landslide/rockslide at the location of the Lower Reservoir I/O. In B-21-4 colluvium is present with an interpreted thickness of 90.7 ft based on the boring data and the seismic lines. The colluvium consists of augen granitic gneiss boulders and quartz feldspar gneiss boulders in a matrix of sandy silt in the upper portions of the boring. Boulders encountered in the boring were slightly to severely weathered. SPT sampling was attempted to 5.7 ft below ground surface and HQ coring proceeded to a depth of 17.0 ft in order to facilitate drilling through boulder material. SPT sampling was resumed from a depth of 17.0 ft to a depth of 38.5 ft. HQ coring was used for the remainder of the borehole past 38.5 ft. Top of rock was encountered at a depth of 90.7 ft. Core recovery in the landslide material interval ranged from 0 to 100 percent and four of the core runs had a recovery of 0 percent. Recovered core was from large blocks of rock within the landslide. Large blocks of TGn were observed in the landslide/rockslide near the location of B-21-4. The blocks are tilted and rotated within a soil matrix. Blow counts of soils in the landslide material indicated loose to medium dense for non-cohesive soils and soft for cohesive soils. A map showing the location of the landslide based on surface mapping and preliminary excavation and stabilization concepts has been developed and is presented in Volume 7 (Geology and Seismology Report).

7 Summary and Considerations

The Bad Creek II Geotechnical Investigation obtained data regarding subsurface conditions and rock and soil properties along the proposed Bad Creek II Power Complex alignment and specifically in the vicinity of the Upper and Lower Reservoir I/O excavations, vertical Intake shafts, and gate shafts. The following observations based on the field program data and analysis present a summary of the most pertinent geotechnical characteristics of the proposed Bad Creek II alignment.

- The bedrock is composed entirely of TGn and up to seven lithologic variations exist within the drilled zones. Granitic gneiss is the predominant lithology (90 percent of drilled core) with minor amounts of biotite gneiss, hard sheared rock, quartz feldspar gneiss, banded augen granitic gneiss, and weathered sheared rock.
- A zone of severely to moderately weathered, intensely to moderately fractured (with some very intensely fractured zones) rock and significant iron staining on fracture surfaces ranges from TWR to approximate depths of 0-35 ft below TWR.
- In the borings at depths ranging from 15 to 35 ft below the top of PWR and extending to depths as great as 220 ft, the TGn is moderately hard to very hard, moderately to slightly weathered with some moderately to severely weathered fracture surfaces, and moderately to slightly fractured with few limited intensely fractured zones. The top of this zone would generally be consistent with the TFR interpreted from the surface seismic refraction and MASW surveys.
- From depths ranging from 75 to 220 ft below the top of PWR and extending to total boring depth, the Toxaway gneiss is hard to very hard, fresh to slightly weathered, and predominantly slightly fractured to unfractured. This rock condition, if reached with surface seismic survey depth, would present the highest velocities on the refraction and MASW surveys.
- Foliation dips to the SE 19 to 36 degrees (with the exception of zones of intense folding) with dip generally decreasing to the SE. Foliation strikes N34E to N-60E.
- Foliation joints are the most predominant (in terms of number) discontinuity in the borings in the rock mass.
- Zones of sheared hard rock occur along foliation exist in the rock mass and were developed under ductile conditions.
- A series of faults dipping generally 55 to 70 degrees to the NW exist in the Toxaway Gneiss. From core description fault zones range from 5-10 millimeters thick and are healed with chlorite, calcite, epidote, and quartz.
- The rock mass exhibits low hydraulic conductivity, k = E-05 to E-06 cm/sec, with permeability only along discontinuities. Exceptions to the low permeability exist in the weathered zone in the upper 35 ft of the rock profile and along distinct continuous weathered shear zones as in the case of Boring B-21-3 at depth 266.2-269.2 ft.
- Zones of sheared weathered rock parallel to foliation exist in the rock mass and exhibited enhanced hydraulic conductivity in B-21-3.

- The landslide/rockslide at the proposed Lower Reservoir I/O is of significant width (see Figure 1) and a depth of 91 ft based at the location of Boring B-21-5.

Geotechnical conditions at the proposed Bad Creek II location present a number of advantages as well as potential challenges for consideration:

- The Toxaway Gneiss exhibits overall excellent rock mass quality with respect to rock strength, discontinuity frequency, low permeability, and weathering profile.
- The consistent dip of foliation to the SE and the prevalence of joints along foliation could present conditions of lowered stability in the north to west sides of excavations if foliation joints are continuous.
- Depending on orientation of excavation slopes, weathered shear zones present in excavation slopes could present lowered stability conditions.
- Weathered shear zones (as encountered in Boring B-21-3 at depth 266.2-269.2 ft) have significant permeability and may require mitigation or water management if encountered significant depths.
- Landslide/colluvium is a significant geotechnical hazard at the Lower Reservoir I/O.
- Depending on orientation, biotite gneiss layers daylighting in excavation slopes could present planes of weakness if weathered.
- Dense to very dense soils are favorable for excavation slope geometry. Loose to medium dense soils may require decreased slope angle to maintain stability.
- Northwest dipping faults encountered in the borings with chlorite (low shear strength) mineralization are planes of weakness that may impact excavation slopes.

8 Limitations

Recommendations and findings provided in this report are based on limited subsurface explorations, laboratory testing, and field observations. Subsurface conditions including soil and bedrock conditions may vary between or beyond the points explored or observed. Groundwater conditions may vary from the conditions observed at the time of data collection. Information and recommendations presented in this report should not be used for other projects on this site, should not be extrapolated to other areas, and should not be used for projects in other locations without HDR’s review and approval.

9 References

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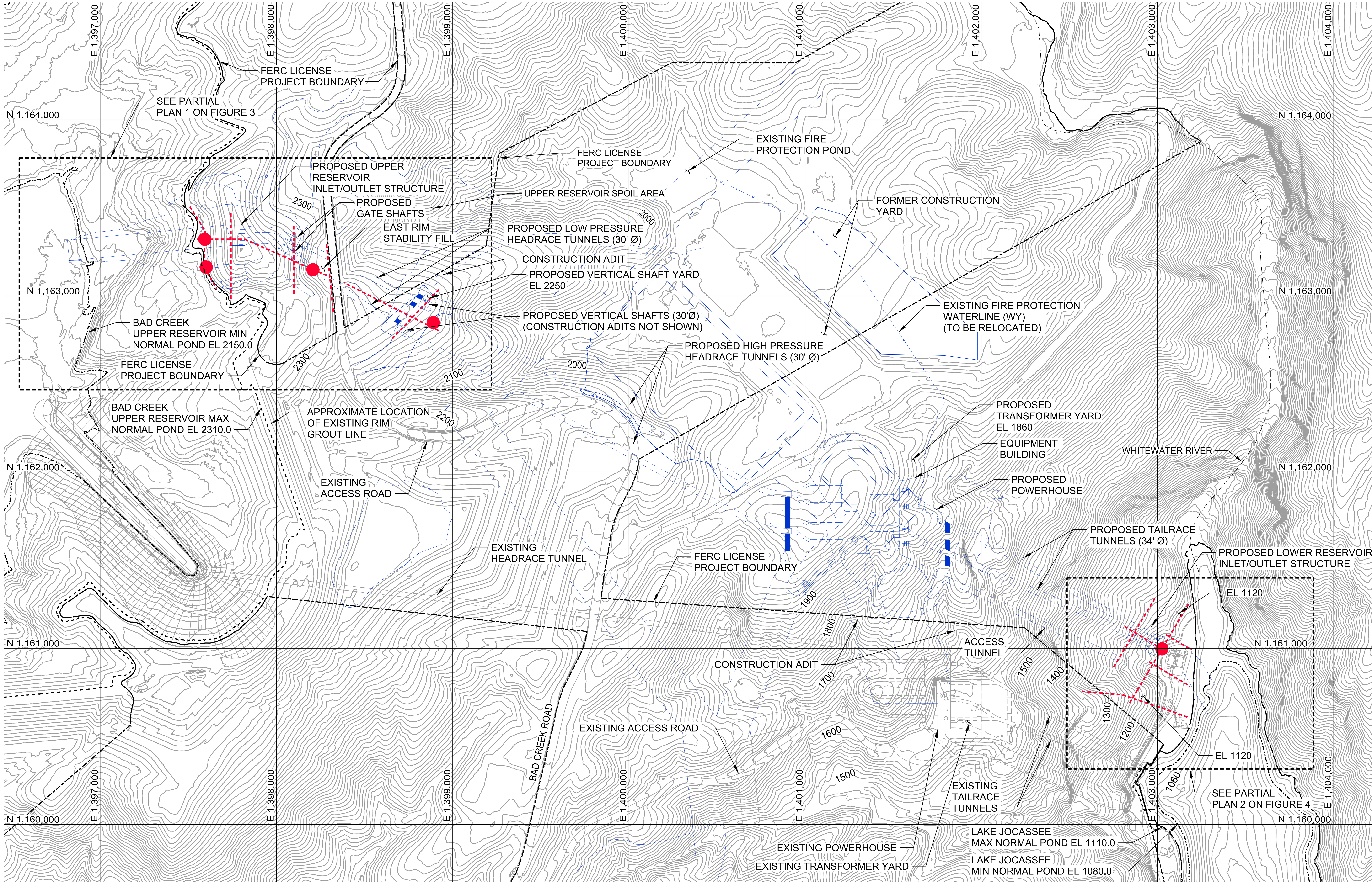
Appendix A

Project Drawings



PLAN

SCALE 1" = 300'

LEGEND

2200 (line)	EXISTING MAJOR CONTOUR
(line)	EXISTING MINOR CONTOUR
(line)	FERC LICENSE PROJECT BOUNDARY
(line)	MAX NORMAL POND
(line)	MIN NORMAL POND
(line)	PROPOSED GEOPHYSICAL LINES
(dot)	PROPOSED BORING

30 0 30 60

SCALE IN FEET

HDR Engineering, Inc. of the Carolinas

SOUTH CAROLINA HDR ENGINEERING, INC. OF THE CAROLINAS No. C0318 CERTIFICATE OF AUTHORIZATION

PRELIMINARY NOT FOR CONSTRUCTION OR RECORDING

PE SEAL

NO.	DATE	REVISION	DRN	DSGN	CHKD	APPR	CIVIL	ELEC	MECH
			SJP	DRG	—	—	—	—	—

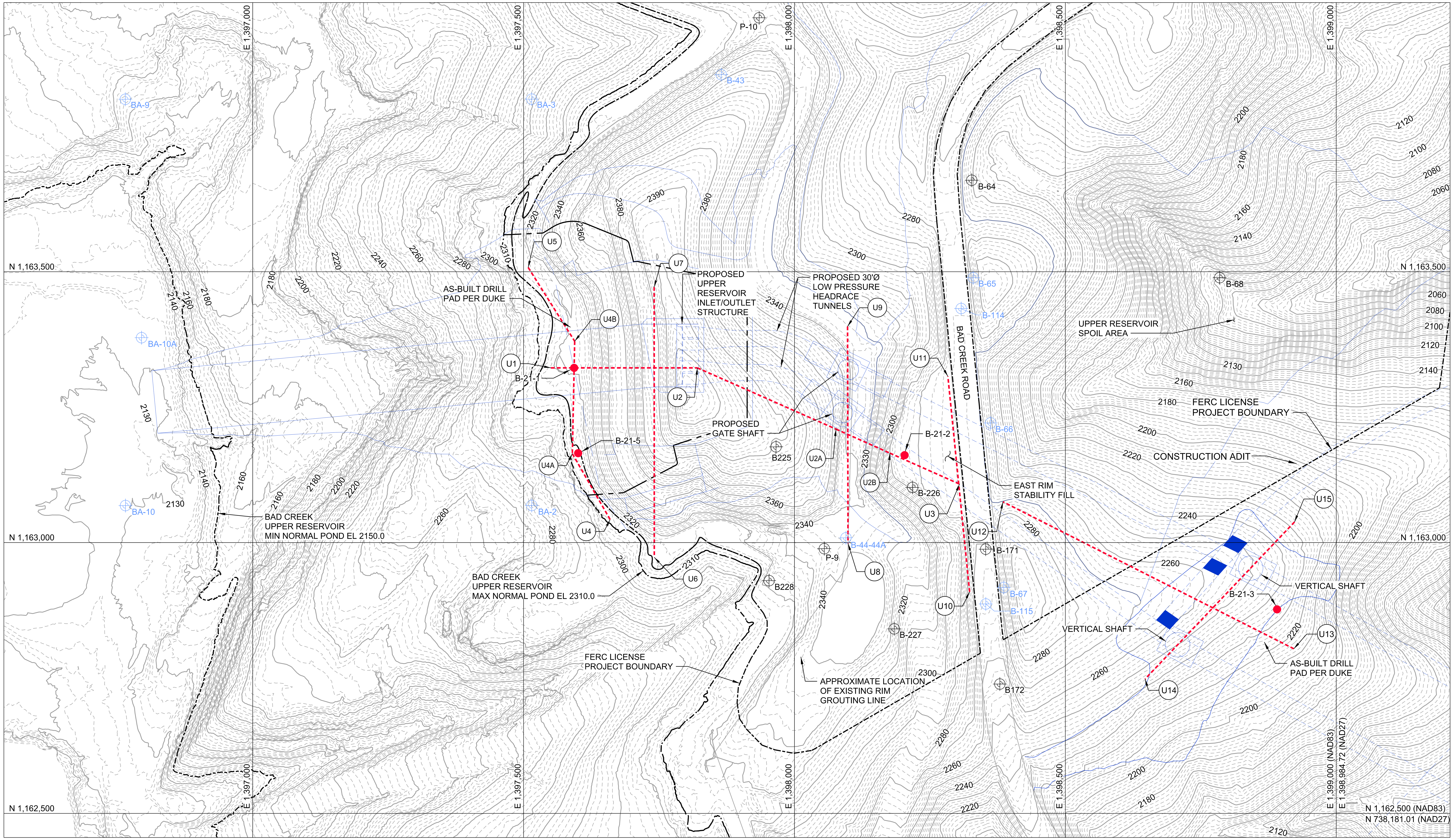
DRAWN BY: SJ PAWLOWSKI	CIVIL
DESIGNED BY: DR GRADY	MECHANICAL
CHECKED BY:	ELECTRICAL
APPROVED BY:	DATE:
PROJECT NUMBER: 10270481	

DUKE ENERGY CAROLINAS, LLC

BAD CREEK II PUMPED STORAGE PROJECT

FEASIBILITY STUDY POWER COMPLEX PLAN GEOTECHNICAL EXPLORATION PLAN

SCALE: AS NOTED DRAWING/SHEET NO. 10270481 - P-58 REV. -



1 FIG 2 **PARTIAL PLAN**
SCALE: 1"=100'

LEGEND

- 2200 — EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- FERC LICENSE PROJECT BOUNDARY
- MAX NORMAL POND
- MIN NORMAL POND
- PROPOSED GEOPHYSICAL LINES
- PROPOSED BORING
- XXX EXISTING BORING WITH LOGS
- XXX EXISTING BORING

BORING	NORTHING	EASTING	ELEVATION
B-21-1	1163323	1397590	2320.6
B-21-2	1163161	1398203	2283.0
B-21-3	1162877	1398891	2235.0
B-21-5	1163165	1397601	2315.0

GENERAL NOTES:

1. HORIZONTAL DATUM: SOUTH CAROLINA STATE PLANE, NAD83 2011
VERTICAL DATUM: NGVD29

GEOPHYSICAL LINE	LENGTH (FT)
U1 TO U2	270
U2 TO U2A	280
U2A TO U2B	109
U2B TO U3	141
U4 TO U4A	140
U4A TO U4B	207
U4B TO U5	161
U6 TO U7	499
U8 TO U9	400
U10 TO U11	400
U12 TO U13	602
U14 TO U15	400

POINT	NORTHING	EASTING
U1	1163323	1397550
U2	1163323	1397821
U2A	1163209	1398077
U2B	1163165	1398176
U3	1163108	1398305
U4	1163043	1397660
U4A	1163164	1397590
U4B	1163372	1397594
U5	1163508	1397509
U6	1162973	1397741
U7	1163472	1397741
U8	1162999	1398099
U9	1163399	1398098
U10	1162909	1398323
U11	1163307	1398283
U12	1163075	1398385
U13	1162804	1398922
U14	1162748	1398647
U15	1163038	1398923

EXISTING BORING	NORTHING	EASTING
B-43	1163863	1397864
B-44-44A	1163008	1398095
B-64	1163668	1398327
B-65	1163488	1398329
B-66	1163220	1398362
B-67	1162916	1398386
B-68	1163489	1398784
B-114	1163432	1398307
B-115	1162886	1398353
B-172	1162738	1398379
B-225	1163176	1397965
B-226	1163101	1398218
B-227	1162840	1398184
B-228	1162929	1397953
BA-2	1163068	1397515
BA-3	1163818	1397514
BA-9	1163818	1396764
BA-10	1163068	1396765
BA-10A	1163068	1396765
P-9	1162988	1398055
P-10	1163968	1397934

100 0 100
SCALE: FEET

HDR Engineering, Inc. of the Carolinas

PRELIMINARY NOT FOR CONSTRUCTION OR RECORDING

PE SEAL

NO.	DATE	REVISION	DRN	DSGN	CHKD	APPR	CIVIL	ELEC	MECH
			RMM	DRG	—	—	—	—	—

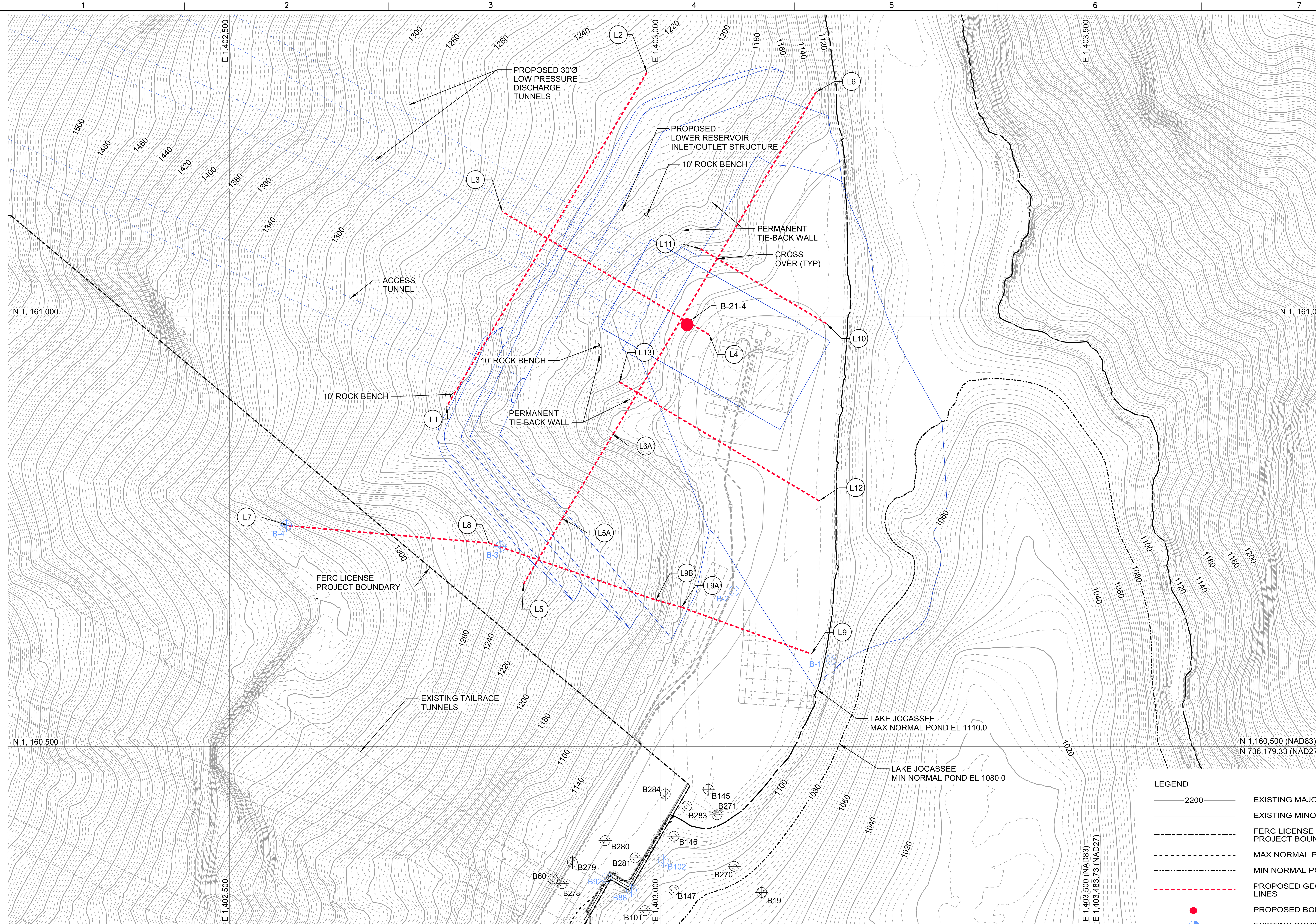
DRAWN BY: RM MAKEE — CIVIL
DESIGNED BY: DR GRADY — MECHANICAL
CHECKED BY: — ELECTRICAL
APPROVED BY: — DATE:
PROJECT NUMBER: 10270481

DUKE ENERGY CAROLINAS, LLC
BAD CREEK II PUMPED STORAGE PROJECT

FEASIBILITY STUDY
UPPER RESERVOIR INLET/OUTLET
GEOTECHNICAL EXPLORATION PLAN

SCALE:

10270481 - P-61



LEGEND

2200	EXISTING MAJOR CONTOUR
	EXISTING MINOR CONTOUR
	FERC LICENSE PROJECT BOUNDARY
	MAX NORMAL POND
	MIN NORMAL POND
	PROPOSED GEOPHYSICAL LINES
	PROPOSED BORING
XXX	EXISTING BORING WITH LOGS
XXX	EXISTING BORING

2 FIG 2 PARTIAL PLAN

SCALE: 1"=60'

60 0 60

SCALE: FEET

GENERAL NOTES:

1. HORIZONTAL DATUM: SOUTH CAROLINA STATE PLANE, NAD83 2011
VERTICAL DATUM: NGVD29

GEOPHYSICAL LINE	LENGTH (FT)
L1 TO L2	453
L3 TO L4	280
L5 TO L5A	89
L5A TO L6A	115
L6A TO L6	462
L7 TO L8	233
L8 TO L9B	205
L9B TO L9A	31
L9A TO L9	161
L10 TO L11	170
L12 TO L13	270

POINT	NORTHING	EASTING
L1	1160895	1402752
L2	1161283	1402985
L3	1161121	1402817
L4	1160978	1403057
L5	1160688	1402841
L5A	1160765	1402887
L6	1161260	1403181
L6A	1160863	1402946
L7	1160756	1402569
L8	1160736	1402801
L9	1160607	1403176
L9A	1160662	1403025
L9B	1160670	1402995
L10	1160991	1403194
L11	1161078	1403047
L12	1160785	1403185
L13	1160923	1402953

BORING	NORTHING	EASTING
B-21-4	1160990	1403032

EXISTING BORING	NORTHING	EASTING
B-1	1160601	1403199
B-2	1160680	1403086
B-3	1160732	1402815
B-4	1160757	1402566
B-19	1160330	1403118
B-60	1160346	1402875
B-88	1160333	1402967
B-92	1160347	1402938
B-101	1160309	1402983
B-102	1160367	1403004
B-145	1160450	1403056
B-146	1160395	1403016
B-147	1160333	1403016
B-270	1160360	1403086
B-271	1160420	1403066
B-278	1160340	1402886
B-279	1160365	1402898
B-280	1160390	1402936
B-281	1160370	1402971
B-283	1160430	1403031
B-284	1160444	1403006

HDR Engineering, Inc. of the Carolinas

SOUTH CAROLINA HDR ENGINEERING, INC. OF THE CAROLINAS No. C0318 CERTIFICATE OF AUTHORIZATION

PRELIMINARY NOT FOR CONSTRUCTION OR RECORDING

PE SEAL

NO.	DATE	REVISION	RMM DRN	DRG DSGN	— CHKD	— APPR	— CIVIL	— ELEC	— MECH

DRAWN BY: RM MAKEE
DESIGNED BY: DR GRADY
CHECKED BY:
APPROVED BY:
CIVIL
MECHANICAL
ELECTRICAL
DATE:
PROJECT NUMBER: 10270481

DUKE ENERGY CAROLINAS, LLC
BAD CREEK II PUMPED STORAGE PROJECT
FEASIBILITY STUDY
LOWER RESERVOIR INLET/OUTLET GEOTECHNICAL EXPLORATION PLAN

SCALE: AS NOTED
DRAWING/SHEET NO. 10270481 - P-61
REV. -

Appendix B

Boring Logs and Photographs

440 S. Church Street, Suite 900
Charlotte, NC 28202-2075
Phone: 704-338-6700
hdrinc.com/follow-us

BORING NUMBER B-21-1

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA
DATE STARTED 4/6/21 **COMPLETED** 4/13/21
GROUND ELEVATION TBD **HOLE SIZE(S)** 3.782 inches
DRILLING CONTRACTOR S&ME, Inc.
NORTHING TBD **EASTING** TBD
DRILLING METHOD TWR, HQ Core
GROUND WATER LEVELS:
LOGGED BY C. Gruenberg **CHECKED BY** N. Yacobi
DATE/TIME 4/16/2021 36.01 ft Before downhole testing 4/16/21
NOTES
DATE/TIME 4/19/2021 34.65 ft Before grouting 4/19/21

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
0						0.3 **Silty GRAVEL (GM)** from pad (FILL)	0.0 - 37.5': Tricone Wash Rotary 0.3': **USCS=SP-SM, LL= --, PL=NP, PI=NP, NMC=3.0, %200=10.0**
	SS - 1	17-31-50/0"	12			**Poorly Graded SAND with SILT and GRAVEL (SP-SM)**, grayish dark brown (10YR 4/2), very dense, moist to wet, fine to coarse grained SAND, fine to coarse grained GRAVEL, micaceous, (PWR) 0.6': Gray (10 R 6/1), moist, coarse grained GRAVEL, subangular, some to little biotite 3.1': Grayish brown (10YR 5/2), moist to wet	1.2': Drill rig chatter HW casing advanced to 2.0'
	SS - 2	50/4"	4				3.1': **USCS=SP-SM, LL= --, PL=NP, PI=NP, NMC=8.6, %200=11.4** 3.4': Drill rig chatter; Flushing hole
5						5.8 **Silty SAND with GRAVEL (SM)**, gray (10YR 6/1), very dense, moist, fine to medium grained SAND, coarse grained GRAVEL, subangular, some to little biotite, (PWR) 8.5': White (10YR 8/1) 8.8': Gray (10YR 6/1)	
	SS - 3	50-50/5"	10				8.1': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=12.0, %200=16.2** 8.1': Gneissic gravels and PWR
10							
	SS - 4	50/1"	0				13.1 - 36.9': Driller noted alternating hard and soft layers, approximately 0.1 - 0.3' thick
15							
	SS - 5	50/4"	0				
20							
	SS - 6	50/1"	0				
25							

NORTH CAROLINA BORING LOG-NO WELL COLUMN - GINT STD US LAB.GDT - 4/6/22 11:08 - C:\PWWORKING\EAST01\D2014647\BADCREEKII_GEOTECHNICAL_GINT.GPJ

440 S. Church Street, Suite 900
Charlotte, NC 28202-2075
Phone: 704-338-6700
hdrinc.com/follow-us

BORING NUMBER B-21-1

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
25						**Silty SAND with GRAVEL (SM)**, gray (10YR 6/1), very dense, moist, fine to medium grained SAND, coarse grained GRAVEL, subangular, some to little biotite, (PWR) *(continued)*	
	SS - 7	50/1"	0				
30							
	SS - 8	50/1"	0				32.6 - 34.7': Soft layer
35							
36.9						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.2 - 1.5 cm), trace hornblende (0.2 - 2.0 cm), interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1 - 0.4' thick	36.9': End of day (04/06/2021) 36.9 - 37.5': Rock chewed up when setting casing HW casing advanced to 37.5' 37.5': Start HQ coring 37.5': FOLIATION dipping 25° - 30° 37.5 - 38.9': Slight weathering 37.5 - 40.8': Close joint spacing 38.4': JOINT, 20° dip, open 38.9': JOINT, 10° dip, open, trace Fe staining 38.9 - 41.1': Moderate to moderately severe weathering 39.0 - 40.9': Core loss
40	RC - 1			45	42		
	RC - 2			98	88		39.9 - 45.4': **PACKER TEST 5: k=3.1E-05 cm/sec** 40.8 - 41.1': Very close joint spacing 41.1 - 45.8': Close joint spacing 41.1 - 46.8': Very slight to slight weathering 41.1': JOINT, 20° dip, open 41.5': FOLIATION JOINT , 20°, open 42.1': FOLIATION JOINT, 25°, open 43.6': JOINT, 30° dip, open 44.8': JOINT, 15° dip, open
45							45.2 - 50.7': **PACKER TEST 4: Could not build pressure** 45.8 - 50.8': Close to moderately close joint spacing 46.1': JOINT, 0° dip, open 46.7': JOINT, 30° dip, open
	RC - 3			90	84	46.8 - 47.5': Moderately hard 47.5 - 50.8': Hard	46.8 - 47.5': Moderately severe weathering, very close joint spacing 47.0 - 47.5': Core Loss 47.5 - 50.8': Close to moderately close joint spacing
50							

NORTH CAROLINA BORING LOG-NO WELL COLUMN - GINT STD US LAB.GDT - 4/6/22 11:08 - C:\PWWORKING\EAST01\D2014647\BADCREEKII_GEOTECHNICAL_GINT.GPJ

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II
PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
50	RC - 4			100	96	**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.2 - 1.5 cm), trace hornblende (0.2 - 2.0 cm), interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1 - 0.4' thick *(continued)* 50.8 - 65.5': Very hard	47.5 - 50.8': Very slight to slight weathering 47.5': JOINT, 30° dip, open 47.8': JOINT, 40° dip, open, trace Fe staining 48.2': JOINT, 30° dip, paritally open 48.3': FOLIATION JOINT, 20°, open, trace clay infilling 49.4': JOINT, 20° dip, open 50.1': JOINT, 15° dip, open 50.2': JOINT, 15° dip, open, trace clay infilling 50.8 - 54.1': Wide joint spacing 50.8 - 65.8': Fresh to very slight weathering 52.9': FOLDING in quartz/feldspar band 54.1 - 55.8': Close joint spacing 54.1': JOINT, 0° dip, open, Fe staining 54.3': JOINT, 15° dip, open 54.8': JOINT, 0° dip, open
55	RC - 5			100	100		55.0': FOLIATION JOINT, 30° dip, open 55.8': FOLIATION JOINT, 30° dip, open 55.8 - 71.4': Close to moderately close joint spacing 55.8 - 56.3': Potassium feldspar 56.7 - 57.0': Potassium feldspar 57.0': JOINT, 10° dip, closed 58.4': JOINT, 30° dip, open 59.9': FOLIATION JOINT, 30° dip, closed
60	RC - 6			100	78		60.2 - 65.7': **PACKER TEST 3: k=5.4E-05 cm/sec** 60.4': JOINT, 30° dip, open 60.8 - 75.8': FOLIATION dipping 20°- 40° 61.1 - 61.2': Very close joint spacing 61.2': JOINT, 20° dip, open 61.7': JOINT, 0° dip, open 62.0': JOINT, 0° dip, closed, trace Fe staining 62.2': FOLIATION JOINT, 20° dip, closed, trace Fe staining 62.4': FOLIATION JOINT, 20° dip, trace Fe staining 64.2': JOINT, 10° dip, closed, trace Fe staining 64.3': JOINT, 20° dip, closed, trace Fe staining 64.8': JOINT, 30° dip, trace Fe staining
65						65.5 **QUARTZ-FELDSPAR GNEISS**, yellowish gray (5Y 8/1) to pinkish gray (5YR 8/1), very hard, coarse to very coarse grained, trace biotite and hornblende	65.8 - 70.8': Fresh weathering
	RC - 7			100	94	67.0 67.9 **GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard to very hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.2 - 1.5 cm), trace hornblende (0.2 - 2.0 cm), interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick 69.7	67.1': JOINT, 0° dip
70	RC - 8			100	98	**QUARTZ-FELDSPAR GNEISS**, yellowish gray (5Y 8/1) to pinkish gray (5YR 8/1), very hard, coarse to very coarse grained, trace biotite and hornblende	70.2': FOLIATION JOINT, 30° dip, open, Fe staining 70.3': JOINT, 10° dip 70.8 - 71.4': Close joint spacing 70.8 - 77.6': Fresh to very slight weathering 70.9': JOINT, 30° dip, partially open 71.4': JOINT, 15° dip, open 71.4 - 75.8': Wide joint spacing
75							

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %
75					
80	RC - 9			98	86
85	RC - 10			98	86
90	RC - 11			100	96
95	RC - 12			98	92
100	RC - 13			98	94

DESCRIPTION

GRANITIC GNEISS, medium light gray (N6) to medium gray (N5), hard to very hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.2 - 1.5 cm), trace hornblende (0.2 - 2.0 cm), interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*

79.4

79.9

QUARTZ-FELDSPAR GNEISS, yellowish gray (5Y 8/1) to pinkish gray (5YR 8/1), very hard, coarse to very coarse grained, trace biotite and hornblende

81.1

81.6

GRANITIC GNEISS, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.2 - 1.5 cm), trace hornblende (0.2 - 2.0 cm), interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick
80.8 - 90.8': Very hard

QUARTZ-FELDSPAR GNEISS, yellowish gray (5Y 8/1) to pinkish gray (5YR 8/1), very hard, coarse to very coarse grained, trace biotite and hornblende

GRANITIC GNEISS, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.4 - 2.2 cm), trace hornblende (0.2 - 2.7 cm), trace epidote, trace garnet (0.2 to 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick

REMARKS

75.2 - 80.7': **PACKER TEST 2: k=7.3E-05 cm/sec**
75.8 - 77.6': Moderately close joint spacing
75.8': FOLIATION dipping 15° - 30°
77.0': FOLIATION JOINT, 30° dip, closed
77.6 - 78.1': Very close joint spacing
77.6 - 78.2': Moderately severe weathering
77.8 - 77.9': Core loss
77.9': JOINT, healed with chlorite, 75° dip
78.1 - 95.1': Close to moderately close joint spacing
78.2 - 79.8': Very slight to slight weathering
78.2': FOLIATION JOINT, 20° dip, open, Fe staining
78.2 - 79.4': Increase in potassium-feldspar content
78.8 - 79.1': FAULT, normal sense of displacement, healed with chlorite, 2.0 cm displacement
79.8 - 95.1': Fresh to very slight weathering
79.1': JOINT, 20° dip, open, trace Fe staining
79.9': FOLIATION JOINT, 20° - 30° dip, open, clay infilling
80.8': Driller reports harder drilling
80.8': FOLIATION dipping 10° - 30°
81.1': FOLIATION JOINT, 20° dip, open
81.2': FOLIATION JOINT, 20° dip, open
81.3': FOLIATION JOINT, 20° dip, open
82.0': FOLIATION JOINT, 25° dip, open
82.3': JOINT, 0° dip, open
82.8': JOINT, 10° dip, open
85.1': JOINT, 10° - 15° dip, open
85.6': JOINT, 10° dip, open
85.8': End of day (04/07/2021); Depth to water 35.52' below ground surface, casing at 37.5' below ground surface (04/08/2021); Driller reported slower, harder drilling, switched from series 8 bit to series 10 bit
86.8': JOINT, 20° dip, open
87.2': JOINT, 20° dip, open
88.0 - 95.1': Very close joint spacing, slight to moderate weathering
88.0': JOINT 20° dip, open
88.1': JOINT, 15° dip, open
89.9': FOLDING
90.8': FOLIATION dipping 20° - 40°
91.4 - 97.1': **PACKER TEST 1: 2.4E-05 cm/sec**
93.7': JOINT, 20° dip, open
95.1 - 95.3': Slight weathering
95.1 - 95.8': Very close joint spacing
95.1': JOINT, 30° dip, open
95.1 - 95.2': Core loss
95.2': JOINT, 30° dip, open
95.3 - 104.3': Fresh to very slight weathering
95.5': JOINT, 30° dip, open
95.8 - 100.8': Wide joint spacing
95.8': FOILIATION dipping 0° - 10°
95.9 - 96.0': Core loss
96.1': JOINT, 30° dip, open

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
100						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.4 - 2.2 cm), trace hornblende (0.2 - 2.7 cm), trace epidote, trace garnet (0.2 to 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)* 100.8 - 105.8': Thickly foliated	100.8 - 109.1': Moderately close to close joint spacing 100.8': FOLIATION dipping 0° - 30° 102.7': JOINT, 20° dip 102.8': JOINT, 30° dip 102.85 - 103.35': **SAMPLE B-21-1-1T**, Splitting Tensile Test, TS= 1,410 psi 103.35 - 104.0': **SAMPLE B-21-1-2C**, UCS, uw= 166 pcf, ucs= 17,412 psi 104.3 - 109.1': Very close to close joint spacing 104.3 - 105.8': Very slight to slight weathering 104.5 - 104.7': Core loss 104.6': JOINT, 0° dip, closed 105.3': JOINT, 0° dip, closed 105.5': JOINT, 10° dip, open
	RC - 14			96	80		
105							105.8 - 135.8': Fresh to very slight weathering 105.8: FOLIATION dipping 10° - 20° 106.6': FOLIATION JOINT, 20° dip, closed 107.1': FOLIATION JOINT, 10° dip, closed 107.9': FOLIATION JOINT, 20° dip, closed 109.1 - 250.8': Very wide joint spacing
	RC - 15			100	100		
110						110.1 - 125.8': Medium grained	110.1': FOLIATION dipping 10° - 25°
	RC - 16			100	100		
115							
	RC - 17			100	100		
120							121.9 - 122.35': **SAMPLE B-21-1-3T**, Splitting Tensile Test, TS= 1,650 psi
	RC - 18			100	100		
125							

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BORING NUMBER B-21-1

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
125						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.4 - 2.2 cm), trace hornblende (0.2 - 2.7 cm), trace epidote, trace garnet (0.2 to 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	125.0 - 125.5': **SAMPLE B-21-1-4C**, UCS, uw= 166 pcf, ucs= 23,733 psi
	RC - 19			100	100		
130							130.8': FOLIATION dipping 0° - 20°
	RC - 20			100	100		
135							135.8': FOLIATION dipping 20° - 30° 135.8': End of day (04/08/2021); Depth to water 24.40' below ground surface, casing at 37.5' below ground surface (04/09/2021) 135.8 - 180.8': Fresh weathering
	RC - 21			100	100		
140							
	RC - 22			100	100		
145							145.8': FOLIATION dipping 15° - 30° 146.2 - 146.8': **SAMPLE B-21-1-5CM** (UCS/EM), uw= 168 pcf, ucs= 20,681 psi, em=3.24E+06 psi, PR= 0.21, at the low stress range (2,100-7,600 psi)
	RC - 23			100	100		
150							149.5 - 156.0': FOLDING

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BORING NUMBER B-21-1

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
150						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.4 - 2.2 cm), trace hornblende (0.2 - 2.7 cm), trace epidote, trace garnet (0.2 to 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	150.8': FOLIATION dipping 30° - 60°
	RC - 24			100	100		
155	RC - 25			100	100		155.8': FOLIATION dipping 20° - 30°
160	RC - 26			98	98		160.8': FOLIATION dipping 30° - 40°
165	RC - 27			100	100		165.8': FOLIATION dipping 20° - 30°
170	RC - 28			100	100		170.8': FOLIATION dipping 10° - 20° 174.2 - 174.9': **SAMPLE B-21-1-6C**, UCS, uw=168 pcf, ucs= 17,884 psi
175							

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BORING NUMBER B-21-1

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
175						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.4 - 2.2 cm), trace hornblende (0.2 - 2.7 cm), trace epidote, trace garnet (0.2 to 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	174.9 - 175.35': **SAMPLE B-21-1-7T**, Splitting Tensile Test, TS= 1,590 psi 175.8': End of day (04/09/2021); Depth to water 25.50' below ground surface, casing at 37.5' below ground surface (04/12/2021)
	RC - 29			100	100		
180	RC - 30			100	100		180.8 - 185.8': Very slight weathering 180.8': FOLIATION dipping 20° - 30° 181.5 - 182.2': FOLDING 183.0 - 184.0': JOINT, healed with potassium feldspar, 65° - 70° dip 184.6': FAULT ZONE , 60° dip, brecciation of feldspar and quartz grains, biotite-epidote-garnet in matrix, chlorite and calcite on fault planes, foliation planes offset, NE strike/ NW dip 184.9 - 194.0': Potassium feldspar
185	RC - 31			100	100		185.8': FOLIATION dipping 10° - 30° 185.8 - 190.8': Fresh to very slight weathering 189.0 - 189.4': JOINT, healed with potassium feldspar, 30° - 35° dip
190	RC - 32			100	100		190.8': FOLIATION dipping 10° - 20° 190.8 - 200.8': Fresh weathering 190.8 - 191.8': FOLDING
195	RC - 33			100	100		195.8': FOLIATION dipping 10° - 20°
200							

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BORING NUMBER B-21-1

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
200						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.4 - 2.2 cm), trace hornblende (0.2 - 2.7 cm), trace epidote, trace garnet (0.2 to 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	200.8 - 205.8': Fresh to very slight weathering 201.8 - 202.3': FAULT ZONE, 70° dip, brecciation of quartz, potassium feldspar, and plagioclae in matrix, chlorite on fault planes, foliation planes offset, NE stike/ NW dip
	RC - 34			100	100		
205	RC - 35			100	100		205.8': FOLIATION dipping 10° - 15° 205.8 - 250.8': Fresh weathering
210	RC - 36			100	100	210.8 - 235.8': Few to little feldspar augen (0.7 - 2.2 cm)	210.8': FOLIATION dipping 0° - 10° 210.8': End of day (04/12/2021); Depth to water 25.00' below ground surface, casing at 37.5' below ground surface (04/13/2021) 212.3 - 212.9': **SAMPLE B-21-1-8C**, UCS, uw=169 pcf, ucs= 20,886 psi 212.9 - 213.3': **SAMPLE B-21-1-9T**, Splitting Tensile Test, TS= 1,520 psi
215	RC - 37			100	100		216.3': JOINT, healed with potassium feldspar and chlorite, 70° dip
220	RC - 38			100	100		
225							

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
225						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augen (0.4 - 2.2 cm), trace hornblende (0.2 - 2.7 cm), trace epidote, trace garnet (0.2 to 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	225.8': FOLIATION dipping 10° - 20° 226.2': Potassium feldspar
	RC - 39			100	100		
230	RC - 40			100	100		231.4 - 231.95': **SAMPLE B-21-1-10CM** (UCS/EM), uw= 168 pcf, ucs= 19,967 psi, em= 3.43E+06 psi, PR= 0.24 at the low stress range (2,000-7,300 psi)
235							234.2': FOLDING
	RC - 41			100	100		
240	RC - 42			100	100	243.5 **QUARTZ-FELDSPAR GNEISS**, very light gray (N8), very hard, coarse to very coarse grained, very thinly foliated	
245						244.1 **GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augens (0.8 - 2.0 cm), trace hornblende (0.2 - 0.6 cm), trace epidote, with interlayered quartz-, feldspar-, potassium feldspar-, horblende- pegmatite, spaced close to very close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	
250	RC - 43			100	100		249.3 - 249.5': Potassium feldspar

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BORING NUMBER B-21-1

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
250						250.8	

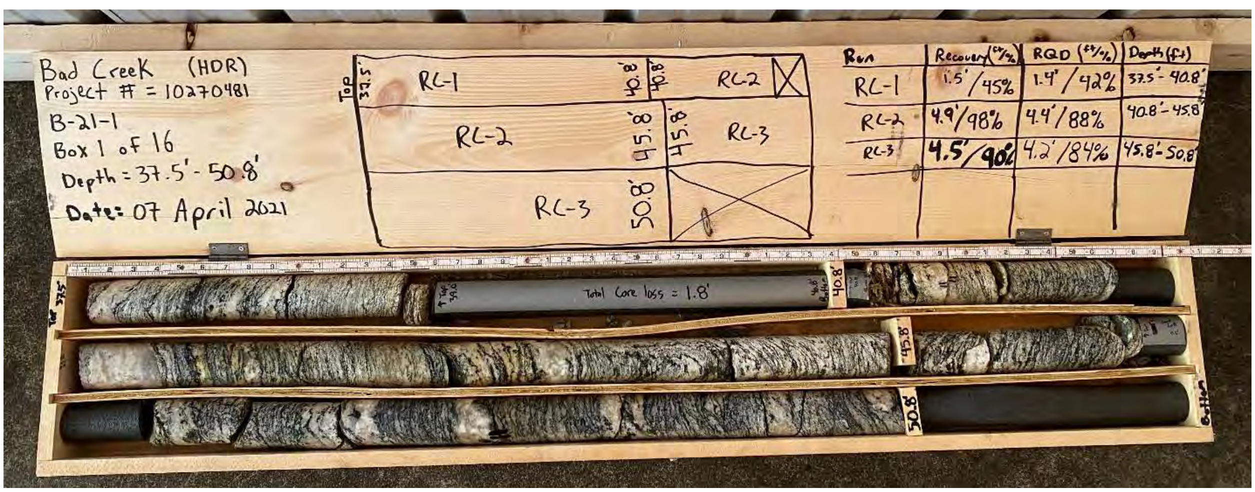
Coring termianted at 250.8 feet below ground surface
Bottom of borehole at 250.8 feet.

250.8': End of day; Depth to water 22.40' below ground surface, casing at 37.5' below ground surface (04/14/2021); Depth to water 25.58' below ground surface, casing at 37.5' below ground surface (04/15/2021)

Photograph 1. **B-21-2:** SS-1 **Depth:** 0.3-1.2 ft **Date:** 04/06/21

Photograph 2. **B-21-2:** SS-2 **Depth:** 3.1-3.4 ft **Date:** 04/06/21

Photograph 3. **B-21-2:** SS-3 **Depth:** 8.1-9.0 ft **Date:** 04/06/21



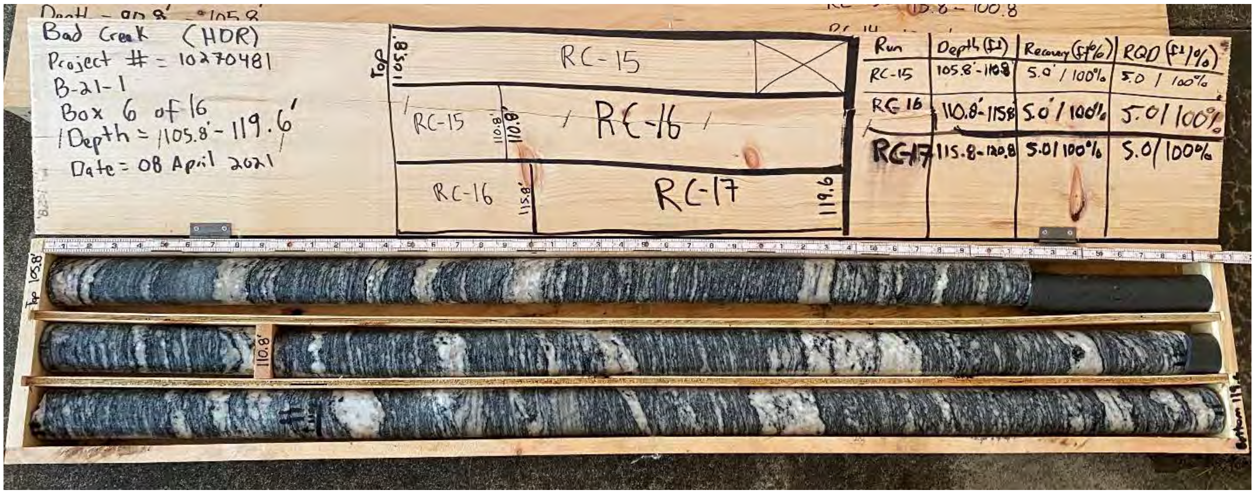
Photograph 4. **B-21-1:** Box 1 of 16 **Depth:** 37.5-50.8 ft **Date:** 04/07/21

Photograph 5. **B-21-1:** Box 2 of 16 **Depth:** 50.8-64.8 ft **Date:** 04/07/21

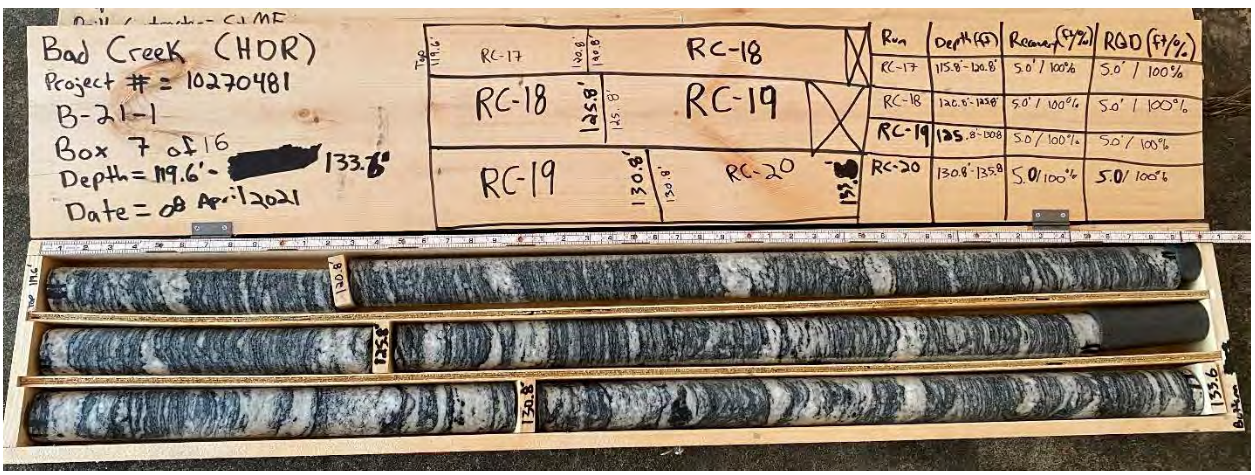
Photograph 6. **B-21-1:** Box 3 of 16 **Depth:** 64.8-78.2 ft **Date:** 04/07/21

Photograph 7. **B-21-1:** Box 4 of 16 **Depth:** 78.2-90.8 ft ft **Date:** 04/08/21

Photograph 8. **B-21-1:** Box 5 of 16 **Depth:** 90.8-105.8 ft **Date:** 04/08/21



Photograph 9. **B-21-1:** Box 6 of 16 **Depth:** 105.8-119.6 ft **Date:** 04/08/21



Photograph 10. **B-21-1:** Box 7 of 16 **Depth:** 119.6-133.6 ft **Date:** 04/08/21

Photograph 11. **B-21-1:** Box 8 of 16 **Depth:** 133.6-147.9 ft **Date:** 04/09/21

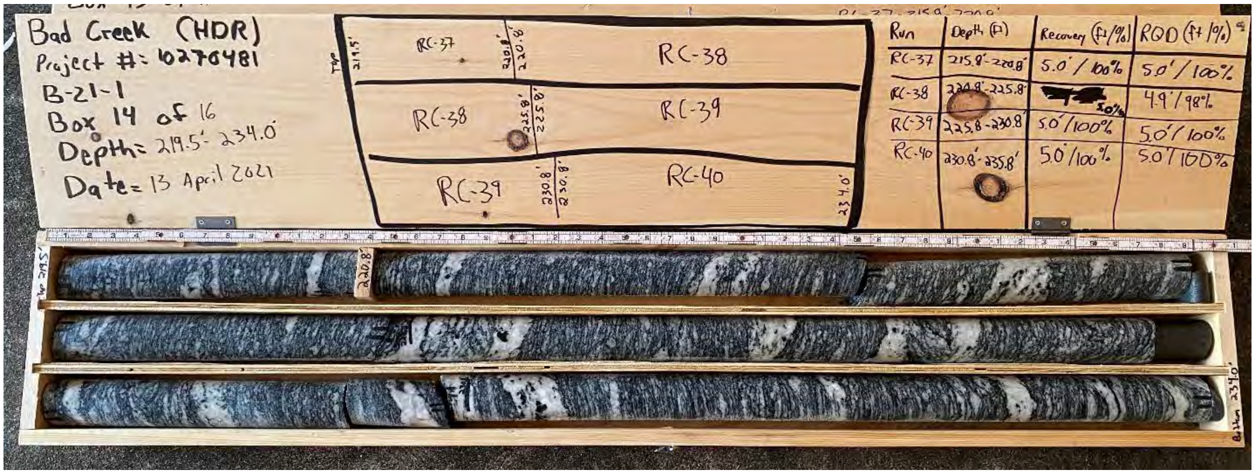
Photograph 12. **B-21-1:** Box 9 of 16 **Depth:** 147.9-160.8 ft **Date:** 04/09/21

Photograph 13. **B-21-1:** Box 10 of 16 **Depth:** 160.8-175.8 ft **Date:** 04/09/21

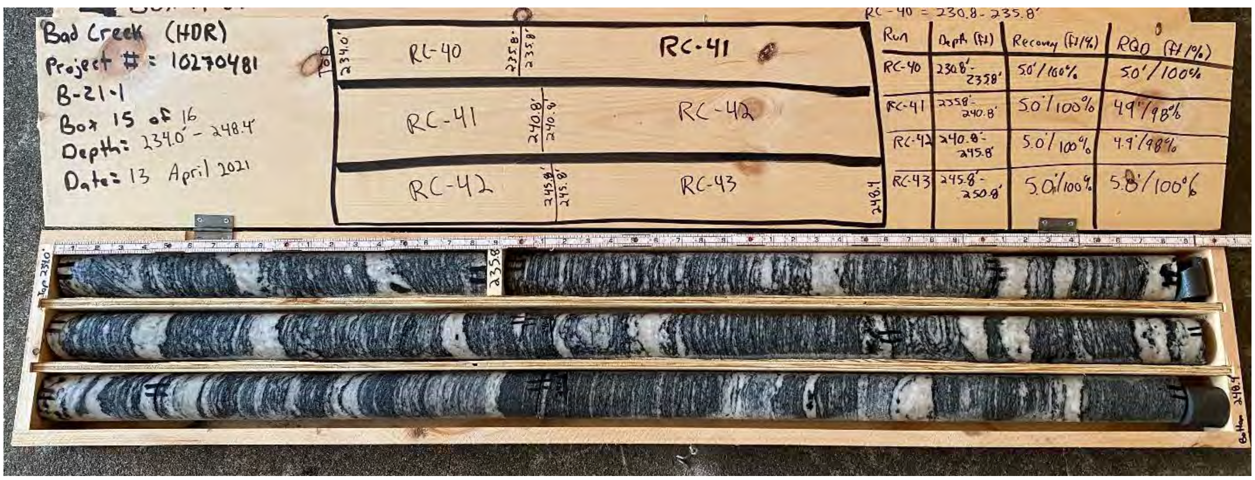
Photograph 14. **B-21-1:** Box 11 of 16 **Depth:** 175.8-190.8 ft **Date:** 04/12/21

Photograph 15. **B-21-1:** Box 12 of 16 **Depth:** 190.8-205.8 ft **Date:** 04/12/21

Photograph 16. **B-21-1:** Box 13 of 16 **Depth:** 205.1-219.5 ft **Date:** 04/13/21



Photograph 17. **B-21-1:** Box 14 of 16 **Depth:** 219.5-234.0 ft **Date:** 04/13/21



Photograph 18. **B-21-1:** Box 15 of 16 **Depth:** 234.0-248.4 ft **Date:** 04/13/21

Photograph 19. **B-21-1:** Box 16 of 16 **Depth:** 248.4-250.8 ft **Date:** 04/13/21

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BORING NUMBER B-21-2

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA
DATE STARTED 4/20/21 **COMPLETED** 5/13/21
GROUND ELEVATION TBD **HOLE SIZE(S)** 3.782 inches
DRILLING CONTRACTOR S&ME, Inc.
NORTHING TBD **EASTING** TBD
DRILLING METHOD HSA, TMR, HQ Core
GROUND WATER LEVELS:
LOGGED BY N. Yacobi/ J. Ruffing **CHECKED BY** N. Yacobi/C. Gruenberg
DATE/TIME 4/19/2021 34.65 ft Before grouting
NOTES
DATE/TIME ---

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
0	SS - 1	10-11-12 (23)	11			**Well Graded SAND with SILT and GRAVEL (SW-SM)**, dark gray (5Y 4/1), medium dense, dry, fine to coarse grained SAND, (FILL)	0': Hollow Stem Auger 0': **USCS=SW-SM, LL= --, PL=NP, PI=NP, NMC=2.9, %200=10.8**
3.3						**Poorly Graded SAND with SILT and GRAVEL (SP-SM)**, dark gray (5Y 4/1), dense, dry, fine to coarse grained SAND, (FILL)	
5	SS - 2	32-23-17 (40)	9				5.0': **USCS=SP-SM, LL= --, PL=NP, PI=NP, NMC=4.3, %200=8.6**
7.5						**Clayey SAND (SC)**, yellowish red (5YR 4/6), loose, low plasticity, moist, fine to medium grained SAND, (SAPROLITE)	
10	SS - 3	7-5-4 (9)	18				8.5': **USCS=SC, LL=33, PL=22, PI=11, NMC=19.2, %200=46.5**
11.8						**Silty SAND (SM)**, yellowish red (5YR 4/6), loose, low plasticity, moist, fine to medium grained SAND, (SAPROLITE)	
15	SS - 4	2-2-3 (5)	12				13.5': **USCS=SM, LL=30, PL=25, PI=5, NMC=16.7, %200=33.3**
20	SS - 5	3-3-4 (7)	16			18.5': Brown (10YR 4/3)	18.5': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=15.1, %200=23.0**
25	SS - 6	3-4-5 (9)	19			23.5': Yellowish red (5YR 6/6)	23.5': **USCS=SM, LL=32, PL=27, PI=5, NMC=20.9, %200=35.8**

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
25						**Silty SAND (SM)**, yellowish red (5YR 4/6), loose, low plasticity, moist, fine to medium grained SAND, (SAPROLITE) *(continued)*	
30	SS - 7	6-5-6 (11)	18			28.5': Yellowish brown (10YR 5/4), medium dense, dry	28.5': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=14.4, %200=22.8** 30': End of day (4/20/21) 30.1': Switch to mud rotary
35	SS - 8	6-8-14 (22)	14			33.5': Fine to medium SAND, trace coarse GRAVEL	33.5': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=22.5, %200=20.7**
40	SS - 9	4-6-9 (15)	12				
45	SS - 10	6-8-11 (19)	14				
50	SS - 11	4-6-9 (15)	13				48.5': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=26.4, %200=22.9**

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BORING NUMBER B-21-2

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
50						**Silty SAND (SM)**, yellowish red (5YR 4/6), loose, low plasticity, moist, fine to medium grained SAND, (SAPROLITE) *(continued)* 52.0': Grayish brown (10YR 5/2), dense, moist, poorly graded	
55	SS - 12	11-18-24 (42)	12				53.5': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=20.4, %200=25.6**
						56.8 **Silty SAND with GRAVEL (SM)**, grayish brown (10YR 5/2), very dense, moist to wet, fine to coarse SAND, fine to coarse GRAVEL, round to angular, (PWR)	
60	SS - 13	50/5"	3				58.5': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=17.5, %200=24.0**
65	RC - 1			100	86	61.5 **GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), moderately hard, fine to very coarse grained, thickly foliated, trace to few reddish brown garnets, with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick 65.8 - 75.8': Hard to very hard	HW casing advanced to 61.4' 61.45': Start HQ coring 61.45 - 66.5': Moderate weathering, close to very close joint spacing 62.2': FOLIATION JOINT, 30° dip, open, Fe staining 63': FOLIATION JOINT, 40° dip, open, Fe staining 63.8': FOLIATION JOINT, 10° dip, open, Fe staining 64.5 - 70.0': **PACKER TEST 10: k=3.8E-05 cm/sec** 64.6': FOLIATION JOINT, 10° dip, open, Fe staining 65.3': FOLIATION JOINT, 20° dip, open, Fe staining
70	RC - 2			100	97		66': FOLIATION JOINT, 30° dip, open, Fe staining 66.5 - 75.8': Slight weathering, close to moderately close joint spacing 70.5 - 76.0': **PACKER TEST 9: k=1.2E-05 cm/sec**
75	RC - 3			100	88		72.2': FOLIATION JOINT, 10° dip, open 73.2': FOLATION JOINT, 10° dip, closed, Fe staining 73.6': FOLIATION JOINT, 10° dip, closed, Fe staining 74': FOLIATION JOINT, 25° dip, closed, Fe staining 74.2': FOLIATION JOINT, 30° dip, closed, Fe staining

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PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
75						**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), moderately hard, fine to very coarse grained, thickly foliated, trace to few reddish brown garnets, with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)* 75.8 - 76.2': Moderately hard 76.2 - 88.8': Hard to very hard	74.4': FOLIATION JOINT, 20° dip, open 75.8 - 76.2': Moderate weathering 75.8- 102.2': Wide to very wide joint spacing 75.9': FOLIATION JOINT, 10° dip, open, Fe staining 76': FOLIATION JOINT, 25° dip, open, Fe staining 76.2 - 89.3': Fresh to slight weathering 76.2': FOLIATION JOINT, 30° dip, open, Fe staining 78.0': FOLIATION dipping 30°
	RC - 4			98	91		
80	RC - 5			100	100		81.0 - 81.8': FOLDING 82.4': FOLIATION dipping 20°
85	RC - 6			97	96		85.5 - 91.0': **PACKER TEST 8: k=1.2E-04 cm/sec, Questionable results** 85.8 - 91.0': FOLDING
88.8 89.3						**QUARTZ-FELDSPAR GNEISS**, white (N8), to yellowish gray (5Y 8/1), very hard, coarse to very coarse, trace potassium feldspar and biotite	89.3 - 90.1': Slight weathering
90	RC - 7			96	95	**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	90': JOINT, 40° dip, open, Fe staining 90.1 - 102.2': Fresh to very slight weathering 94.5': FOLIATION dipping 10° - 20°
95	RC - 8			100	100		98.6': FOLIATION dipping 20° - 30° 99.5 - 105.0': **PACKER TEST 7: k=1.7E-06 cm/sec**
100							

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DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
100						**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)* 102.2 - 102.7': Soft 102.7 - 125.8': Hard to very hard	100.8': End of day (4/22/21) 102.2 - 102.7': Moderate weathering, close to very close joint spacing 102.2': Multiple JOINTS, 0 - 20° dip, open, Fe staining, highly fractured 102.7 - 117.6': Fresh weathering, very wide joint spacing 103.5': FOLIATION JOINT, 40° dip, open 103.8': FOLIATION dipping at 20° - 30°
105	RC - 9			100	93		105.8 - 106.25': **SAMPLE B-21-2-1T**, Splitting Tensile Test, TS= 1,620 psi 106.25 - 106.75': **SAMPLE B-21-2-2C**, UCS, uw=168 pcf, ucs= 19,973 psi
110	RC - 10			100	97		
	RC - 11			100	100		112.4': FOLIATION dipping 20° - 30°
115							115.5 - 121.0': **PACKER TEST 6: k=1.5E-06 cm/sec, Questionable results** 117.0': FOLIATION dipping 20° - 30°
120	RC - 12			100	83		117.6': JOINT, 10° dip, open, Fe staining 117.6 - 121.0': Moderate weathering, close joint spacing 118': FOLIATION JOINT, 20° dip, tight, Fe staining 118.1': FOLIATION JOINT, 20° dip, tight, Fe staining 118.3': JOINT, 10° dip, tight, Fe staining 118.7': FOLIATION JOINT, 20° dip, tight, Fe staining 119': FOLIATION JOINT, 10° dip, tight, Fe staining 119.4': FOLIATION JOINT, 5° dip, open, Fe staining 120.8': JOINT, 10° dip, open, Fe staining
125	RC - 13			96	96		121.0 - 143.9': Fresh weathering 121.0 - 144.2': Very wide joint spacing 121.2': FOLIATION JOINT, 10° dip, tight, Fe staining 122.2': FOLIATION dipping 30° - 40° 123.4 - 128.9': **PACKER TEST 5: k=2.7E-06 cm/sec, Questionable results**

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BORING NUMBER B-21-2

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
125						**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	
	RC - 14			100	100	125.8 - 130.8': Moderately hard	127.8': FOLIATION dipping 20° - 30°
130	RC - 15			94	94	130.8 - 144.2': Hard	130.79': End of day (4/23/21) 130.8': Depth to water 31.44 feet below ground surface 132.21 - 132.65': **SAMPLE B-21-2-3CM**, (UCS/EM), uw=167 pcf, ucs= 18,760 psi, em= 3.22E+06 psi, PR= 0.28 at the low stress range (1,900-6,900 psi)
135	RC - 16			100	93		135.8': FOLIATION dipping 0° - 10° 137.9': FOLIATION JOINT, 10° dip, open
140	RC - 17			100	86	144.2 - 145.4': Medium hard	143.9 - 147.9': Slight weathering 143.9 - 148.5': FOLDING 144': FOLIATION dipping 10° - 30° 144.2': JOINT, 20° dip, open, Fe staining 144.2 - 148.4': Close joint spacing 144.6': JOINT, 10° dip, tight, Fe staining 144.8': JOINT, 10° dip, tight, Fe staining
145	RC - 18			100	84	145.4 - 255.8': Hard to very hard	145.3': FOLIATION JOINT, 0° dip, open, minor Fe staining 145.8': JOINT, 20° dip, open, Fe staining 146.1': FOLIATION JOINT, 20° dip, open, Fe staining 146.5': JOINT, 10° dip, open, Fe staining 147': FOLIATION JOINT, 20° dip, tight, Fe staining 147.4': JOINT, 20° dip, open, Fe staining
150							

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PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
150						**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	147.8 - 149.3': Multiple JOINTS, 10° - 40° dip, Fe staining, highly fractured 147.9 - 162.5': Fresh weathering 148.4 - 168.8': Moderately close to close joint spacing 149.4': FOLIATION JOINT, 10° dip, open 149.7 - 154.3': FOLDING
	RC - 19			100	93		153.9': JOINT, 5° dip, tight
155							155.0': FOLIATION dipping 0° - 10° 155.6': JOINT, 0° dip, tight, minor clay infilling 157': FOLIATION dipping 10° - 30°
	RC - 20			100	98		158.2': FOLIATION JOINT, 30° dip, open, minor Fe staining 158.9 - 159.2': JOINT, 50° dip, tight 159.25 - 159.9': **SAMPLE B-21-2-4T**, Splitting Tensile Test, TS= 1,780 psi
160						161 - 220.8': Thinly foliated	159.4 - 160.4': **SAMPLE B-21-2-5C**, UCS, uw=167 pcf, ucs= 18,775 psi 161': Potassium feldspar, Fe staining 161.15': JOINT, 20° dip, tight 161.5 - 167.0': **PACKER TEST 4: k=2.8E-05 cm/sec** 162.1': JOINT, 20° dip, tight 162.5 - 168.8': Slight to very slight weathering
	RC - 21			100	95		
165							164.7': FOLIATION dipping 20° - 30° 165': FOLIATION JOINT, 10° dip, tight 165.8': JOINT, 65° dip, open, Fe staining, partial clay infilling 166.2 - 166.85': **SAMPLE B-21-2-6CM**, (UCS/EM), uw= 168 pcf, ucs= 18,161 psi, em= 3.71E+06 psi, PR= 0.21 at the low stress range (1,800-6,700 psi) 166.5 - 172.0': **PACKER TEST 5a: k=8.7E-05 cm/sec** 166.6': FOLIATION JOINT, 0° dip, tight 166.9 - 167.3': JOINT, healed with potassium feldspar, 60° dip 167.0 - 172.5': **PACKER TEST 3: k=6.4E-05 cm/sec** 167.2': FAULT ZONE, 30° dip, brecciation of feldspar and quartz, chlorite in matrix, chlorite on fault plane, 3 - 5 mm thick 167.7': FOLIATION dipping 0° - 10° 168': JOINT, 70° dip, tight, Fe staining 168.5 - 169.4': Multiple JOINTS, 70° dip, open, highly fractured 168.8 - 169.4': Very close joint spacing, moderate to moderately severe weathering 169.4 - 170.8': Close joint spacing, very slight
	RC - 22			100	87		
170							
	RC - 23			100	100		
175							

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DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
175						**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	weathering 170': JOINT, 10° dip, tight, Fe staining 170.8 - 180.1': Wide fracture spacing 173.2': FOLIATION dipping 20° - 30° 175.8': FOLIATION dipping 10° - 20°
	RC - 24			100	100		179.5 - 185.0': **PACKER TEST 2: k=6.5E-05 cm/sec**
180	RC - 25			90	77		180.1 - 182.3': Close to very close fracture spacing 180.8 - 181.3': Moderately severe to moderate weathering 180.8 - 181.3': Core loss 180.8 - 182.3': Multiple JOINTS, 60° dip, open, highly fractured 181.3 - 193.9': Slight to very slight weathering 182': FOLIATION JOINT, 20° dip, tight 182.3 - 190.1': Moderately close joint spacing 183.7': FOLIATION JOINT, 20° dip, open, minor Fe staining
185	RC - 26			100	96		185.6': JOINT, 20° dip, tight, Fe staining 187.5 - 193.0': **PACKER TEST 1: k=9.2E-06 cm/sec** 188': FOLIATION dipping 20° - 30° 189.7': JOINT, 45° dip, tight, Fe staining
190	RC - 27			97	90		190.1 - 192.0': Close to very close joint spacing 190.5': JOINTS, 20° and 60°, open, Fe staining 190.8': FOLIATION JOINT, 30° dip, open, Fe staining 191.6 - 192.0': Multiple JOINTS, 10° - 30° dip, open, Fe staining, highly fractured 191.9 - 194.5': JOINT, healed with chlorite, 90° dip, Fe staining 192.0 - 228.1': Close to moderately close joint spacing 192.9': JOINT, 10° dip, tight, Fe staining 193.9 - 201.0': Fresh weathering 194.6': JOINT, 5° dip, tight, minor Fe staining
195	RC - 28			99	99		197.1': JOINT, 30° dip, open 198': FOLIATION dipping 20° - 30° 198.9': JOINT, 0° dip
200							

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PROJECT NAME BAD CREEK II
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PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
200 205	RC - 29			100	96	**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	199.9': JOINT, 10° dip, calcite and Fe staining 200.4': JOINT, 30° dip, open 200.8': JOINT, 30° dip, open, trace Fe staining 200.9': FOLIATION dipping 20° - 30° 201.0 - 202.2': Slight to very slight weathering 201.3': JOINT, 30° dip, open 201.6': JOINT, 0° dip, open 202.2 - 207.7': Fresh weathering 203.2 - 203.5': SHEAR ZONE, 30° dip, mylonitic, porphyroclasts of feldspar-quartz-biotite in the matrix, anastomosing planes 205': FOLIATION dipping 20° - 30°
210	RC - 30			98	94		206.5 - 206.7': SHEAR ZONE, 10° dip, mylonitic, porphyroclasts of plagioclase and quartz 207.4': JOINT, 10° dip, minor Fe staining 207.7 - 228.1': Slight weathering 207.7 - 210.4': JOINT, partially healed with chlorite and calcite, 90° dip 207.8': JOINT, 10° dip, open, minor Fe staining 208.4 - 217.6': Trace potassium feldspar 208.6': JOINT, 0° dip, tight, Fe staining 208.7': JOINT, 10° dip, open, minor Fe staining
215	RC - 31			100	90		211.7 - 212.2': JOINT, healed with calcite and chlorite (1 - 2 mm thick), 70° dip, Fe staining 212.3': JOINT, 20°, open 212.3 - 212.7': JOINT, healed with calcite and chlorite (1 - 2 mm thick), 70° dip, Fe staining 212.7': FOLIATION dipping 10° - 20° 212.8 - 213.3': HEALED JOINT with calcite and chlorite (1 - 2 mm thick), 70° dip, Fe staining 213.3': JOINT, 20° dip, open with crushed rock, highly fractured
220	RC - 32			100	100		213.3 - 213.7': JOINT, healed with calcite and potassium feldspar (1 - 2 mm thick), 70° dip 213.3 - 213.5': JOINT, healed with calcite and chlorite (1 - 2 mm thick), 70°, Fe staining 214.3': JOINT, 10° dip, tight 214.4 - 214.8': JOINT, healed with calcite and chlorite (1 - 2 mm thick), 70° dip 215.2': JOINT, 10° dip, tight 215.3 - 215.8': FAULT ZONE , 60° dip, brecciated (0.5 - 1.0 cm thick), quartz and potassium feldspar in a quartz-chlorite-calcite matrix, quartz and calcite on fault planes
225	RC - 33			100	86	220.8 - 258.7': Medium gray (N5), thickly foliated	215.7': JOINT, 10° dip, open, calcite infilling 215.8': End of day (4/27/21), water 31.7' below ground surface 216.9': FOLIATOIN JOINT, 20° dip, tight, biotite discolored 217.1': FOLIATION dipping 10° - 20° 217.2 - 217.9':**SAMPLE B-21-2-7T**, Splitting Tensile Test, TS= 1,510 psi 219.4': JOINT, 50° dip, tight, minor calcite

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DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
225						**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	219.9 - 220.4':**SAMPLE B-21-2-8C**, UCS, uw=168 pcf, ucs= 18,747 psi 220.4': JOINT, 20° dip, tight, calcite 221.7': FOLIATION dipping 20° - 30° 223.3 - 224.3': JOINTS, 70° dip, with cross cutting joints at 0° (1 - 2 mm wide), druzy quartz and minor calcite, Fe staining and calcite at 224.2' 225.0': JOINT, healed with calcite (1 - 2 mm thick), 60° dip, 225.6': JOINT, healed with calcite (1 - 2 mm thick), 60° dip 225.8': JOINT, 60° dip, partially open 226.3': JOINT, 30° dip, epidote, chlorite, clay infilling 226.4': JOINT, 60° dip, open, epidote, chlorite, and calcite 227.3': FOLIATION dipping 10° - 20° 228.1': FOLIATION JOINT dip, 10° - 20°, open, minor chlorite 228.1 - 300.8': Fresh weathering, very wide joint spacing 231.6 - 244.3': FOLDING
	RC - 34			100	96		
230							
	RC - 35			100	100		
235							
	RC - 36			100	100		238.0 - 238.55': **SAMPLE B-21-2-9T**, Splitting Tensile Test, TS= 1,240 psi 238.55 - 239.1': **SAMPLE B-21-2-10C**, UCS, uw=166 pcf, ucs= 22,699 psi
240							
	RC - 37			100	100		
245							
	RC - 38			100	100		247.7': FOLIATION dipping 30° - 40°
250							

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PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %
250 – 255	RC - 39			100	100
255 – 260	RC - 40			100	94
260 – 265	RC - 41			100	100
265 – 270	RC - 42			100	100
270 – 275	RC - 43			100	100

DESCRIPTION

GRANITIC GNEISS, light gray (N6) to medium dark gray (N4), hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*

255.8 - 256.2': Medium hard, thickly foliated

256.2 — **BIOTITE SCHIST**, black (N1), medium hard, medium to coarse grained

257.0 — **GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), medium hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende-, pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick

258.7 — **QUARTZ-FELDSPAR GNEISS**, light gray (N7) to white (N8), very hard, coarse to very coarse grained, trace biotite and hornblende

259.3 — **GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard to very hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm) with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick

260.8': Thickly foliated

REMARKS

252.1 - 285.1': FOLDING

255.2 - 255.8': **SAMPLE B-21-2-11CM**, (UCS/EM), uw= 168 pcf, ucs= 19,552 psi, em= 3.85E+06 psi, PR= 0.20 at the low stress range (2,000-7,200 psi)
255.8': End of day (5/6/21), water 34.9' below ground surface
256.0': FOLIATION JOINT, 15° dip, open
256.3 - 256.75': **B-21-2-A Petrographic Analysis**

260.3': FOLIATION dipping 0° - 10°

267.15 - 267.75': **SAMPLE B-21-2-12CM**, (UCS/EM), uw= 169 pcf, ucs= 20,648 psi, em= 4.23E+06 psi, PR=0.18 at the low stress range (2,100-7,600 psi)

270.8': Trace potassium feldspar
270.9 - 271.1': JOINT, healed with chlorite (5 - 6 mm thick), 40° dip

272.6': FOLIATIONS dipping 20° - 30°

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BORING NUMBER B-21-2

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
275						**GRANITIC GNEISS**, light gray (N6) to medium dark gray (N4), hard to very hard, fine to very coarse grained, thickly foliated, trace feldspar augen (up to 3 cm), trace hornblende (up to 1 cm), trace reddish brown garnets (0.1 - 0.4 cm) with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, pinkish light gray (5YR 8/1) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	275.8': End of day (5/7/21) 278.0': FOLIATION dipping 20° - 30°
	RC - 44			100	100		
280	RC - 45			100	100		
285	RC - 46			100	100		285.1': FOLIATION dipping 20° - 30° 285.8': End of day (5/10/21)
290	RC - 47			100	100	290.8 - 300.8': Medium light gray (N6) to medium gray (N5), fine to coarse grained, thinly to intensely foliated	289.7 - 290.3': **SAMPLE B-21-2-13T**, Splitting Tensile Test, TS= 1,320 psi 290.8': Depth to water 36.3 feet below ground surface 291.2': FOLIATION dipping 30° 293.9 - 294.5': FAULT ZONE, 75° dip, chlorite and calcite on fault planes, trace pyrite, 1 - 6 cm displacement, NE strike/ NW dip 294.0 - 294.4': **B-21-2-B Petrographic Analysis**
295	RC - 48			100	100	295.8 - 300.8': Very fine to coarse grained	295.05 - 295.7': **SAMPLE B-21-2-14C**, UCS, uw=168 pcf, ucs= 19,903 psi 296.8': Large hornblende crystal, roughly 4 cm in length 299.0 - 299.6': **SAMPLE B-21-2-15CM**, (UCS/EM), uw= 169 pcf, ucs= 19,803 psi, em= 3.42E+06 psi,
300							

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BORING NUMBER B-21-2

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
300						300.8	PR= 0.17 at the low stress range (2,000-7,300 psi)

Coring termianted at 300.8 feet below ground surface
Bottom of borehole at 300.8 feet.

Photograph 20. **B-21-2:** SS-1 **Depth:** 0-1.5 ft **Date:** 04/20/21

Photograph 21. **B-21-2:** SS-2 **Depth:** 5.0-6.5 ft **Date:** 04/20/21

Photograph 22. **B-21-2:** SS-3 **Depth:** 8.5-10.0 ft **Date:** 04/20/21

Photograph 23. **B-21-2:** SS-4 **Depth:** 13.5-15.0 ft **Date:** 04/20/21

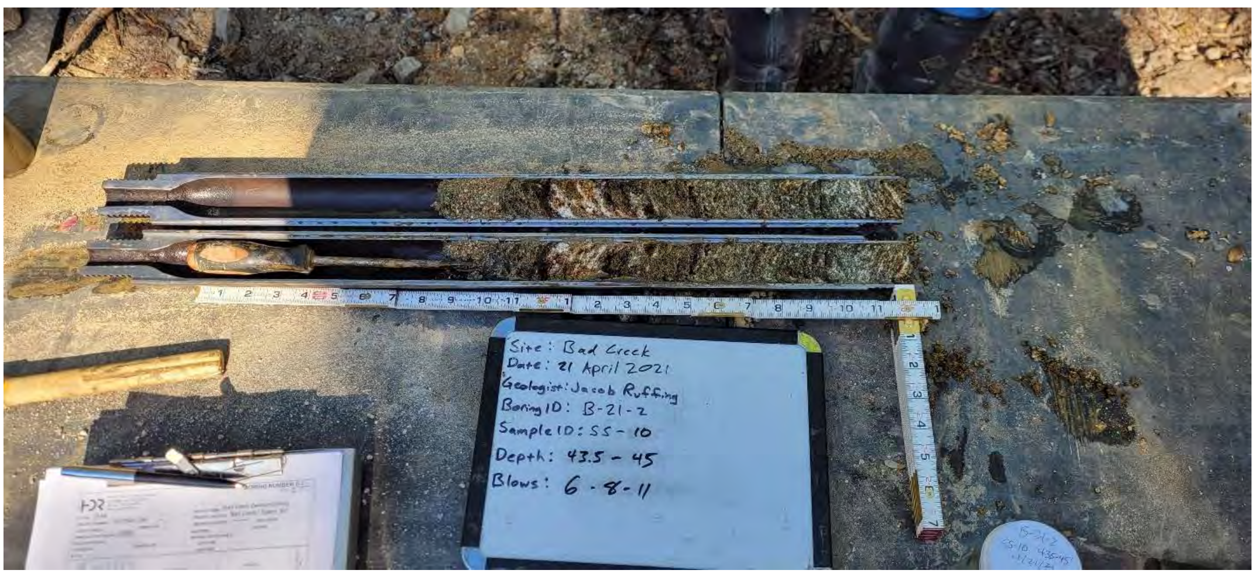
Photograph 24. **B-21-2:** SS-5 **Depth:** 18.5-20.0 ft **Date:** 04/20/21

Photograph 25. **B-21-2:** SS-6 **Depth:** 23.5-25.0 ft **Date:** 04/20/21

Photograph 26. **B-21-2:** SS-7 **Depth:** 28.5-30.0 ft **Date:** 04/20/21

Photograph 27. **B-21-2:** SS-8 **Depth:** 33.5-35.0 ft **Date:** 04/21/21

Photograph 28. **B-21-2:** SS-9 **Depth:** 38.5-40.0 ft **Date:** 04/21/21



Photograph 29. **B-21-2:** SS-10 **Depth:** 43.5-45.0 ft **Date:** 04/20/21

Photograph 30. **B-21-2:** SS-11 **Depth:** 548.5-50.0 ft **Date:** 04/21/21

Photograph 31. **B-21-2:** SS-12 **Depth:** 53.5-55.0 ft **Date:** 04/21/21

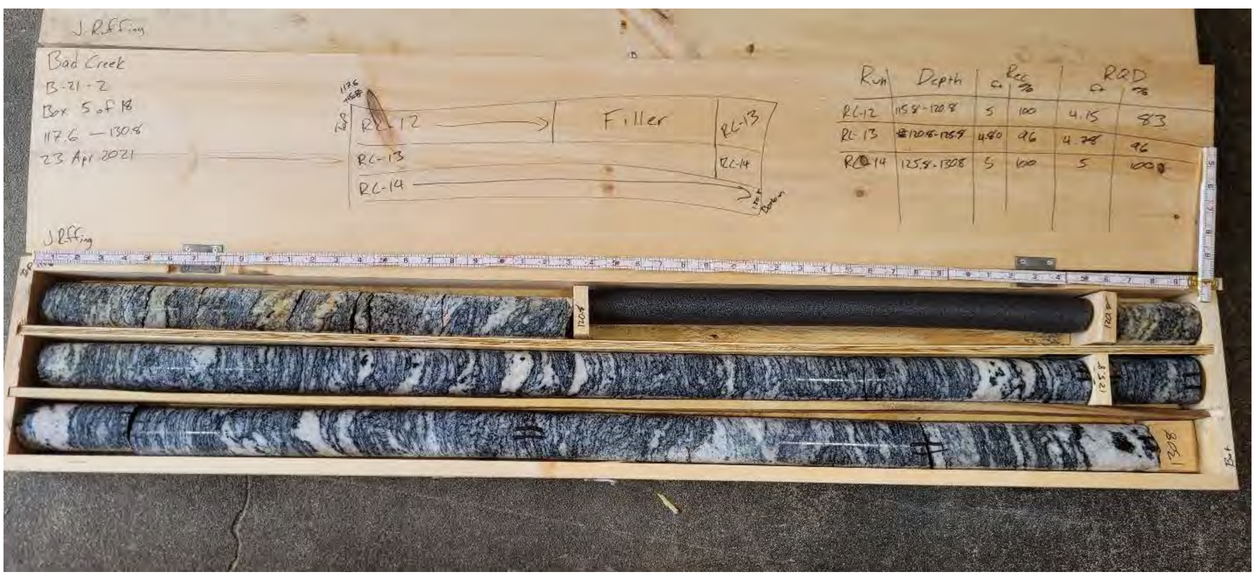
Photograph 32. **B-21-2:** SS-13 **Depth:** 58.5-60.0ft **Date:** 04/21/2

Photograph 33. **B-21-2:** Box 1 of 18 **Depth:** 61.45-75.8 ft **Date:** 04/21/21

Photograph 34. **B-21-2:** Box 2 of 18 **Depth:** 75.8-90.8 ft **Date:** 04/22/21

Photograph 35. **B-21-2:** Box 3 of 18 **Depth:** 90.-105.0 ft **Date:** 04/22/21

Photograph 36. **B-21-2:** Box 4 of 18 **Depth:** 105.0-117.6 ft **Date:** 04/23/21



Photograph 37. **B-21-2:** Box 5 of 18 **Depth:** 117.6-130.8 ft **Date:** 04/23/21

Photograph 38. **B-21-2:** Box 6 of 18 **Depth:** 130.8-145.8 ft **Date:** 04/26/21

Photograph 39. **B-21-2:** Box 7 of 18 **Depth:** 145.8-160.8 ft **Date:** 04/26/21

Photograph 40. **B-21-2:** Box 8 or 18 **Depth:** 160.8-175.8 ft **Date:** 04/26/21

Photograph 41. **B-21-2:** Box 9 of 18 **Depth:** 175.8-190.8 ft **Date:** 04/27/21

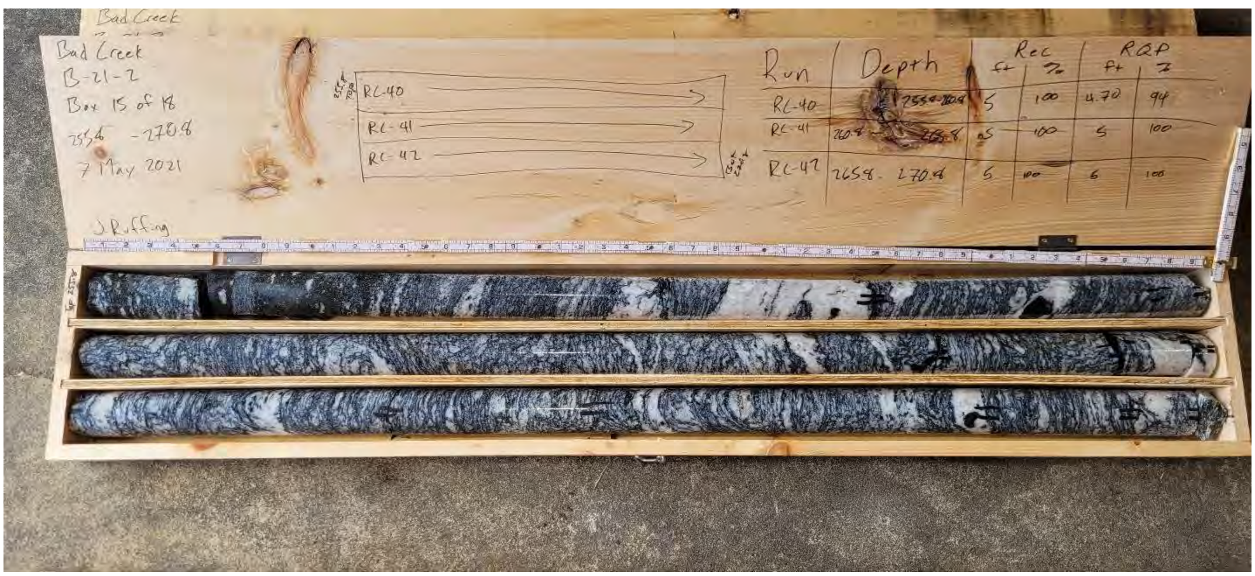
Photograph 42. **B-21-2:** Box 10 of 18 **Depth:** 190.8-205.8 ft **Date:** 04/27/21

Photograph 43. **B-21-2:** Box 11 of 18 **Depth:** 205.8-220.8 ft **Date:** 04/27/21

Photograph 44. **B-21-2:** Box 12 of 18 **Depth:** 220.8-230.8 ft **Date:** 05/05/21

Photograph 45. **B-21-2:** Box 13 to 18 **Depth:** 230.8-245.3 ft **Date:** 05/05/21

Photograph 46. **B-21-2:** Box 14 of 18 **Depth:** 245.3-255.8 ft **Date:** 05/05/21



Photograph 47. **B-21-2:** Box 15 of 18 **Depth:** 255.8-270.8 ft **Date:** 05/07/21

Photograph 48. **B-21-2:** Box 16 of 18 **Depth:** 270.8-285.8 ft **Date:** 05/07/21

Photograph 49. **B-21-2:** Box 17 of 18 **Depth:** 285.5-295.8 ft **Date:** 05/11/21

Photograph 50. **B-21-2:** Box 18 of 18 **Depth:** 295.8-300.8 ft **Date:** 05/13/21

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA
DATE STARTED 4/20/21 **COMPLETED** 5/12/21
GROUND ELEVATION TBD **HOLE SIZE(S)** 3.782 inches
DRILLING CONTRACTOR S&ME, Inc.
NORTHING TBD **EASTING** TBD
DRILLING METHOD TWR, HQ Core
GROUND WATER LEVELS:
LOGGED BY C. Gruenberg **CHECKED BY** N. Yacobi
DATE/TIME 4/29/2021 56.25 ft
NOTES
DATE/TIME 5/11/2021 146.55 ft

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
0	SS - 1	2-3-3 (6)	14			**Silty SAND (SM)**, red (2.5YR 4/8), loose, nonplastic, dry to moist, noncohesive, fine to medium grained SAND with trace coarse grains, micaceous (SOIL)	0': Tricone Wash Rotary from 0.0' - 20.5' 0.1': 2 mm organic lens 0.4': Few coarse quartz sand, few fine gravels 0.0':**USCS=SM, LL=33, PL=25, PI=8, NMC=16.3, %200=46.8**
	SS - 2	11-11-10 (21)	12			2.1': Brownish yellow (10YR 6/6), medium dense, dry, little biotite, (SAPROLITE) 3.2': Biotite lens 3.3': Light gray (10YR 7/2) 4.1 - 20.7': Trace to few gneissic gravel	2.7': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=13.6, %200=22.3** 3.1 - 3.3': Fe staining 3.1 - 4.2': Foliations from parent rock
5							
	SS - 3	4-6-7 (13)	13			7.7 - 20.7': Trace Fe staining, trace 3 mm Fe nodules	7.7': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=18.0, %200=20.6**
10							
	SS - 4	50-50/4"	10			12.7': Light gray (10YR 7/1), very dense, dry to moist, fine to coarse grained SAND, saprolitic, (PWR)	12.7': **USCS=SM, LL= --, PL=NP, PI=NP, NMC=13.9, %200=17.6**
15							
	SS - 5	50/0"	0			17.7': NO RECOVERY	17.3 - 20.5': Water loss 17.7': SPT refusal
20						20.7	
	RC - 1			86	35		20.5': TWR Refusal at 20.5' 20.5 ': Casing advanced to 20.7'; rock crushed when setting casing 20.5': Start HQ coring 20.5': FOLIATION dipping 20° - 30° 20.7 - 24.0': Slight to moderate weathering 20.7 - 22.2': Very close joint spacing 20.7 - 21.5': Fe staining 20.7 - 46.0': Trace potassium feldspar 20.7': End of day (04/20/2021)
25							

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %
25					
	RC - 2			98	66
30	RC - 3			0	0
	RC - 4			84	60
35					
	RC - 5			100	94
40					
	RC - 6			100	100
45					
	RC - 7			100	100
50					

DESCRIPTION

GRANITIC GNEISS, medium light gray (N6) to medium gray (N5), moderately hard to hard, medium to coarse grained, thinly to thickly foliated, trace to few feldspar augens (0.5 - 1.5 cm), trace hornblende (0.1 - 1.3 cm), trace reddish brown garnets (0.2 - 0.9 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*

48.1 - 48.5': Poorly foliated

REMARKS

20.9 - 21.2': Partial water loss
21.5': FOLIATION JOINT, 30° dip, open, trace Fe staining
21.7': JOINT, 20° dip, open, trace Fe staining
21.9': JOINT, 40° dip, open, trace potassium feldspar
22.1': JOINT, 40° dip, open
22.2 - 24.4': Close joint spacing
23.1 - 23.4': JOINT, 60° dip, open, Fe staining
23.8 - 23.9': Highly JOINTED, 20° - 30° dip, partially open
23.9': JOINT, 30° dip, open, minor clay infilling, Fe staining
24.0': Highly JOINTED, saprolitic, soil
24.0 - 24.8': Severe to very severe weathering
24.1 - 24.8': Core loss
24.4 - 24.7': Partial water loss
24.4 - 25.6': Very close joint spacing
24.8 - 25.6': Slight to moderate weathering
25.3': FOLIATION JOINT, 30° dip, open, minor clay infilling, Fe staining
25.5': JOINT, 10° dip, open, minor clay infilling, Fe staining
25.6': JOINT, 10° dip, open, trace Fe staining
25.6 - 26.4': Slight weathering
25.6 - 26.7': Very close joint spacing
25.8': JOINT, 20° dip, open
26.1': JOINT, 10° dip, open
26.2': JOINT, 10° dip, open, minor Fe staining
26.7 - 26.9': Very close joint spacing
26.4': FOLIATION JOINTS, multiple fractures, 20° - 50° dip, open and partially open, minor clay infilling, Fe staining, trace potassium feldspar
26.4 - 26.9': Moderately severe weathering
26.9 - 27.8': Close joint spacing
26.9 - 30.6': Very slight to slight weathering
27.3': JOINT, 30° dip, open, trace Fe staining
27.4': JOINT, 10° dip, open, Fe staining
27.8 - 33.3': Moderately close joint spacing
27.9': FOLIATION JOINT, 30° dip, open, minor clay infilling, trace Fe staining
28.9': JOINT, 35° - 40° dip, open, minor clay infilling, Fe staining
30.5 - 30.6': Core loss
30.5': JOINT, 60° dip, open, rough, trace Fe staining
30.6 - 32.6': Driller reported softer drilling
HW casing advanced to 32.9'
32.9 - 33.3': Core loss
33.3': JOINT, 0° dip, open
33.3 - 37.5': Close joint spacing
33.3 - 35.4': Very slight to slight weathering
33.9': JOINT, 30° dip, open, minor clay infilling, Fe staining
34.1': FOLIATION JOINT, 0° dip, open, Fe staining, trace potassium feldspar
34.4': JOINT, 20° dip, open
35.4 - 40.4': Very slight weathering
36.4': FOLIATION JOINT, 10° - 15° dip, open, oxidized biotite, Fe staining, trace potassium feldspar

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY

PROJECT NAME BAD CREEK II

PROJECT NUMBER 10270481

PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %
50					
	RC - 8			100	100
55					
	RC - 9			100	98
60					
	RC - 10			100	98
65					
	RC - 11			100	98
70					
	RC - 12			100	100
75					

DESCRIPTION

51.8

QUARTZ-FELDSPAR GNEISS, light gray (N7) to white (N9), very hard, coarse to very coarse grained, thinly foliated, trace biotite and hornblende

52.8

GRANITIC GNEISS, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace feldspar augens (0.4 - 1.6 cm), trace hornblende (0.3 - 2.6 cm), trace epidote, trace reddish brown garnets (0.2 - 0.8 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick

REMARKS

37.3': FOLIATION JOINT, 30° dip, open, oxidized biotite, trace Fe staining
37.5': JOINT, 20° dip, open, oxidized biotite, trace Fe staining
37.5 - 40.4': Moderately close joint spacing
38.8': FOLIATION JOINT, 15° - 20° dip, open, oxidized biotite
39.4': FOLDING
40.4 - 42.0': Close joint spacing
40.4 - 45.4': Very slight to slight weathering
40.9 - 41.1': Heavily stained feldspars
41.0': Joint, 30° dip, open, oxidized biotite, Fe oxide, trace potassium feldspar
41.0': Complete water loss, driller used EZ mud to regain circulation
42.0 - 45.4': Moderately close joint spacing
42.1': JOINT, 30° dip, open, oxidized biotite, trace Fe staining
42.9': JOINT, 25° dip, open, oxidized biotite, Fe staining
45.4': FOLIATOIN JOINT, 15°-20° dip, open, Fe staining
45.4 - 80.4': Wide joint spacing
45.4 - 50.4': Very slight weathering
46.6 - 46.7': FOLDING
48.5 - 49.7': Potassium feldspar
49.2': FOLIATION JOINT, 10° - 15° dip, open, oxidized biotite
50.4 - 50.9': Fresh to very slight weathering
50.4': Driller switched from series 8 to series 12 bit due to hardness of rock
50.9 - 51.6': Slight weathering with trace potassium feldspar
51.6 - 55.6': Fresh to very slight weathering
55.6 - 56.0': Slight weathering with trace potassium feldspar
56.0 - 58.7': Fresh to very slight weathering
58.1': JOINT, 30° dip, open, oxidized biotite, fine sand
58.1 - 58.4': **B-21-3-A Petrographic Analysis**
58.7 - 58.8': Slight weathering with trace potassium feldspar
58.8 - 60.4': Fresh to very slight weathering
60.4 - 61.4': Very slight weathering
60.4': FOLIATION dipping 0° - 15°
61.4 - 61.5': Very severe weathering
61.5': Highly JOINTED, very severe weathering, 0° - 10° dip, open, saprolitic, build up of silt and sand in joints
61.5 - 85.4': Fresh to very slight weathering
61.5 - 62.3': Trace potassium feldspar
68.5 - 74.0': **PACKER TEST 7: k=1.1E-04 cm/sec**
69.5': JOINT, 25° dip, open, oxidized biotite, trace Fe staining
70.4': FOLIATION dipping 10° - 30°
70.4 - 75.4': Trace potassium feldspar
72.9': FOLIATOIN JOINT, 20° dip, open, oxidized biotite
74.0 - 74.1': Trace potassium feldspar

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
75						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace feldspar augens (0.4 - 1.6 cm), trace hornblende (0.3 - 2.6 cm), trace epidote, trace reddish brown garnets (0.2 - 0.8 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	74.6 - 74.8': BIOTITE SCHIST, black (N1), hard, fine grained, lens of quartz-plagioclase, few 0.2 - 0.5 cm reddish brown garnets 75.0 - 80.5': **PACKER TEST 6: Flow to high for a complete test. HIGH PERMEABILITY ZONE** 75.4': End of day (04/21/2021)
	RC - 13			100	96		79.2': JOINT, 20° dip, open, trace Fe staining, minor clay infilling 79.3': FOLIATION JOINT, 30° dip, open, sand build up
80							80.4': Driller added EZ mud to help with circulation 80.4 - 265.4': Very wide joint spacing
	RC - 14			100	100		82.3 - 82.4': Trace potassium feldspar
85							85.4 - 250.4': Fresh weathering
	RC - 15			100	100		
90							
	RC - 16			100	100		92.0' - 97.5': **PACKER TEST 5: No take at 70 psi** 94.8': FOLIATION JOINT, 15° dip, tight, sand infilling
95							95.4': HW Casing advanced to 43.7', getting some (25%) return of drilling fluid
	RC - 17			100	100		
100							

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
100							
	RC - 18			100	100		103.0 - 103.3': **B-21-3-B Petrographic Analysis**
104.6 - 105.3						**QUARTZ-FELDSPAR GNEISS**, light gray (N7) to white (N9), very hard, coarse to very coarse grained, thinly foliated, trace hornblende	
105	RC - 19			100	100	**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace feldspar augens (0.4 - 2.0 cm), trace hornblende (0.2 - 4.1 cm), trace epidote, trace reddish brown garnets (0.1 - 0.8 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	105.4': End of day (04/22/2021); Depth to water 70.79' below ground surface, casing at 43.7' below ground surface (04/23/2021); No return initially, some to most return while coring RC-19
110	RC - 20			100	100		
115	RC - 21			100	100		
120	RC - 22			100	100		122.3': FOLIATION dipping 20°
125							

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CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
125	RC - 23			100	100	**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace feldspar augens (0.4 - 2.0 cm), trace hornblende (0.2 - 4.1 cm), trace epidote, trace reddish brown garnets (0.1 - 0.8 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	128.1': Trace fine grained pyrite
130	RC - 24			100	100		
135	RC - 25			100	100		135.4': End of day (04/23/2021); Depth to water 72.51' below ground surface, casing at 43.7' below ground surface (04/26/2021); No return, HW casing advanced to 53.6', Driller switched from series 12 to series 10 bit
140	RC - 26			100	100		140.4': Driller added EZ mud to help with circulation, half of water return while coring RC-26
145	RC - 27			100	100		145.4': Some (25%) fluid return
150							

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
150	RC - 28			100	100	**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace feldspar augens (0.4 - 2.0 cm), trace hornblende (0.2 - 4.1 cm), trace epidote, trace reddish brown garnets (0.1 - 0.8 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	150.4': End of day (04/26/2021); Depth to water 60.25' below ground surface, casing at 53.6' below ground surface (04/27/2021); Driller added EZ mud to help with circulation; HW casing advanced to 63.1', some fluid return after casing advanced
155	RC - 29			100	100		155.4': Most (75%) fluid return
160	RC - 30			100	100		160.4': FOLIATION dipping 10° - 30° 160.9 - 161.15': **B-21-3-C Petrographic Analysis**
165							
	RC - 31			100	100		
170							
	RC - 32			100	100		
175							

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PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
175						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace feldspar augens (0.4 - 2.0 cm), trace hornblende (0.2 - 4.1 cm), trace epidote, trace reddish brown garnets (0.1 - 0.8 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	
	RC - 33			100	100		
180							180.4': End of day 04/27/2021); Depth to water 57.20' below ground surface, casing at 63.1' below ground surface (04/28/2021); No fluid return at start of RC-34
	RC - 34			100	100		
185							185.4': Some (25%) fluid return initially, most (75%) fluid return at end of RC-35
	RC - 35			100	100		
190							190.4': FOLIATION dipping 10° - 30°
	RC - 36			100	100		
195							196.1 - 196.4': Lower concentration of biotite
	RC - 37			100	100		
200							

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PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
200							
201.3 – 202.0	RC - 38			100	100	**QUARTZ-FELDSPAR GNEISS**, light gray (N7) to white (N9), very hard, coarse to very coarse grained, trace hornblende, trace biotite	
202.0 – 205						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace feldspar augens (0.5 - 2.1 cm), trace hornblende (0.2 - 1.4 cm), trace epidote, trace reddish brown garnets (0.3 - 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	
205 – 210	RC - 39			100	100	205.4 - 215.4': Light gray (N7) to medium light gray (N6), little hornblende (0.2 - 1.4 cm) with few epidote	205.4 - 215.4': Increase concentration of quartz and feldspar; Driller reported harder drilling 205.4': FOLIATION dipping 30° - 35° 205.5': FOLDING
210 – 215	RC - 40			100	100		210.0 - 218.9': FOLDING 212.2 - 212.3': Trace potassium feldspar 213.0 - 213.1': Trace potassium feldspar 213.7' - 213.9': Trace potassium feldspar
215 – 220	RC - 41			100	100	215.4 - 225.4': Medium light gray (N6) to medium gray (N5)	215.2': FOLDING 215.4': Driller reported harder drilling 215.4': FOLIATION dipping 20° - 30° 217.55 - 217.8': **B-21-3-D Petrographic Analysis**
220 – 225	RC - 42			100	100		220.4': End of day (04/28/2021); Depth to water 54.30' below ground surface, casing at 63.1' below ground surface (04/29/2021); No fluid return initially, some return (30%) at end of RC-42 220.4': FOLIATION dipping 10° - 30° 223.2 - 224.8': FOLDING
225							

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CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
225						**GRANITIC GNEISS**, medium light gray (N6) to medium gray (N5), very hard, medium to coarse grained, thinly to thickly foliated, trace feldspar augens (0.5 - 2.1 cm), trace hornblende (0.2 - 1.4 cm), trace epidote, trace reddish brown garnets (0.3 - 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)* 225.4 - 249.4': Light gray (N7) to medium light gray (N6)	225.4': JOINT, healed with quartz and feldspar, 15° - 20° dip 225.9 - 226.7': Higher concentration of quartz and feldspar, very coarse to medium grained, less foliated, massive 228.3 - 228.9': FOLDING 228.9 - 229.2': Quartz vein cross cutting foliation 229.0 - 229.6': Higher concentration of quartz and feldspar, very coarse to medium grained, less foliated, massive 230.4': FOLIATION dipping 20° - 30°
	RC - 43			100	100		
230	RC - 44			100	100		232.65 - 233.1': **SAMPLE B-21-3-1T**, Splitting Tensile Test, TS= 1.380 psi 233.1 - 233.7': **SAMPLE B-21-3-2C**, UCS, uw=167 pcf, ucs= 18,446 psi
235	RC - 45			100	100		237.4 - 238.0': **SAMPLE B-21-3-3CM**, (UCS/EM), uw= 169 pcf, ucs, 14,789 psi, em= 2.26E+06 psi, PR= 0.15 at the low stress range (1,500-5,400 psi)
240	RC - 46			100	100		244.5 - 250.0': **PACKER TEST 4: No take at 70 psi**
245	RC - 47			100	100	245.4 - 249.4': Fine to coarse grained 249.4	248.3': JOINT, 60° dip, closed, chlorite 248.7': FOLIATION JOINT, 20° dip, closed, chlorite
250							

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PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
250	RC - 48			100	100	**QUARTZ-FELDSPAR GNEISS**, white (N9) to very light gray (N8), very hard, medium to coarse grained, lenses and pods of biotite/hornblende, trace epidote *(continued)* 250.4': Very light gray (N8) to light gray (N7), medium to very coarse grained, increasing biotite content with depth	249.8 - 250.4': **SAMPLE B-21-3-4T**, Splitting Tensile Test, TS= 1,770 psi 250.0 - 255.5': **PACKER TEST 3: No take at 70 psi** 250.2': JOINT, healed with quartz and feldspar, 60° dip 250.4': End of day (04/29/2021); Depth to water 56.25' below ground surface, casing at 63.1' below ground surface (04/30/2021); No fluid return initially, some fluid return at end of RC-48 250.4 - 255.4': Fresh to very slight weathering 250.6 - 251.15': **SAMPLE B-21-3-5C**, UCS, uw=162 pcf, UCS= 32,661 psi 251.4': JOINT, healed with calcite and chlorite, 30° dip 252.0': Fine grained pyrite
253.4						**GRANITIC GNEISS**, medium gray (N5) to medium dark gray (N4), hard to very hard, fine to coarse grained, thinly to thickly foliated, trace hornblende (0.2 - 1.2 cm), trace epidote, trace reddish brown garnets (0.2 - 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	253.4': FOLIATION dipping 30° 253.8 - 254.1': SHEAR ZONE, 30° dip, quartz-biotite-plagioclase in matrix, quartz-biotite-Fe staining on shear plane, clay and sand infilling, S-C Indictor, anastomosing 254.0': Shear plane grooved, 30°, generally parallel to dip 254.5': FOLDING
255	RC - 49			100	100		255.4 - 265.4': Fresh weathering
260	RC - 50			98	98		260.4': FOLIATION dipping 0° - 15°
263.3						**QUARTZ-FELDSPAR GNEISS**, very light gray (N8), very hard, coarse to very coarse grained, thinly foliated, trace biotite and hornblende	264.3': FOLIATION dipping 10° - 20° 264.4 - 265.4': Rock fell in hole while pulling core up, 0.9' was retrieved with many mechanical fractures
265	RC - 51			92	56		265.0 - 270.5': **PACKER TEST 2: Interval did not build pressure; HIGH PERMEABILITY related to shear zone** 265.3 - 265.5': FOLDING 265.4': FOLIATION JOINT, 40° dip, open, chlorite, on limb of fold 265.4 - 270.4': Close joint spacing 265.4 - 267.0': Very slight to slight weathering 266.0': FOLIATION JOINT, 30° dip, open, Fe minor staining 266.1': Slightly stained feldspar
266.2						**WEATHERED SHEARED ROCK**, light gray (N7), to medium light gray (N6), hard to moderately hard, fine to coarse grained, thinly to thickly foliated, few feldspar augen (0.4 - 1.2 cm), few hornblende (0.2 - 0.5 cm), few reddish brown garnet (0.2 - 0.4 cm)	266.2': FOLIATION JOINT, 20° dip, open, trace Fe staining; Lost all return at 266.2'; Very close to close joint spacing from 266.2' - 270.4'; Moderate to slight weathering from 266.2' - 267.0' 266.8': JOINT, 10° dip, open, oxidized biotite, trace Fe staining 266.8': FOLIATION dipping 0° - 10° 266.9': JOINT, 20° dip, open, Fe staining, weathered garnets 267.0 - 267.8': Highly JOINTED, 0° to 20° dip, open, Fe staining, clay infilling, sand build up
269.2						**GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, few feldspar augens (0.4 - 2.0 cm), few hornblende (0.2 - 0.5 cm), trace epidote, few reddish brown garnets (0.2 - 0.7 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1 - 0.4' thick	
270	RC - 52			100	100		
275							

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PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
275	RC - 53			100	100	278.0 / 278.7 **QUARTZ-FELDSPAR GNEISS**, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, trace to few biotite and hornblende **GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, few feldspar augens (0.4 - 2.3 cm), trace hornblende (0.2 - 1.8 cm), trace epidote , trace reddish brown garnets (0.2 - 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende-pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1 - 0.4' thick	267.0 - 267.8': Moderately severe weathering 267.0 - 267.5': Driller reported softer drilling 267.4 - 267.8': Core loss 267.8 - 270.4': Slight to moderate weathering 268': FOLIATION JOINT, 30° dip, open, Fe staining, minor clay infilling, sand infilling 268.2 - 268.4': Heavily JOINTED, 0° - 20° dip, clay infilling, sand infilling 269': FOLIATION JOINT, 10° dip, open, Fe staining, minor clay infilling, sand infilling 269.1': FOLIATION JOINT, 10° dip, open, Fe staining 269.2': JOINT, 10° dip, open, Fe staining 270.4 - 285.4': Very wide joint spacing 270.4 - 280.4': Fresh weathering 275.4': No fluid return 277.55 - 278.1': **SAMPLE B-21-3-6T**, Splitting Tensile Test, TS= 1,650 psi 278.7 - 279.3': **SAMPLE B-21-3-7C** NOT TESTED 279.9': 0.5 cm epidote-rich band
280	RC - 54			100	100		280.4 - 285.4': Fresh to very slight weathering 285.4': No return 280.7': 0.3 cm epidote-rich band
285	RC - 55			100	88	285.4': Some light brown (5YR 6/4)	285.4': End of day (04/30/2021); Depth to water 95.23' below ground surface, casing at 63.1' below ground surface (05/05/2021); No fluid return for remainder of coring to a depth of 500.4' 285.4 - 288.7': Moderately close joint spacing 285.4 - 286.2': Very slight weathering 285.5 - 290.4': Trace potassium feldspar 286.1 - 291.6': **PACKER TEST 1: No take at 70 psi** 286.2 - 290.4': Slight to moderate weathering 286.3 - 287.3': JOINT, healed with potassium feldspar, 80° dip 287.1': Joint, 20° dip, open, moderately rough, sand and silt build up 288.7 - 289.2': FAULT ZONE, 60° dip, open, slickensides indicated oblique slip movement, perpendicular fractures throughout, Fe staining, chlorite, clay infilling, NE strike/ NW dip 288.7 - 290.4': Very close to close joint spacing 289.6 - 289.9': Fault plane, 70° dip, open, slickensides indicate oblique slip movement, perpendicular fractures throughout, Fe staining, clay infilling, NE strike/ NW dip
290	RC - 56			100	100		290.4 - 500.4': Very wide joint spacing 290.4 - 295.4': Fresh to slight weathering
295	RC - 57			100	100		295.4 - 316.0': Fresh weathering 295.7': JOINT, healed with calcite, 60° dip 295.8': JOINT, healed with calcite, 60° dip
300							

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300	RC - 58			100	100	**GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, few feldspar augens (0.4 - 2.3 cm), trace hornblende (0.2 - 1.8 cm), trace epidote , trace reddish brown garnets (0.2 - 0.6 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1 - 0.4' thick *(continued)*	
305	RC - 59			100	100	306.0 **QUARTZ-FELDSPAR GNEISS**, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, thinly foliated biotite. 307.3 **GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, trace feldspar augens (0.2 - 2.5 cm), trace hornblende (0.1 - 2.5 cm), trace epidote, trace reddish brown garnets (0.1 - 0.8 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	
310	RC - 60			100	100		310.4': FOLIATION dipping 10° - 15°
315	RC - 61			100	100		316.0': JOINT, healed with chlorite and calcite, 65°, potassium feldspar 316.0 - 316.4': Fresh to very slight weathering 316.4 - 500.4': Fresh weathering
320	RC - 62			100	100		320.8 - 321.1': Less biotite and hornblende
325							

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325						**GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, trace feldspar augens (0.2 - 2.5 cm), trace hornblende (0.1 - 2.5 cm), trace epidote, trace reddish brown garnets (0.1 - 0.8 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	
	RC - 63			100	100		
330	RC - 64			100	100		331.35 - 332.0':**SAMPLE B-21-3-8T**, Splitting Tensile Test, TS= 1,780 psi 332.25 - 332.9': **SAMPLE B-21-3-9C**, UCS, uw=168 pcf, ucs= 21,079 psi
335	RC - 65			100	100	335.9 - 337.1': Medium gray (N5) to medium dark gray (N4) 337.1 - 342.7': Medium light gray (N6) to medium gray (N5), fine to coarse grained	335.4': End of day (05/05/2021); Depth to water 77.83' below ground surface, casing at 63.1' below ground surface (05/06/2021)
340	RC - 66			100	100	342.7 **QUARTZ-FELDSPAR GNEISS**, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, sparsely to thinly foliated, trace to few biotite and hornblende 343.9	
345	RC - 67			100	100	**GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, few feldspar augens (0.4 - 1.2 cm), trace hornblende (0.2 - 0.5 cm), with trace epidote, trace reddish brown garnets (0.2 - 0.4 cm), with interlayered quartz-, feldspar-, potassium feldspar-, hornblende- pegmatites, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very 349.2	344.5': FOLIATION dipping 15° - 20° 347.6': FOLIATION dipping at 10° - 30° 347.8 - 348.3': FOLDING
350							

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350						350.1 coarse grained, 0.1' - 0.4' thick	
	RC - 68			100	100	**QUARTZ-FELDSPAR GNEISS**, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, trace biotite and hornblende *(continued)*	
						352.8 **GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, trace hornblende augen (0.2 - 0.5 cm), trace epidote , trace reddish brown garnets (0.2 - 0.4 cm), trace feldspar augens (0.4 - 1.2 cm), with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	353.6': FOLIATION dipping 0° - 10°
355						353.6	355.4': FOLIATION dipping 20° - 30°
	RC - 69			100	100		356.1 - 356.7': **SAMPLE B-21-3-10CM**, (UCS/EM), uw= 168, ucs= 19,577 psi, em= 2.93E+06 psi, PR= 0.27 at the low stress range (2,000-7,200 psi)
						357.1 **QUARTZ-FELDSPAR GNEISS**, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, trace biotite and hornblende	357.9': Trace fine grained pyrite
						358.4 **GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, trace hornblende augen (0.1 - 1.0 cm), trace epidote, trace reddish brown garnets (0.2 - 0.4 cm), trace feldspar augens (0.4 - 1.2 cm), with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	
360	RC - 70			100	100		360.4': FOLIATION dipping 10° - 15°
365						**QUARTZ-FELDSPAR GNEISS**, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, trace biotite and hornblende	364.7 - 365.2': **SAMPLE B-21-3-11C**, UCS, uw=167 pcf, ucs= 18,777 psi 365.4 - 365.6': Trace potassium feldspar
	RC - 71			100	100	**GRANITIC GNEISS**, light gray (N7) to medium light gray (N6), hard, fine to medium grained, thinly to thickly foliated, trace hornblende augen (0.1 - 1.2 cm), trace epidote, trace reddish brown garnets (0.1 - 0.4 cm), trace feldspar augens (0.4 - 2.0 cm), with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8), to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick 365.4 - 366.2': Poorly foliated	366.5': FOLIATION dipping 10° - 20° 367.2 - 367.6': JOINT, healed with potassium-feldspar and epidote, 60° dip
370							370.4': Slightly higher biotite content 370.4': FOLIATION dipping 20° - 30°
	RC - 72			100	100		
375							

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PROJECT NUMBER 10270481 | **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
375							375.4': FOLIATION dipping 10° - 15°
	RC - 73			100	100		
379.4						**BIOTITE GNEISS**, medium dark gray (N4) to dark gray (N3), hard, fine to medium grained, thinly foliated, with interlayered quartz-feldspar veins, white (N9), very hard, 0.3 - 1.0 cm thick	379.4': FOLIATION dipping 20° 379.6 - 380.15': **SAMPLE B-21-3-12T**, Splitting Tensile Test, TS= 1,530 psi
380	RC - 74			100	100		380.4': End of day (05/06/2021); Depth - water 142.91' below ground surface, casing at 63.1' below ground surface (05/07/2021); No return 380.5 - 381.15': **SAMPLE B-21-3-13C**, UCS, uw= 169 pcf, ucs= 19,250 psi 383.7 - 384.4': **SAMPLE B-21-3-14T**, Splitting Tensile Test, TS= 1,610 psi
385	RC - 75			100	100		385.5 - 385.7': **B-21-3-E Petrographic Analysis** 385.7 - 386.35': **SAMPLE B-21-3-15C**, UCS, uw= 168 pcf, ucs= 20,357 psi 386.5 - 386.7': QUARTZ-FELDSPAR PEGMATITE, very light gray (N8) to white (N9), very hard, coarse to very coarse grained 387.0 - 387.4': GRANTIC GNEISS, medium light gray (N6), hard to very hard, medium to coarse grained, thinly to thickly foliated 389.4 - 389.9': **SAMPLE B-21-3-16CM** (UCS/EM), uw= 167 pcf, ucs= 22,228 psi, em= 3.25E+06 psi, PR= 0.17 at the low stress range (2,200-8,200 psi)
390							
390.4	RC - 76			100	100	**GRANITIC GNEISS**, medium light gray (N6), to medium gray (N5), very hard, fine to coarse grained, thinly to thickly foliated, trace hornblende (0.2 - 1.9 cm), trace epidote, trace reddish brown garnets (0.3 - 0.9 cm), trace feldspar augens (0.7 - 2.2 cm), with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick	390.4': FOLIATION dipping 20° - 30° 394.3': Band of fine to medium grained gneiss
395	RC - 77			100	100		395.4': FOLIATION dipping 10° 395.8 - 396.2': JOINT, healed with quartz and feldspar, 60° dip, SE dip/ NE strike
400							

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
400						**GRANITIC GNEISS**, medium light gray (N6), to medium gray (N5), very hard, fine to coarse grained, thinly to thickly foliated, trace hornblende (0.2 - 1.9 cm), trace epidote, trace reddish brown garnets (0.3 - 0.9 cm), trace feldspar augens (0.7 - 2.2 cm), with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	
	RC - 78			100	100		
405	RC - 79			100	100		405.5': FOLIATION dipping 30° - 35°
410	RC - 80			100	100		410.5 - 411.35': FOLDING
415	RC - 81			100	100		416.2 - 418.0': Trace potassium feldspar 418.8': FOLDING
420	RC - 82			100	100		420.4 - 425.4': Trace potassium feldspar 423.4 - 423.7': FOLDING 424.3 - 428.4': Higher biotite content
425							

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
425	RC - 83			100	100	**GRANITIC GNEISS**, medium light gray (N6), to medium gray (N5), very hard, fine to coarse grained, thinly to thickly foliated, trace hornblende (0.2 - 1.9 cm), trace epidote, trace reddish brown garnets (0.3 - 0.9 cm), trace feldspar augens (0.7 - 2.2 cm), with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)* 428.4 - 430.4': Light gray (N7) to medium light gray (N6)	429.3': FOLDING
430	RC - 84			100	100		430.8 - 431.4': **SAMPLE B-21-3-17T**, Splitting Tensile Test, TS= 1,350 psi 432.95 - 433.6': **SAMPLE B-21-3-18C**, UCS, uw= 168 pcf, ucs= 22,047 psi 434.5 - 435.1': **SAMPLE B-21-3-19CM**, (UCS/EM), uw= 169 pcf, ucs= 20,417 psi, em= 3.74E+06 psi, PR= 0.19 at the low stress range (2,000-7,500 psi)
435	RC - 85			100	100		435.4': FOLIATION dipping 10° - 20° 436.3': FOLDING 437.9 - 438.7': FOLDING
440	RC - 86			100	100		440.4': End of day (05/10/2021); Depth to water 147.3' below ground surface, casing at 63.1' below ground surface (05/11/2021)
445	RC - 87			100	100		444.7': FOLIATION dipping 20° - 30° 445.0 - 459.2': FOLDING
450							

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
450						**GRANITIC GNEISS**, medium light gray (N6), to medium gray (N5), very hard, fine to coarse grained, thinly to thickly foliated, trace hornblende (0.2 - 1.9 cm), trace epidote, trace reddish brown garnets (0.3 - 0.9 cm), trace feldspar augens (0.7 - 2.2 cm), with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	
	RC - 88			100	100		
455	RC - 89			100	100		
460	RC - 90			100	100		463.7 - 500.4': FOLDING
465	RC - 91			100	100		465.4': FOLIATION dipping 10° - 20°
470	RC - 92			100	100	470.7 **QUARTZ-FELDSPAR GNEISS**, light gray (N7), to pinkish gray (5YR 8/1), very hard, coarse to very coarse grained, with interlayered GRANITIC GNEISS, light gray (N7) to medium light gray (N6), very hard, medium to coarse grained (471.4)	
475							

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CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
475	RC - 93			100	100	**GRANITIC GNEISS**, medium light gray (N6), to medium gray (N5), very hard, fine to coarse grained, thinly to thickly foliated, trace hornblende augen (0.1 - 2.7 cm), trace reddish brown garnets (0.3 - 0.9 cm), trace feldspar augens (0.7 - 2.2 cm), with interlayered quartz- potassium feldspar-hornblende pegmatite, spaced close to moderately close, very light gray (N8) to white (N9), very hard, coarse to very coarse grained, 0.1' - 0.4' thick *(continued)*	475.4': End of day (05/11/2021); Depth to water 146.55' below ground surface, casing at 63.1' below ground surface (05/12/2021)
480	RC - 94			100	100		480.4': FOLIATION dipping 30° 480.4 - 481.05': **SAMPLE B-21-3-20T**, Splitting Tensile Test, TS= 1,510 psi 480.8': FOLDING 481.7 - 482.3': **SAMPLE B-21-3-21C**, UCS, uw=168 pcf, ucs= 18,086 psi 483.55 - 484.2': **SAMPLE B-21-3-22CM**, (UCS/EM), uw= 169 pcf, ucs= 10,642 psi, em= 3.54E+06, PR= 0.33 at the low stress range (1,100-3,900 psi)
485	RC - 95			100	100		
490	RC - 96			100	100		490.4': FOLIATION dipping 30°
495	RC - 97			100	100		
500							

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BORING NUMBER B-21-3

CLIENT DUKE ENERGY

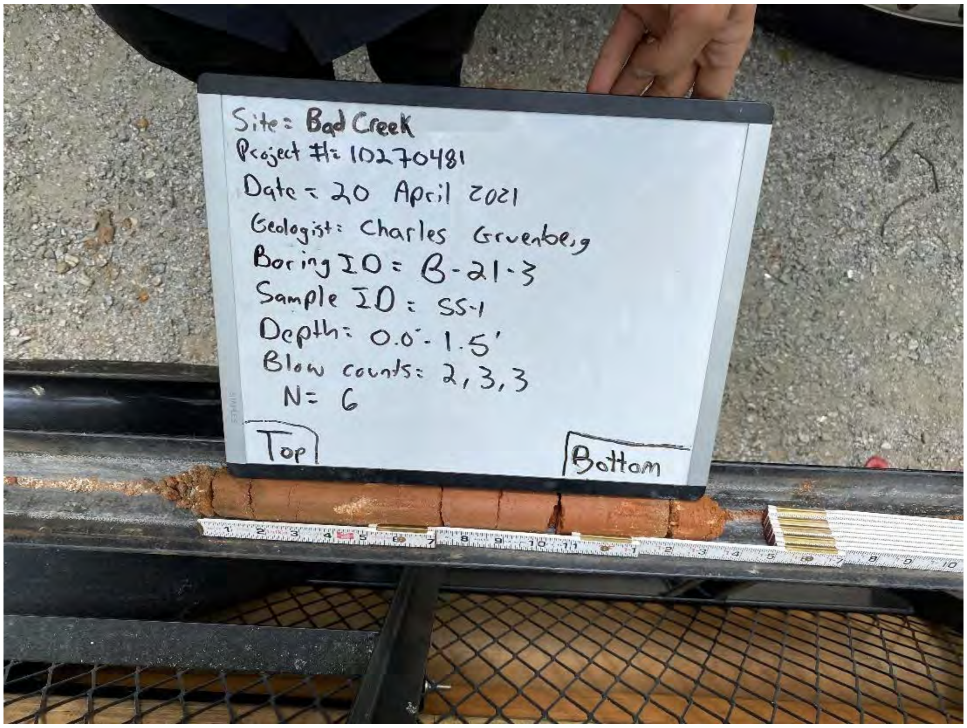
PROJECT NAME BAD CREEK II

PROJECT NUMBER 10270481

PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
500						500.4	

Coring terminated at 500.4 feet below ground surface
Bottom of borehole at 500.4 feet.



Photograph 51. **B-21-3:** SS-1 **Depth:** 0-1.5 ft **Date:** 04/20/21

Photograph 52. **B-21-3:** SS-2 **Depth:** 2.7-4.2 ft **Date:** 04/20/21

Photograph 53. **B-21-3:** SS-3 **Depth:** 7.7-9.2 ft **Date:** 04/20/21

Photograph 54. **B-21-3:** SS-4 **Depth:** 12.7-13.5 ft **Date:** 04/20/21

Photograph 55. **B-21-3:** Box 1 of 34 **Depth:** 20.7-35.4 ft **Date:** 04/21/21

Photograph 56. **B-21-3:** Box 2 of 34 **Depth:** 35.4-49.2 ft **Date:** 04/21/21

Photograph 57. **B-21-3:** Box 3 of 34 **Depth:** 49.2-63.8 ft **Date:** 04/21/21

Photograph 58. **B-21-3:** Box 4 of 34 **Depth:** 63.8-77.1 ft **Date:** 04/21/21-4/22/21

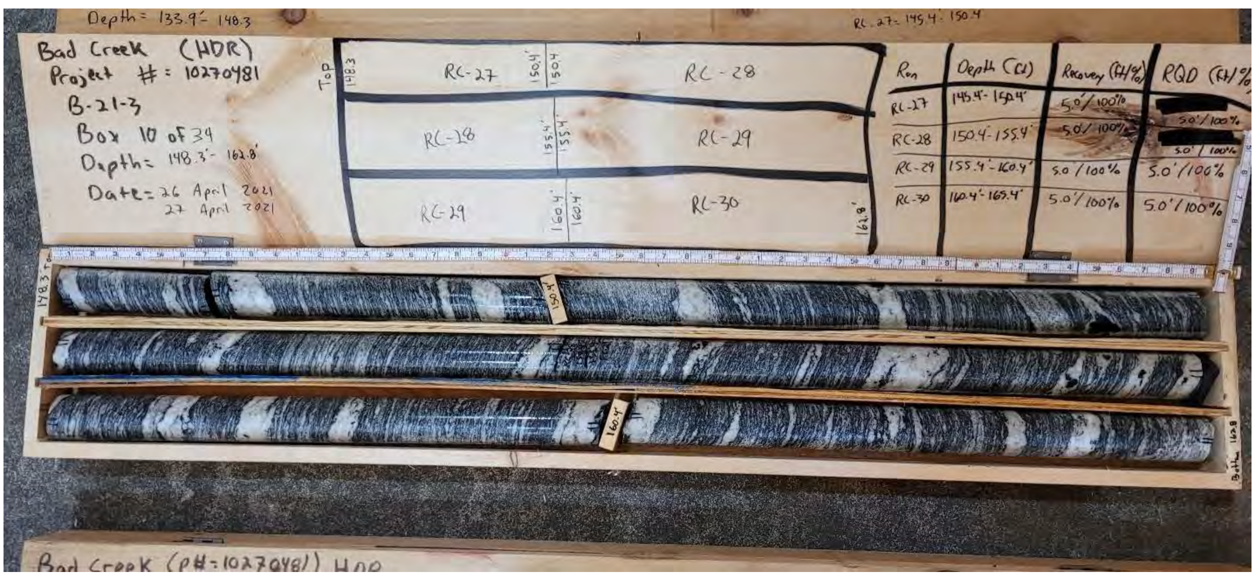
Photograph 59. **B-21-3:** Box 5 of 34 **Depth:** 77.1-91.6 ft **Date:** 04/22/21

Photograph 60. **B-21-3:** Box 6 of 34 **Depth:** 91.6-105.3 ft **Date:** 04/22/21

Photograph 61. **B-21-3:** Box 7 of 34 **Depth:** 105.3-119.4 ft **Date:** 04/25/21

Photograph 62. **B-21-3:** Box 8 of 34 **Depth:** 119.4-133.9 ft **Date:** 04/25/21

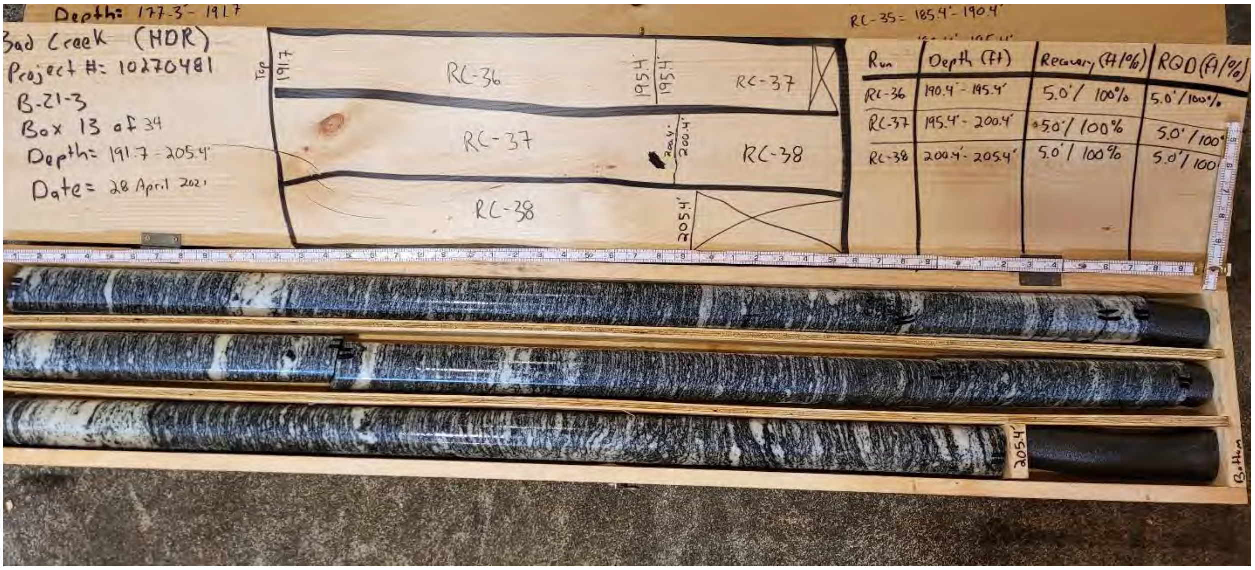
Photograph 63. **B-21-3:** Box 9 of 34 **Depth:** 133.9-148.3 ft **Date:** 04/25/21-04/26/21



Photograph 64. **B-21-3:** Box 10 of 34 **Depth:** 148.3- 162.8 ft **Date:** 04/26/21-04/27/21

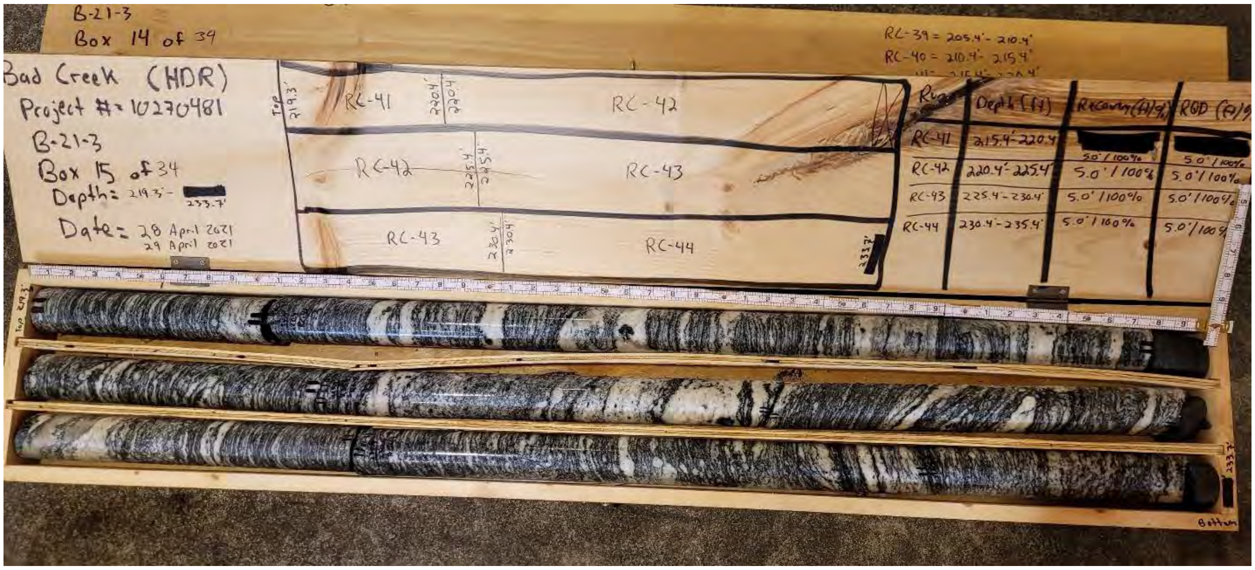
Photograph 65. **B-21-3:** Box 11 of 34 **Depth:** 162.8-177.3 ft **Date:** 04/27/21

Photograph 66. **B-21-3:** Box 12 of 34 **Depth:** 117.3-191.7 ft **Date:** 04/27/21-04/28/21

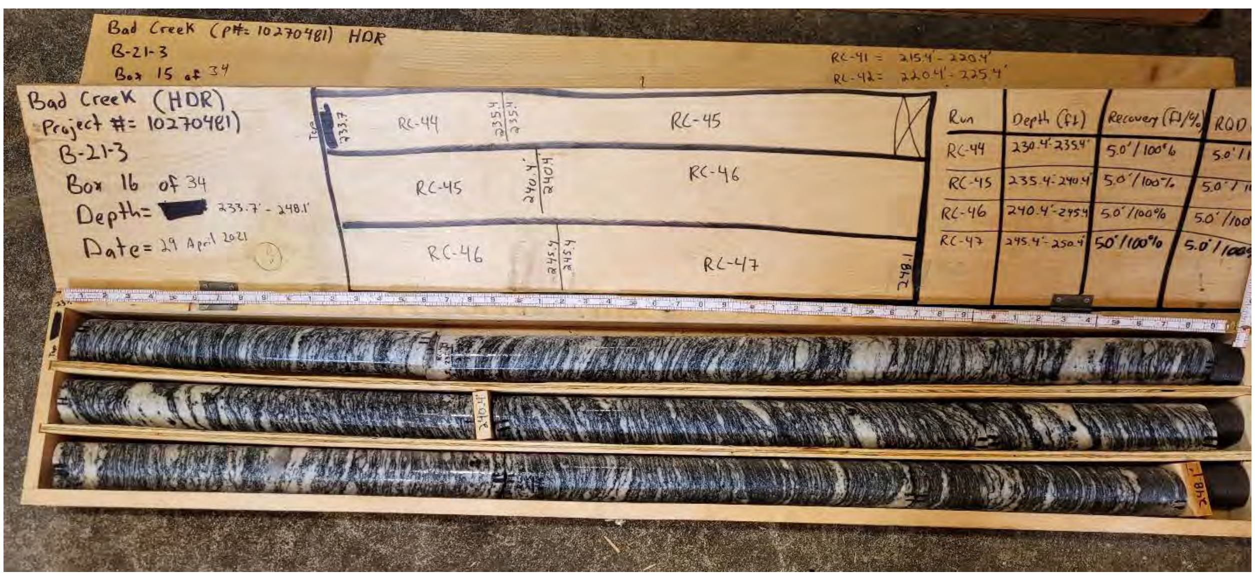


Photograph 67. **B-21-3:** Box 13 of 34 **Depth:** 191.7-205.4 ft **Date:** 04/28/21

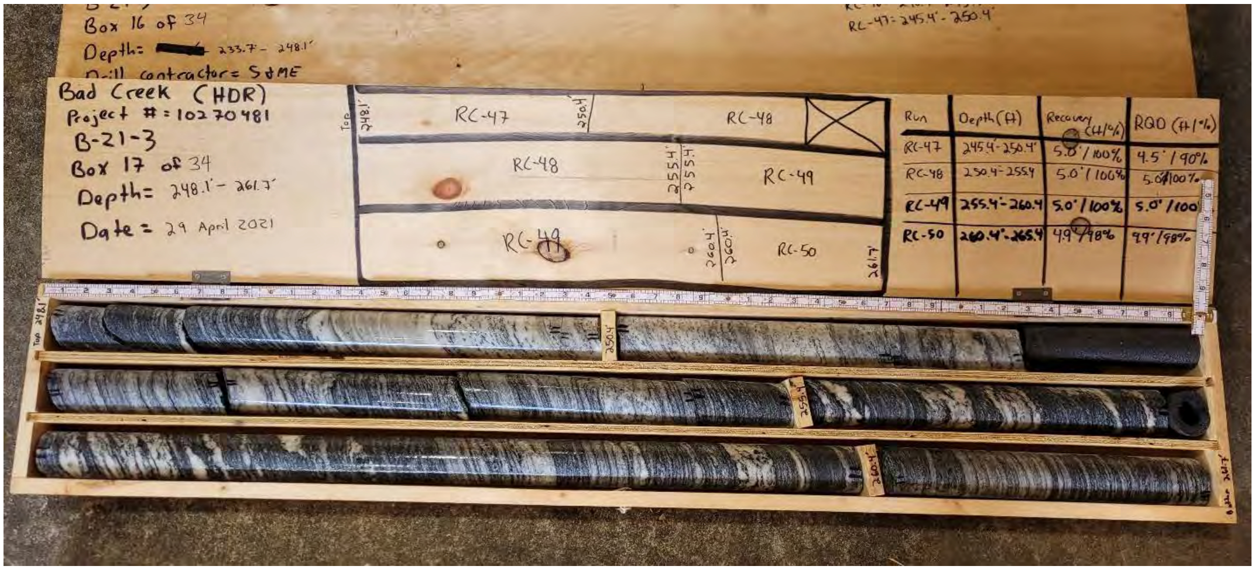
Photograph 68. **B-21-3:** Box 14 of 34 **Depth:** 205.8-219.3 ft **Date:** 04/28/21



Photograph 69. **B-21-3:** Box 15 of 34 **Depth:** 219.3-233.7 ft **Date:** 04/28/21-04/29/21



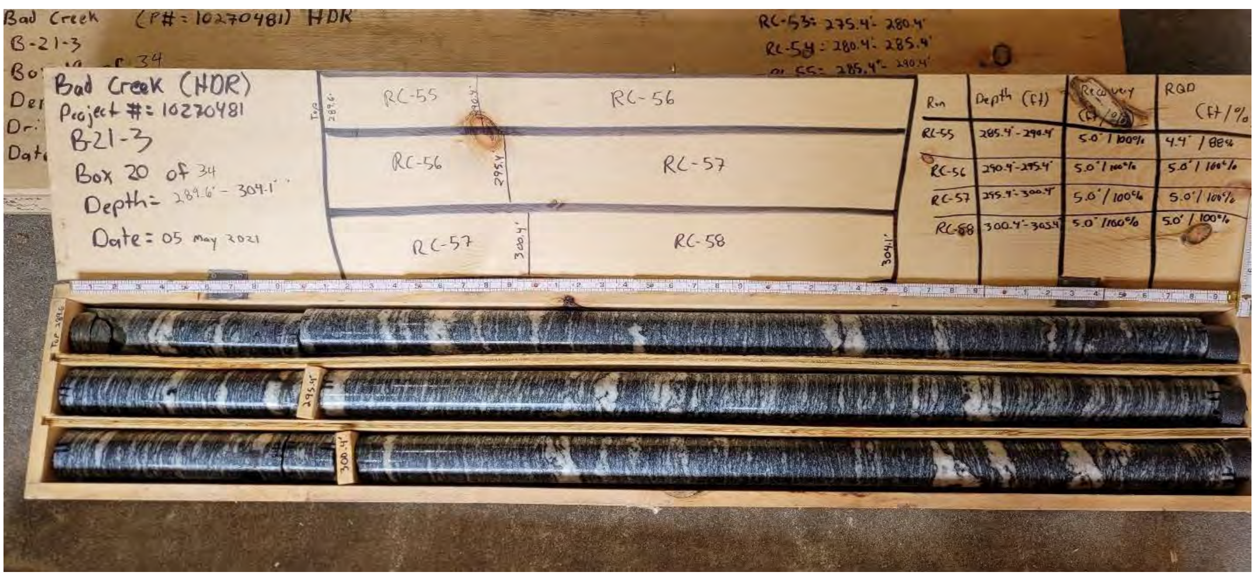
Photograph 70. **B-21-3:** Box 16 of 34 **Depth:** 233.7-248.1 ft **Date:** 04/29/21



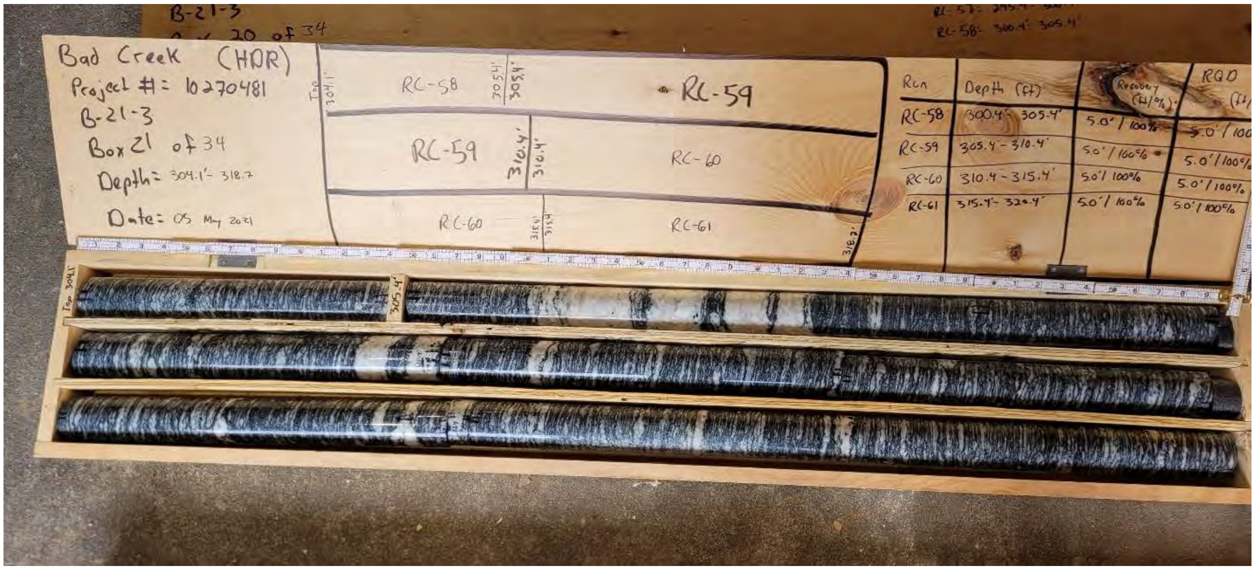
Photograph 71. **B-21-3:** Box 17 of 34 **Depth:** 248.1-261.7 ft **Date:** 04/29/21

Photograph 72. **B-21-3:** Box 18 of 34 **Depth:** 261.7-275.4 ft **Date:** 04/30/21

Photograph 73. **B-21-3:** Box 19 of 34 **Depth:** 275.4-289.6 ft **Date:** 04/30/21-05/05/21

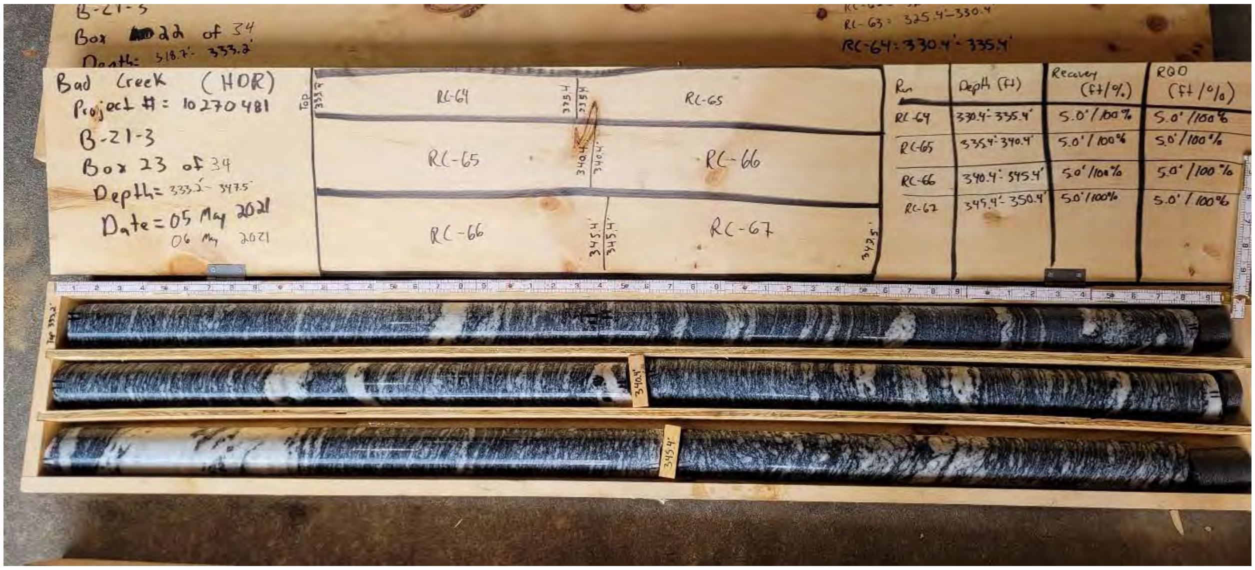


Photograph 74. **B-21-3:** Box 20 of 34 **Depth:** 289.6- 304.1 ft **Date:** 05/05/21

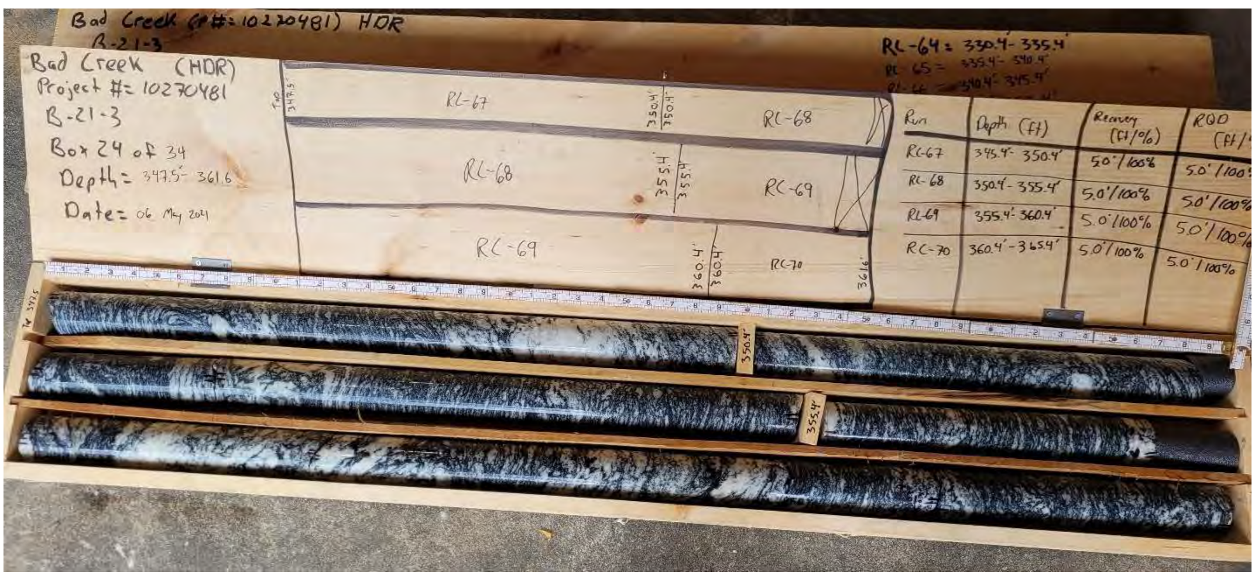


Photograph 75. **B-21-3:** Box 21 of 34 **Depth:** 304.1- 318.7ft **Date:** 05/05/21

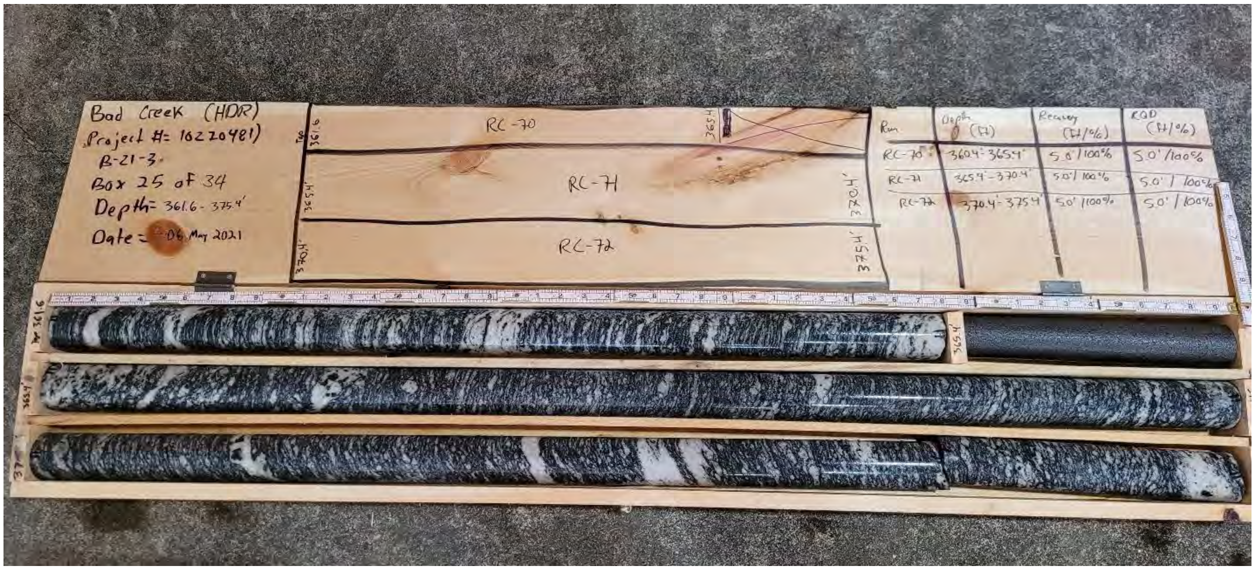
Photograph 76. **B-21-3:** Box 22 of 34 **Depth:** 318.7-333.2 ft **Date:** 05/05/21



Photograph 77. **B-21-3:** Box 23 of 34 **Depth:** 333.2-347.5 ft **Date:** 05/05/21-05/06/21



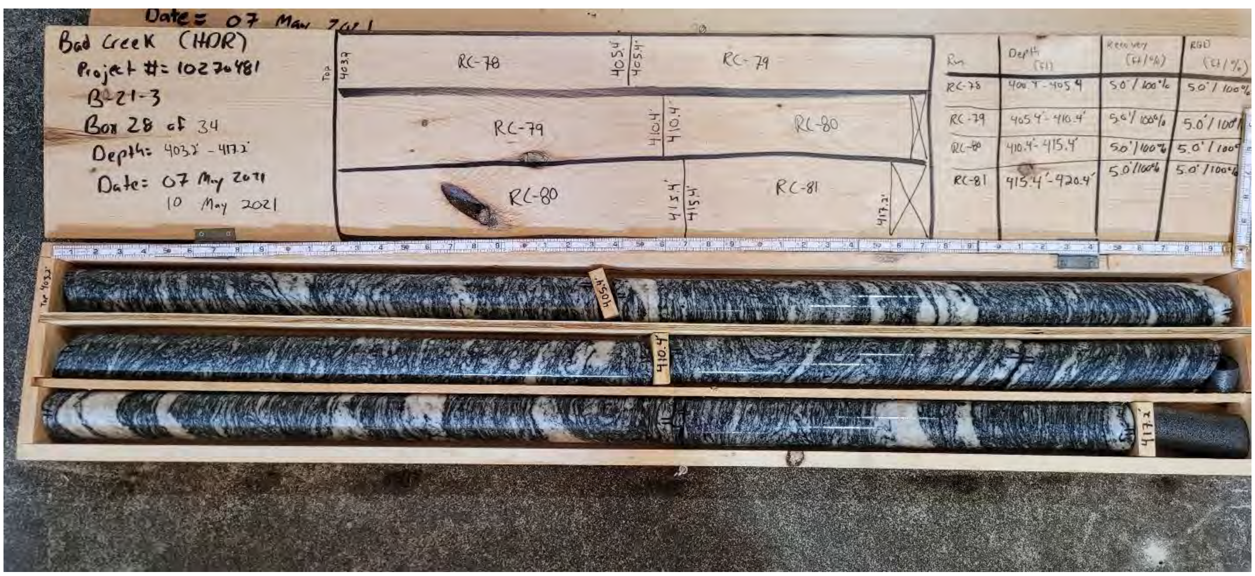
Photograph 78. **B-21-3:** Box 24 of 34 **Depth:** 347.5-361.6 ft **Date:** 05/06/21



Photograph 79. **B-21-3:** Box 25 of 34 **Depth:** 361.6-375.4 ft **Date:** 05/06/21

Photograph 80. **B-21-3:** Box 26 of 34 **Depth:** 375.4-388.8 ft **Date:** 05/06/21-05/07/21

Photograph 81. **B-21-3:** Box 27 of 34 **Depth:** 388.8-403.2 ft **Date:** 05/07/21



Photograph 82. **B-21-3:** Box 28 of 34 **Depth:** 403.2-417.2 ft **Date:** 04/21/21

Photograph 83. **B-21-3:** Box 29 of 34 **Depth:** 417.2-430.3 ft **Date:** 05/10/21

Photograph 84. **B-21-3:** Box 30 of 34 **Depth:** 430.3-444.7 ft **Date:** 05/10/21-05/11/21

Photograph 85. **B-21-3:** Box 31 of 34 **Depth:** 444.7-458.9 ft **Date:** 05/11/21

Photograph 86. **B-21-3:** Box 32 of 34 **Depth:** 458.9-473.3 ft **Date:** 05/11/21

Photograph 87. **B-21-3:** Box 33 of 34 **Depth:** 473.3-487.9 ft **Date:** 05/11/21-05/12/21

Photograph 88. **B-21-3:** Box 34 of 34 **Depth:** 487.9-500.4 ft **Date:** 05/12/21

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BORING NUMBER B-21-4

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA
DATE STARTED 4/5/21 **COMPLETED** 4/13/21
GROUND ELEVATION TBD **HOLE SIZE(S)** 3.782 inches
DRILLING CONTRACTOR S&ME, Inc.
NORTHING TBD **EASTING** TBD
DRILLING METHOD HSA, TWR, HQ Core
GROUND WATER LEVELS:
LOGGED BY J. Ruffing **CHECKED BY** N. Yacobi
DATE/TIME 7.10 ft 4/13/2021 @ 0800
NOTES
DATE/TIME 6.59 ft 4/15/2021 @ 0800

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
0	SS - 1	2-11-12 (23)	16			**Silty SAND with Gravel (SM)** , olive brown (2.5Y 4/3), medium dense, dry, poorly graded, round to subround, Gravel (up to 3")	0': Hollow Stem Auger 3.25" 0.0': **USCS=SP-SM, LL=NP, PL=NP, PI=NP, NMC=3.9, %200=9.3**
1.0						**Sandy GRAVEL (GW)** gray (2.5Y 5/1), dry, well graded, subangular, fine grained GRAVEL (up to 0.75")	3': Switch to Tricone Wash Rotary (2'-15/16")
3.5	SS - 2	26-23-35 (58)	12			**Sandy GRAVEL (GW)**, gray (2.5Y 5/1), very dense, dry, well graded, fine to coarse grained SAND, fine to coarse grained GRAVEL (up to 1.75") (PWR)	3.5': **USCS=SW, LL=NP, PL=NP, PI=NP, NMC=5.9, %200=1.4**
5.7	RC - 1			44	24	**QUARTZ-FELDSPAR GNEISS**, white (N9) to very light gray (N8), very hard, fine to coarse grained, thinly foliated, little 1-2 mm reddish brown garnets (Boulders; Recovered material only)	5.5': End of day (4/5/21) 5.6': No circulation, added EZ mud polymer 5.7': Start HQ Coring 5.7-10.7': Slight weathering (recovered material only) 5.7-15.7': Very close to close joint spacing (recovered material only)
10	RC - 2			0	0		HW casing advanced to 10.0'
15							
17.0	SS - 3	2-1-4 (5)	22			**Clay (CL)**, brown (10YR 5/3), soft, low plasticity, moist, contains wood fragments	18.5':**USCS=SM, LL=28, PL=26, PI=2, NMC=23.4, %200=30.5**
20.0	SS - 4	2-3-5 (8)	24			**Silty GRAVEL (GM)**, yellowish brown (10YR 5/4), loose, wet, fine to coarse grained SAND, fine to coarse grained GRAVEL	23.5': **USCS=SM, LL=27, PL=26, PI=1, NMC=23.2, %200=33.4**
24.5							
25							

NORTH CAROLINA BORING LOG-NO WELL COLUMN - GINT STD US LAB.GDT - 4/6/22 11:19 - C:\PWWORKING\EAST01\D2014647\BADCREEKII_GEOTECHNICAL_GINT.GPJ

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BORING NUMBER B-21-4

CLIENT DUKE ENERGY | **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 | **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
25						**Silty SAND (SM)**, yellowish brown (10YR 5/3), loose, moist, fine to coarse grained SAND *(continued)*	
27.0						**Silty GRAVEL (GM)**, light gray (10YR 7/1), medium dense, wet, fine grained SAND, coarse grained GRAVEL (up to 1.5") (Saprolite)	
30	SS - 5	10-9-7 (16)	7				28.5': **USCS=SM, LL=NP, PL=NP, PI=NP, NMC=16.6, %200=19.2**
32.0						**Silty SAND (SM)**, yellowish brown (10YR 5/4), loose, moist, fine to coarse grained SAND (Saprolite)	HW casing advanced to 32.8'
35	SS - 6	3-3-3 (6)	9				33.5': **USCS=SM, LL=27, PL=25, PI=2, NMC=20.1, %200=29.6**
38.5	SS - 7		0			**BANDED AUGEN GRANITIC GNEISS**, very light gray (N8), soft to medium hard, fine to coarse grained, thinly to thickly foliated, some plagioclase augens (0.2 to 2.5 cm), with interlayered quartz-plagioclase- potassium feldspar-hornblende pegmatite; spaced close to moderately close, white (N9) to very light gray (N8), hard, coarse to very coarse grained, 1-4 mm thick (Boulders)	38.51': End of Day (4/6/21) 38.7-55.7': Moderately severe to severe weathering
40	RC - 3			100	51		
45	RC - 4			33	8		
50	RC - 5			20	0		

CLIENT DUKE ENERGY

PROJECT NAME BAD CREEK II

PROJECT NUMBER 10270481

PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
50	RC - 6			78	55	**BANDED AUGEN GRANITIC GNEISS**, very light gray (N8), soft to medium hard, fine to coarse grained, thinly to thickly foliated, some plagioclase augens (0.2 to 2.5 cm), with interlayered quartz-plagioclase- potassium feldspar-hornblende pegmatite; spaced close to moderately close, white (N9) to very light gray (N8), hard, coarse to very coarse grained, 1-4 mm thick (Boulders) *(continued)*	50.0': Artesian conditions
55	RC - 7			0	0	55.7 **Sandy SILT (ML)**, pale brown (10YR 6/3), nonplastic, noncohesive (Colluvium)	
60	RC - 8			30	0		60.7-65.7': Grab Sample (GS1) 60.7': **USCS=SM, LL=NP, PL=NP, PI=NP, NMC=2.1, %200=27.9**
65	RC - 9			17	0	65.4 **BANDED AUGEN GRANITIC GNEISS**, very light gray (N8) to light gray (N7), medium hard, fine to coarse grained, thinly to thickly foliated, some plagioclase augens (0.2 to 2.5 cm) (Boulders; Recovered material only)	65.4-92.7': Moderately severe to severe weathering (recovered material only)
70	RC - 10			0	0		
75							

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
75						**BANDED AUGEN GRANITIC GNEISS**, very light gray (N8) to light gray (N7), medium hard, fine to coarse grained, thinly to thickly foliated, some plagioclase augens (0.2 to 2.5 cm) (Boulders; Recovered material only) *(continued)*	
	RC - 11			5	0		
80							
80.7	RC - 12			0	0	**Sandy SILT (ML)**, pale brown (10YR 6/3), nonplastic, noncohesive (Colluvium)	
85							
	RC - 13			10	0		
90							
90.7	RC - 14			95	52	**BANDED AUGEN GRANITIC GNEISS**, very light gray (N8) to light gray (N7), medium hard, fine to coarse grained, thinly to thickly foliated, plagioclase augens (0.2 to 2.5 cm), trace reddish brown garnets, with interlayered quartz-plagioclase- potassium feldspar-hornblende pegmatite, spaced close to moderately close, white (N9) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' to 0.4' thick 93.3 to 111.0': Hard	HW casing advanced to 90.7' 90.7-92.7': Heavily jointed, Fe staining, moderate to moderately severe weathering 92.7-121.0': Close to moderately close joint spacing 92.7-141.0': Slight to very slight weathering 92.8': JOINT, 20° dip, open, Fe staining 93.3': JOINT, 30° dip, open, Fe staining 94.0': JOINT, 10° dip, open, Fe staining 94.5': JOINT, 10° dip, open
95							95.8': JOINT, 10° dip, open, Fe staining 96.3': JOINT, 20° dip, open, Fe staining 96.5': JOINT, 30° dip, open, Fe staining
	RC - 15			100	82		98.1': JOINT, 30° dip, open 99.4': JOINT, 20° dip, open, minor Fe staining
100							

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BORING NUMBER B-21-4

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
100						**BANDED AUGEN GRANITIC GNEISS**, very light gray (N8) to light gray (N7), medium hard, fine to coarse grained, thinly to thickly foliated, plagioclase augens (0.2 to 2.5 cm), trace reddish brown garnets, with interlayered quartz-plagioclase- potassium feldspar-hornblende pegmatite, spaced close to moderately close, white (N9) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' to 0.4' thick *(continued)*	
	RC - 16			100	78		101.0-114.6': Slight discoloration of feldspars 101.8': FOLIATION JOINT, 30° dip, open 102.0': JOINT, 40° dip, open 102.3': JOINT, 0° dip, open 102.5': FOLIATION JOINT, 20°v, open, Fe staining 102.9': JOINT, 10° dip, open, Fe staining 103.1': FOLIATION JOINT, 20° dip, open, Fe staining 103.3': FOLIATION dipping 20°-30° 103.5': FOLIATION JOINT, 30° dip, open, Fe staining 103.9': JOINT, 0° dip, open, Fe staining 104.9': FOLIATION JOINT, 20° dip, open, Fe staining
105	RC - 17			100	92		105.3': JOINT, 5° dip, open 105.8': JOINT, 0° dip, closed 107.4': FOLIATION JOINT, 30° dip, open, minor Fe staining 108.3': JOINT, 0° dip, tight, Fe staining 108.4': FOLIATION dipping 10°-20° 109.9': FOLIATION JOINT, 20° dip, tight, Fe staining
110	RC - 18			100	85	111.0 to 113.0': Medium hard 113 to 117.7': Hard	111.1': JOINT, 0° dip, open 111.4': JOINT, 10° dip, open, sand buildup 112.0': FOLIATION JOINT, 20° dip, closed, Fe staining 112.1': JOINT, 30° dip, tight, Fe staining 112.7': JOINT, 20° dip, open, sand and silt buildup 113.0': FOLIATION JOINT, 20° dip, open, sand buildup 113.3': FOLIATION dipping 20°-30° 113.4': FOLIATION JOINT, 20° dip, open 113.8': FOLIATION JOINT, 20° dip, open 114.6': FOLIATION JOINT, 25° dip, open
115	RC - 19			100	86	117.7 to 118.5': Moderately hard 118.5 to 126.1': Hard to very hard	117.3': FOLIATION JOINT, 20° dip 117.6': JOINT, 5° dip, open 118.0': JOINT, 10° dip, open, minor Fe staining 118.2': FOLIATION dipping 20°-30° 118.3': FOLIATION JOINT, 20° dip, open, minor Fe staining 119.95-120.4':**SAMPLE B-21-4-1T**, Splitting Tensile Test, TS= 1,270 psi
120	RC - 20			98	89		120.5': JOINT, 20° dip, open, Fe staining 121': End of day (4/8/21) 121.0-124.8': Wide joint spacing 122.0-122.6': **SAMPLE B-21-4-2C**, UCS, uw=168 pcf, UCS= 15,546 psi 122.6-122.8': **B-21-4-A, Petrographic Analysis** 123.7': FOLIATION dipping 20°-30° 124.15-124.65': **SAMPLE B-21-4-3CM**, (UCS/EM), uw= 168 pcf, ucs= 12,121 psi, em= 1.90E+06 psi,
125							

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BORING NUMBER B-21-4

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
125						126.1 126.9 **HARD SHEARED ROCK**, very light gray (N8) to light gray (N7), hard, fine to coarse grained, shear planes at 126.2' and 126.8', mylonitic texture, shear zone dips 40°-45° **BANDED AUGEN GRANITIC GNEISS**, very light gray (N8) to light gray (N7), very hard, fine to coarse grained, thinly to thickly foliated, some plagioclase augens (0.2 to 2.5 cm), trace reddish brown garnets, with interlayered Quartz-Plagioclase-Potassium Feldspar-Hornblende Pegmatite, spaced close to moderately close, white (N9) to very light gray (N8), very hard, coarse to very coarse grained, 0.1' to 0.4' wide 128.0 to 129.0': Moderately hard	PR=0.21 at the low stress range (1200-4400 psi) 124.8': FOLIATION JOINT, 30° dip, open, Fe staining 124.8-146.0': Close to moderately close JOINT spacing 124.9': FOLIATION JOINT, 30° dip, open, Fe staining 125.7': FOLIATION JOINT, 30° dip, tight, minor Fe staining 126.4': FOLIATION dipping 30°-40° 127.3': JOINT, 20° dip, open 127.6': JOINT, 20° dip, open, Fe staining 127.9': JOINT, 20° dip, tight, Fe staining 127.9': FOLIATION dipping 0°-10° 128.2': JOINT, 20° dip, open 128.6': JOINT, 20° dip, open, minor Fe staining 129.9 - 130.4': **SAMPLE B-21-4-4T**, Splitting Tensile Test, TS= 1,170 psi
	RC - 21			99	75		
130	RC - 22			100	100		130.4 - 134.95':**SAMPLE B-21-4-5C**, UCS, uw=168 pcf, ucs= 16,463 psi 133.5': FOLIATION dipping 20°-30° 134.0': JOINT, 60° dip, open, minor Fe staining
135	RC - 23			95	57		135.15-135.70':**SAMPLE B-21-4-6CM**, (UCS/EM), uw= 168 pcf, ucs= 20,238 psi, em= 3.13E+06 psi, PR= 0.16 at teh low stress range (2000-7400 psi) 136.0 - 136.6':**SAMPLE B-21-4-7T**, Splitting Tensile Test, TS= 929 psi 137.4': FOLIATION JOINT, 0° dip, open, Fe staining 137.6': FOLIATION JOINT, 10° dip, open, Fe staining 138.0': FOLIATION JOINT, 0° dip, open, minor Fe staining 138.2': FOLIATION JOINT, 10° dip, open 138.3': FOLIATION dipping 0°-10° 138.5': FOLIATION JOINT, 20° dip, open 139.1': FOLIATION JOINT, 0° dip, open, Fe staining 139.4': FOLIATION JOINT, 0° dip, open 139.6': FOLIATION JOINT, 0° dip, open
140	RC - 24			100	70		141.0': FOLIATION JOINT, 10° dip, tight, Fe staining 141.0 - 151.0': Fresh weathering 141.3': JOINT, 5° dip, open 141.5': JOINT, 0° dip, open 141.5 - 141.7': **B-21-4-B Petrographic Analysis** 141.7': JOINT, 0° dip, open, Fe staining 141.7 - 142.25': **SAMPLE B-21-4-8CM** (UCS/EM), uw= 168 pcf, ucs= 15,555 psi, em= 2.28E+06 psi, PR= 0.13 at the low stress range (1600-5700 psi) 142.3': FOLIATION dipping 0°-10° 143.5': JOINT, 40° dip, open 144.4': JOINT, 0° dip, trace potassium feldspar
145	RC - 25			100	100		145.0 - 146.0': JOINT, 80° dip, open 146.0 - 151.0': Wide joint spacing 147.8': FOLIATION dipping 0°-10°
150							

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BORING NUMBER B-21-4

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
150						151.0	

Coring termianted at 151.0 feet below ground surface
Bottom of borehole at 151.0 feet.

Photograph 89. **B-21-4:** SS-1 **Depth:** 0.0-1.5 ft **Date:** 04/05/21

Photograph 90. **B-21-4:** SS-3 **Depth:** 18.5-20.0 ft **Date:** 04/06/21

Photograph 91. **B-21-4:** SS-4 **Depth:** 23.5-25.0ft **Date:** 04/06/21

Photograph 92. **B-21-4:** SS-5 **Depth:** 23.5-25.0 ft **Date:** 04/06/21

Photograph 93. **B-21-4:** SS-6 **Depth:** 28.5-30.0 ft **Date:** 04/06/21

Photograph 94. **B-21-4:** SS-7 **Depth:** 38.5-40.0 ft **Date:** 04/06/21

Photograph 95. **B-21-4:** Box 1 of 6 **Depth:** 5.7-60.7 ft **Date:** 04/06/21

Photograph 96. **B-21-4:** Box 2 of 6 **Depth:** 60.7-101.0ft **Date:** 04/07/21

Photograph 97. **B-21-4:** Box 3 of 6 **Depth:** 101.0-116.0 ft **Date:** 04/08/21

Photograph 98. **B-21-4:** Box 4 of 6 **Depth:** 116.0-126.0 ft **Date:** 04/08/21

Photograph 99. **B-21-4:** Box 5 of 6 **Depth:** 126.0-140.5 ft **Date:** 04/13/21

Photograph 100. **B-21-4:** Box 6 of 6 **Depth:** 140.5-151.0 ft **Date:** 04/13/21

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BORING NUMBER B-21-5

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA
DATE STARTED 6/2/21 **COMPLETED** 6/8/21
GROUND ELEVATION TBD **HOLE SIZE(S)** 3.782 inches
DRILLING CONTRACTOR S&ME, Inc.
NORTHING TBD **EASTING** TBD
DRILLING METHOD Mud Rotary, Tricone Rollercone, HQ Core
GROUND WATER LEVELS:
LOGGED BY J. Ruffing/ J. Charlton **CHECKED BY** N. Yacobi
▽ **DATE/TIME** 12.40 ft 6/3/2021 @ 1630
NOTES
▼ **DATE/TIME** 16.50 ft 6/8/2021 @ 1100

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
0						**Poorly Graded GRAVEL with Sand (GP)**, light brownish gray (10YR 6/2), very dense, dry, contains boulders (FILL)	
	SS - 1	50/4"	3				2.6': **USCS=SM, LL=NP, PL=NP, PI=NP, NMC=14.5, %200=20.1**
5						5.0 **Silty SAND (SM)**, grayish brown (10YR 5/2), very dense, dry, fine to coarse SAND (PWR)	
	SS - 2	12-12-14 (26)	14			7.6': Brown (10YR 4/3), medium dense, wet, Fe staining, (SOIL/SAPROLITE)	7.6': **USCS=SM, LL=NP, PL=NP, PI=NP, NMC=15.1, %200=27.8**
10							
	SS - 3	14-22-40 (62)	11			12.6': Grayish brown (10YR 5/2), very dense, with trace coarse Gravel (up to 2.0 inches)	12.6': **USCS=SM, LL=NP, PL=NP, PI=NP, NMC=13.7, %200=24.3**
15							
	SS - 4	50/3"				17.6': (PWR)	17.6': **USCS=SM, LL=NP, PL=NP, PI=NP, NMC=12.5, %200=16.1**
20							
	SS - 5	50/0"	0				
25							

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BORING NUMBER B-21-5

CLIENT DUKE ENERGY
PROJECT NAME BAD CREEK II
PROJECT NUMBER 10270481
PROJECT LOCATION SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
25						17.6': (PWR) *(continued)*	
	SS - 6	23-24-30 (54)				27.6': Very dense, (SOIL/SAPROLTE) 28.7': White (10YR 8/1), 0.3' quartz-feldspar vein	27.6': **USCS=SM, LL=NP, PL=NP, PI=NP, NMC=21.3, %200=27.3**
30							
	SS - 7	32-50/3"	9			33.1': (PWR)	32.6': **USCS=SM, LL=27, PL=NP, PI=NP, NMC=19.3, %200=29.8**
35							
	SS - 8	48-50/3"	9				37.6': **USCS=SM, LL=27, PL=NP, PI=NP, NMC=18.7, %200=29.7**
40							
	SS - 9	50/1"	0				
45							
	SS - 10	50/2"	2				47.6': **USCS=SM, LL=NP, PL=NP, PI=NP, NMC=14.4, %200=26.1**
50							

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BORING NUMBER B-21-5

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
50						33.1': (PWR) *(continued)*	
	SS - 11	22-45-48 (93)	18			52.6': (SOIL/SAPROLITE) 53.5': White (10YR 8/1) 53.6': Strong brown (7.5YR 5/6)	52.6': **USCS=SC-SM, LL=27, PL=22, PI=5, NMC=11.8, %200=19.6**
55							
	SS - 12	50/1"	0				58.1': End of day (06/02/2021); depth to water 12.1' below ground surface (06/03/2021) HW casing advanced to 59.2' 59.2': Start HQ coring
60	RC - 1			100	91	**GRANITIC GNEISS**, medium light gray (N6), very hard, medium to coarse grained, very thinly to thinly banded, some feldspar augens, some hornblende, trace garnets, with interlayered quartz-plagioclase-potassium felspar-hornblende pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, very thinly foliated, 0.1'-0.3' thick	59.5': FOLIATION dipping 30°-40° 60.1': JOINT, healed, 40° dip, Fe staining
	RC - 2			100	100	62.8 63.4 **QUARTZ-FELDSPAR GNEISS**, very light gray (N8), very hard, coarse to very coarse grained	62.5 - 68.0': **PACKER TEST 2: K=5.7E-06 cm/sec** 64.4': 0.1' epidote vein, 50° 64.8': FOLIATION dipping 20°-30°
65						**GRANITIC GNEISS**, medium light gray (N6), very hard, medium to coarse grained, very thinly to thinly foliated, some augens, some hornblende, trace garnets, with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1'-0.3' thick	65.4': FOLIATION JOINT, 30° dip, trace Fe staining and clay
	RC - 3			100	100	69.5	67.5 - 73.0': **PACKER TEST 1: NO take at 60 psi** 68.7': FOLIATION dipping 20°-30°
70						70.0 **QUARTZ-FELDSPAR GNEISS**, very light gray (N8), very hard, coarse to very coarse grained	
	RC - 4			100	100	**GRANITIC GNEISS**, medium light gray (N6), very hard, medium to coarse grained, very thinly to thinly banded, some feldspar augens, trace garnets, with interlayered quartz- potassium feldspar- hornblende pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1' -0.3' thick 71.9 72.3	72.9': FOLIATION dipping 15° 74.1': FOLIATION dipping 10° 74.5': FOLIATION dipping 20°
75							

NORTH CAROLINA BORING LOG-NO WELL COLUMN - GINT STD US LAB.GDT - 4/6/22 11:20 - C:\PWWORKING\EAST01\D2014647\BADCREEKII_GEOTECHNICAL_GINT.GPJ

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BORING NUMBER B-21-5

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
75						**QUARTZ-FELDSPAR GNEISS**, very light gray (N8), very hard, coarse to very coarse grained	75.0': End of day (06/03/2021); depth to water 12.4'
	RC - 5			100	100	**GRANITIC GNEISS**, medium light gray (N6), very hard, medium to coarse grained, very thinly to thinly banded, some feldspar augens, trace garnets, with interlayered quartz-potassium-feldspar-hornblende pegmatitie, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, very thinly foliated, 0.1-0.3' thick *(continued)*	78.8 - 79.2': JOINT, healed with chlorite, 70°, Fe staining
80	RC - 6			100	100		80.3': FOLDING 80.9': FOLIATION dipping 20° 82.6 - 84.3': JOINT, healed with chlorite, 70°-90° dip
85	RC - 7			100	100		85.4': FOLIATION dipping 20°-30° 86.3': JOINT with chlorite, 70° dip 88.6-88.9': JOINT, healed with chlorite, 60° dip 88.7-89.4': FOLDING
90	RC - 8			100	100		90.7 - 92.4': Thinly to thickly laminated 90.8': JOINT with chlorite and calcite, 70° dip, tight 91.5-92.1': OPEN FOLDING 92.9': FOLIATION dipping 30°-40° 93.6': JOINT, healed with chlorite and epidote (1-2 mm wide), 60° dip
95	RC - 9			100	100	98.7	
						GRANITIC GNEISS, light gray (N7), medium to coarse grained, with interlayered quartz-feldspar pegmatite,	98.8': FOLIATION dipping 30°
100						100.0	99.5 - 99.75': **B-21-5-A Petrographic Analysis**

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BORING NUMBER B-21-5

CLIENT DUKE ENERGY **PROJECT NAME** BAD CREEK II

PROJECT NUMBER 10270481 **PROJECT LOCATION** SALEM, SOUTH CAROLINA

DEPTH (ft)	SAMPLE TYPE/ NO./CORE RUN	BLOW COUNTS (N VALUE)	SOIL RECOVERY (in)	ROCK RECOVERY %	ROCK RQD %	DESCRIPTION	REMARKS
100						pinkish gray (5YR 8/1), to light gray (N7), very hard, coarse to very coarse grained, spaced very close to close, well-foliated but no indications of shearing	100.3 - 106.0': Fresh weathering 100.3 - 107.0': JOINT, healed with quartz and chlorite (2-3 mm wide), 90° dip 100.3': End of day (06/04/2021) 100.3': FOLIATION dipping 10°-15° 100.3': Trace hornblende crystals (1-4 mm diameter)
	RC - 10			100	100	103.0 **GRANITIC GNEISS**, medium light gray (N6), hard to very hard, medium to coarse grained, very thinly to thinly banded, some feldspar augens, trace garnets, with interlayered quartz- potassium feldspar-hornblende pegmatite, spaced close to moderately close, very light gray (N8), very hard, coarse to very coarse grained, 0.1'-0.3' thick	
105						103.6 103.3': Hard sheared rock, light gray (N7), very hard, fine to medium grained	106.0 - 120.3': Fresh to slight weathering 106.0': FOLIATION dipping 30°
	RC - 11			100	100	**GRANITIC GNEISS**, medium light gray (N6), hard to very hard, medium to coarse grained, very thinly to thinly banded, some feldspar augens, trace garnets, with interlayered quartz- potassium feldspar-hornblende pegmatite, spaced close to moderatel	108.0 - 109.0': JOINT, healed with quartz (1-2 mm wide), 80° dip 109.8': FOLIATION dipping at 30°
110	RC - 12			100	100		111.3': FOLIATION dipping 10°-20° 111.7 - 112.1': JOINT, with chlorite and calcite, 80° dip, open
115						115.3 **QUARTZ-FELDSPAR GNEISS**, very light gray (N8), very hard, coarse to very coarse grained, very thinly foliated	
	RC - 13			100	100	116.1 **GRANITIC GNEISS**, medium light gray (N6), very hard, medium to coarse grained, very thinly to thinly banded, some feldspar augens, trace garnets, with interlayered quartz- potassium feldspar-hornblende pegmatite	118.7': FOLIATION dipping 0°-10°
120						120.3	

Coring termianted at 120.3 feet below ground surface

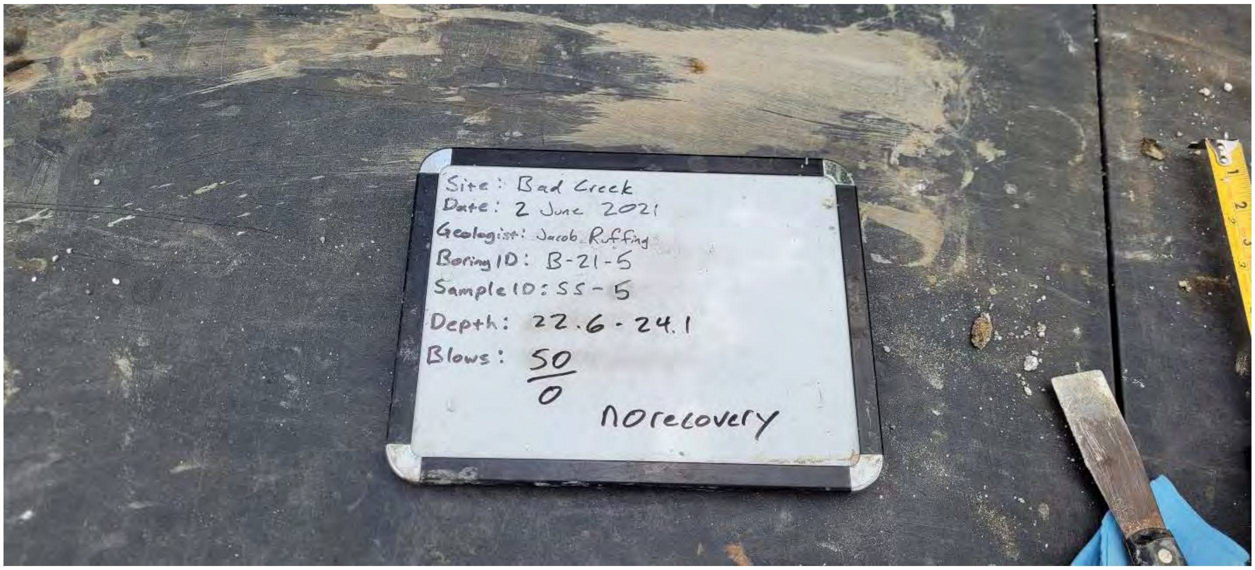
Bottom of borehole at 120.3 feet.

Photograph 101. **B-21-5:** SS-1 **Depth:** 2.6-4.1 ft **Date:** 06/02/21

Photograph 102. **B-21-5:** SS-2 **Depth:** 7.6-9.1 ft **Date:** 06/02/21

Photograph 103. **B-21-5:** SS-3 **Depth:** 12.6-14.1 ft **Date:** 06/02/21

Photograph 104. **B-21-5:** SS-4 **Depth:** 17.6-19.1 ft **Date:** 06/02/21

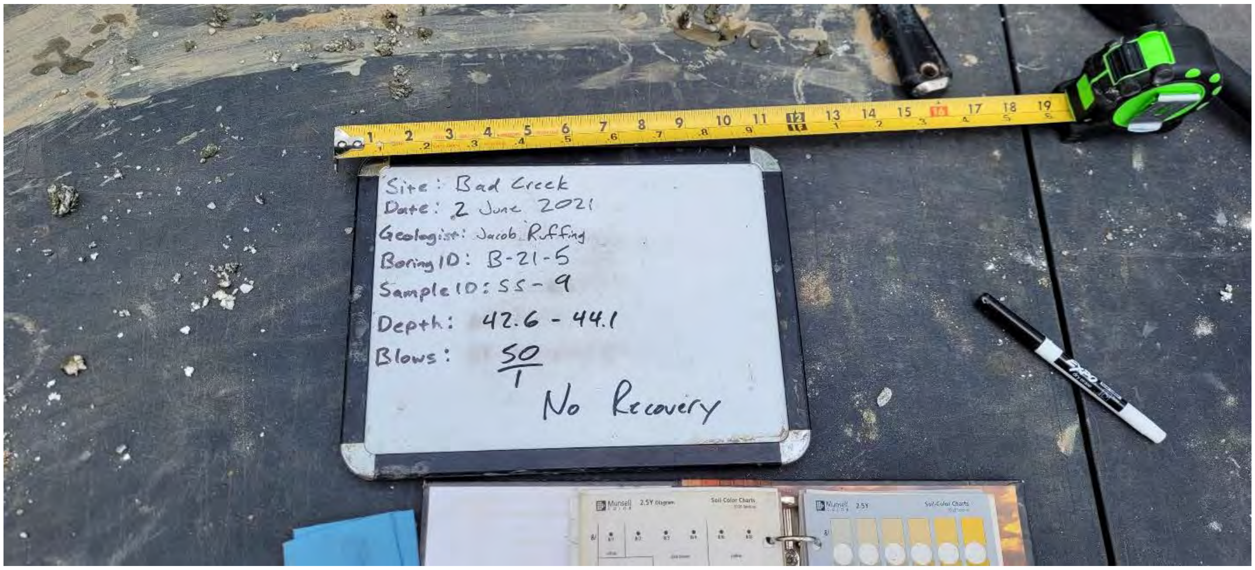


Photograph 105. **B-21-5:** SS-5 **Depth:** 22.6-241. ft **Date:** 06/02/21

Photograph 106. **B-21-5:** SS-6 **Depth:** 27.6-29.1 ft **Date:** 06/02/21

Photograph 107. **B-21-5:** SS-7 **Depth:** 32.6-34.1 ft **Date:** 06/02/21

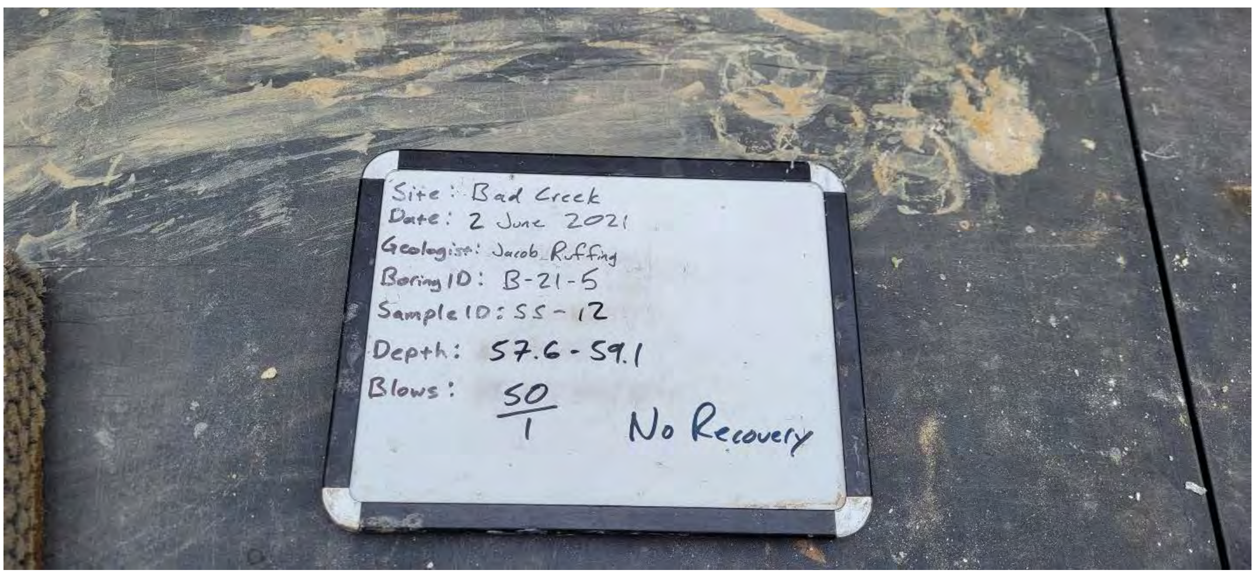
Photograph 108. **B-21-5:** SS-8 **Depth:** 37.6-39.1 ft **Date:** 06/02/21



Photograph 109. **B-21-5:** SS-9 **Depth:** 42.6-44.1 ft **Date:** 06/02/21

Photograph 110. **B-21-5:** SS-10 **Depth:** 47.6-49.1 ft **Date:** 06/02/21

Photograph 111. **B-21-5:** SS-11 **Depth:** 52.6-54.1 ft **Date:** 06/02/21



Photograph 112. **B-21-5:** SS-12 **Depth:** 57.6-59.1 ft **Date:** 06/02/21

Photograph 113. **B-21-5:** Box 1 of 4 **Depth:** 59.2-70.3 ft **Date:** 06/03/21

Photograph 114. **B-21-5:** Box 2 of 4 **Depth:** 70.3-80.3 ft **Date:** 06/03/21

Photograph 115. **B-21-5:** Box 3 of 4 **Depth:** 80.3-90.3 ft **Date:** 06/04/21

Photograph 116. **B-21-5:** Box 4 of 4 **Depth:** 90.3-100.3 ft **Date:** 06/04/21

Photograph 117. **B-21-5:** Box 5 of 6 **Depth:** 100.3-110.3 ft **Date:** 06/04/21

Photograph 118. **B-21-5:** Box 6 of 6 **Depth:** 110.3-120.3 ft **Date:** 06/04/21

Appendix C

Water Pressure Test Results and Data Sheets

Not Included - Available Upon Request

Appendix D

SCDHEC Monitoring Well Approval Letter

Not Included - Available Upon Request

Appendix E

GEL Solutions Surface Geophysical Report

Not Included - Available Upon Request

Appendix F

GEL Solutions Downhole Geophysical Survey Report

Not Included - Available Upon Request

Appendix G

Soil Sample Laboratory Testing Report

September 7, 2021

HDR Engineering, Inc.
1122 Lady Street, Suite 1100
Columbia, South Carolina 29201

Attention: Mr. John Charlton via email: cjohn.charlton@hdrinc.com

Reference: **Laboratory Testing Results**
Bad Creek Phase 2 Feasibility Study Project
Salem, Oconee County, South Carolina
S&ME Project No. 213045

Dear Mr. Charlton:

S&ME, Inc. (S&ME) has completed the laboratory testing as it pertains to the Bad Creek Phase 2 Feasibility Study Project in Salem, Oconee County, South Carolina. Our work was performed in general accordance with the Task Order: SME-10270481-2021-001 dated March 25, 2021. The purpose of this letter is to provide the laboratory test results.

S&ME performed the requested laboratory testing of 34 soil samples provided by HDR Engineering, Inc (HDR) on July 27, 2021 via mail. The laboratory testing program consisted of natural moisture content, grain-size analysis with #200 wash, and Atterberg Limits testing (plasticity). Note that S&ME did not test rock cores collected during the exploration. A Summary of Laboratory Test Data and individual laboratory test sheets are provided in Attachment I.

S&ME appreciates the opportunity to offer our engineering assistance to this project. If you have any questions concerning the information presented or if we can be of further assistance, please feel free to contact us.

Sincerely,
S&ME, Inc.

Khiya Armstrong
Staff Professional I
karmstrong@smeinc.com

Frank P. Morris, P.E.
Project Engineer-Manager
fmorris@smeinc.com

Enclosure:
Attachment I – Laboratory Test Data

Attachments

Attachment I – Summary of Laboratory Test Data & Laboratory Test Data

48 Brookfield Oaks Drive, Suite F
Greenville, SC 29607
864.297.9944

SUMMARY OF LABORATORY TEST DATA

Geotechnical Exploration and Evaluation - Bad Creek Phase II Feasibility Study Project
Salem, Oconee County, South Carolina
S&ME Project No. 213045

Borehole	Sample ID	Sample Depth (feet)	USCS Symbol	SPT (N) (bpf)	Natural Moisture (%)	Percent Finer #200 (%)	Atterberg Limits	
							LL (%)	PI (%)
B-21-1	SS-1	0.3	SP-SM	81	3.0	10.0	---	NP
B-21-1	SS-2	3.1	SP-SM	-	8.6	11.4	---	NP
B-21-1	SS-3	8.1	SM	50/6"	12.0	16.2	---	NP
B-21-2	SS-1	0	SW-SM	23	2.9	10.8	---	NP
B-21-2	SS-2	5	SP-SM	40	4.3	8.6	---	NP
B-21-2	SS-3	8.5	SC	9	19.2	46.5	33	11
B-21-2	SS-4	13.5	SM	5	16.7	33.3	30	5
B-21-2	SS-5	18.5	SM	7	15.1	23.0	---	NP
B-21-2	SS-6	23.5	SM	9	20.9	35.8	32	5
B-21-2	SS-7	28.5	SM	11	14.4	22.8	---	NP
B-21-2	SS-8	33.5	SM	22	22.5	20.7	---	NP
B-21-2	SS-11	48.5	SM	15	26.4	22.9	---	NP
B-21-2	SS-12	53.5	SM	42	20.4	25.6	---	NP
B-21-2	SS-13	58.5	SM	-	17.5	24.0	---	NP
B-21-3	SS-1	0	SM	6	16.3	46.8	33	8
B-21-3	SS-2	2.7	SM	21	13.6	22.3	---	NP
B-21-3	SS-3	7.7	SM	13	18.0	20.6	---	NP
B-21-3	SS-4	12.7	SM	50/6"	13.9	17.6	---	NP
B-21-4	SS-1	0	SP-SM	23	3.9	9.3	---	NP
B-21-4	SS-2	3.5	SW	58	5.9	1.4	---	NP
B-21-4	SS-3	18.5	SM	5	23.4	30.5	28	2
B-21-4	SS-4	23.5	SM	8	23.2	33.4	27	1
B-21-4	SS-5	28.5	SM	16	16.6	19.2	---	NP
B-21-4	SS-6	33.5	SM	6	20.1	29.6	27	2
B-21-4	RC-1	60.7	SM	-	2.1	27.9	---	NP
B-21-5	SS-1	2.6	SM	-	14.5	20.1	---	NP
B-21-5	SS-2	7.6	SM	26	15.1	27.8	---	NP
B-21-5	SS-3	12.6	SM	62	13.7	24.3	---	NP
B-21-5	SS-4	17.6	SM	-	12.5	16.1	---	NP
B-21-5	SS-6	27.6	SM	-	21.3	27.3	---	NP
B-21-5	SS-10	47.6	SM	-	14.4	26.1	---	NP
B-21-5	SS-17	32.6	SM	50/6"	19.3	29.8	27	NP
B-21-5	SS-18	37.6	SM	50/6"	18.7	29.7	27	NP
B-21-5	SS-21	52.6	SC-SM	93	17.6	36.0	27	5

Notes:
USCS = Unified Soil Classification System
SPT = Standard Penetration Test
bpf = blows per foot
LL = Liquid Limit
PI = Plasticity Index

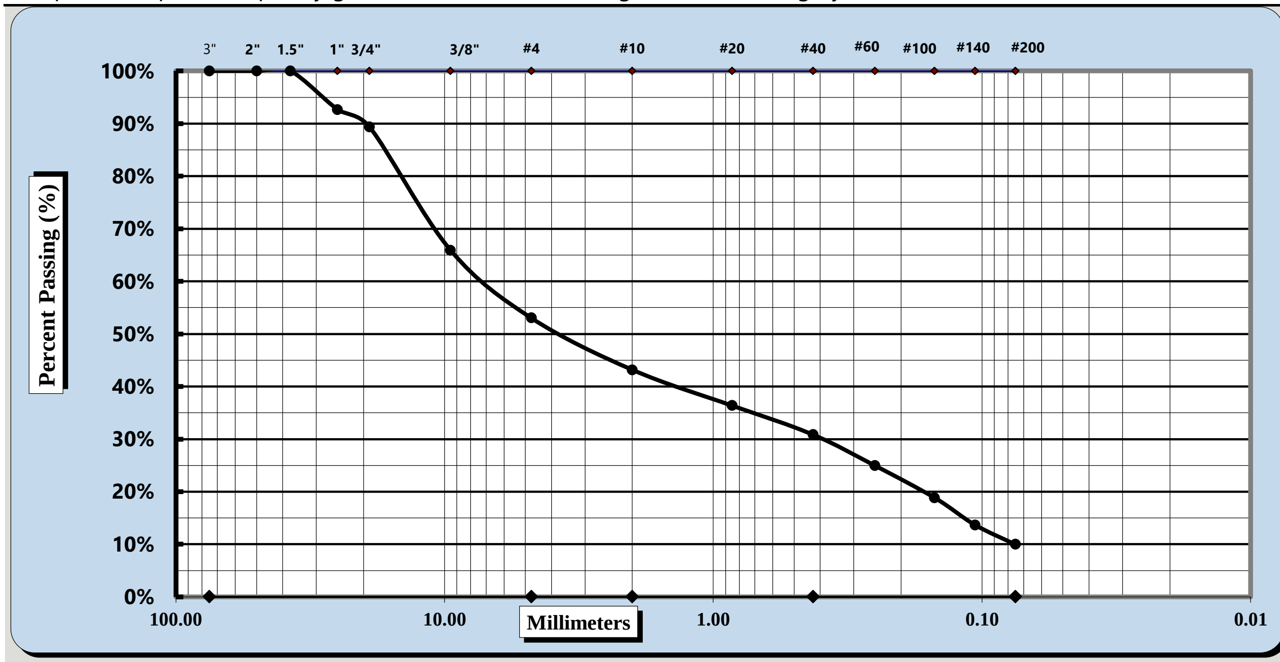
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/24/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-1	Log #:	96g	Sample Date:	4/06/21
Sample ID:	SS-1	Type:	Split-spoon	Depth:	0.3'

Sample Description: poorly graded SAND with silt and gravel (SP-SM) - gray white, coarse to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	37.50 mm	Coarse Sand	9.9%	Fine Sand	20.9%
Gravel	47.0%	Medium Sand	12.3%	Silt & Clay	10.0%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	3.0%		

$Cc = D_{30}^2/(D_{10} \times D_{60})$ **0.3** $Cu = D_{60}/D_{10}$ **100.0**

D10 = **0.075** D30 = **0.40** D60 = **7.50**

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

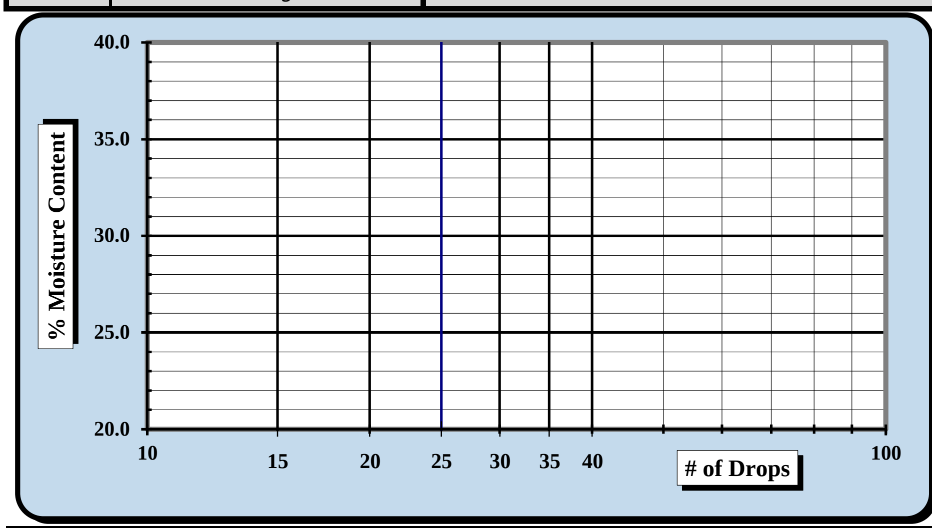
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-1	Log #:	96g	Sample Date:	4/06/21
Sample ID:	SS-1	Type:	Split-spoon	Depth:	0.3'

Sample Description: poorly graded SAND with silt and gravel (SP-SM) - gray white, coarse to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SP-SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 10.0%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

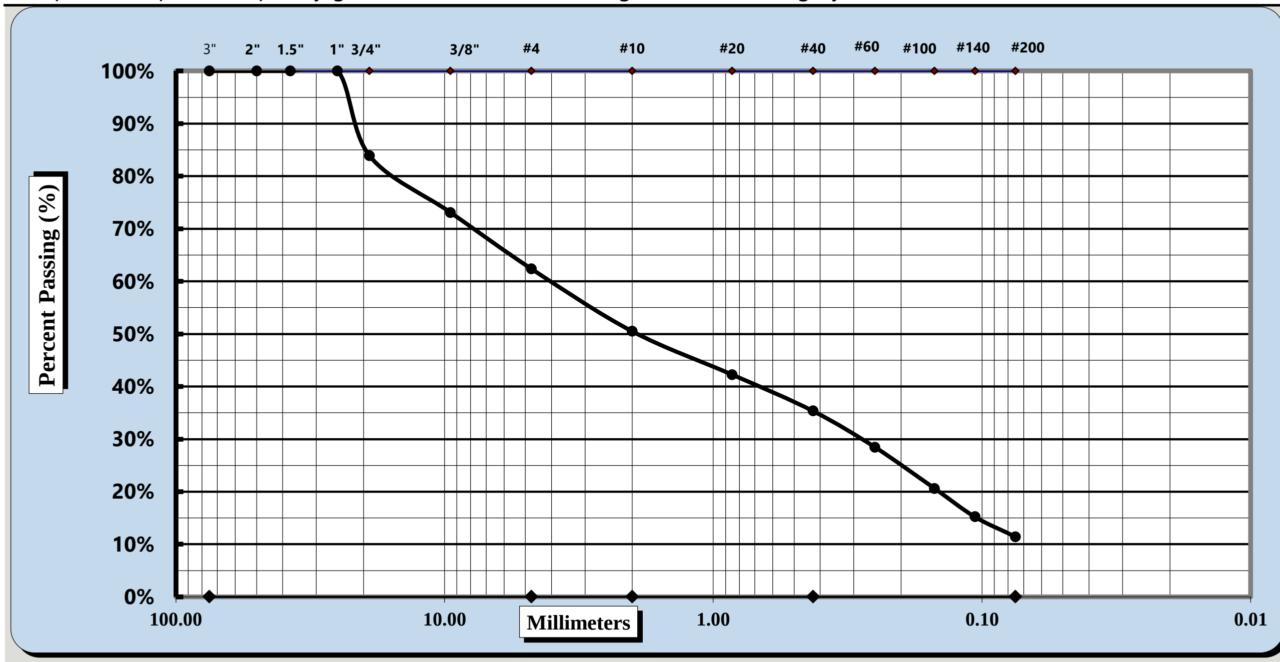
SIEVE ANALYSIS OF SOIL

Single sieve set — *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/24/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-1	Log #:	96g	Sample Date:	4/06/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	3.1'

Sample Description: poorly graded SAND with silt and gravel (SP-SM) - gray white, coarse to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B — Procedure for obtaining Specimen: Moist — Dispersion Process: Dispersant

Maximum Particle Size	25.00 mm	Coarse Sand	11.9%	Fine Sand	23.9%
Gravel	37.6%	Medium Sand	15.1%	Silt & Clay	11.4%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 8.6%

$Cc = D_{30}^2/(D_{10} \times D_{60})$ **0.3** — $Cu = D_{60}/D_{10}$ **63.1**

D10 = **0.07** — D30 = **0.29** — D60 = **4.10**

Notes / Deviations / References:

Frank Morris, P.E.	[signature]	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

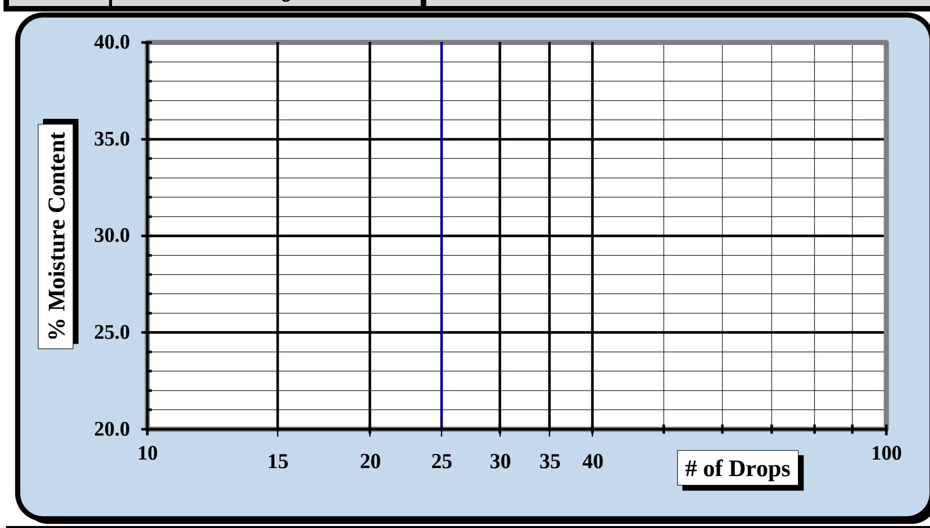
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-1	Log #:	96g	Sample Date:	4/06/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	3.1'

Sample Description: poorly graded SAND with silt and gravel (SP-SM) - gray white, coarse to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	---
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SP-SM**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 11.4%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

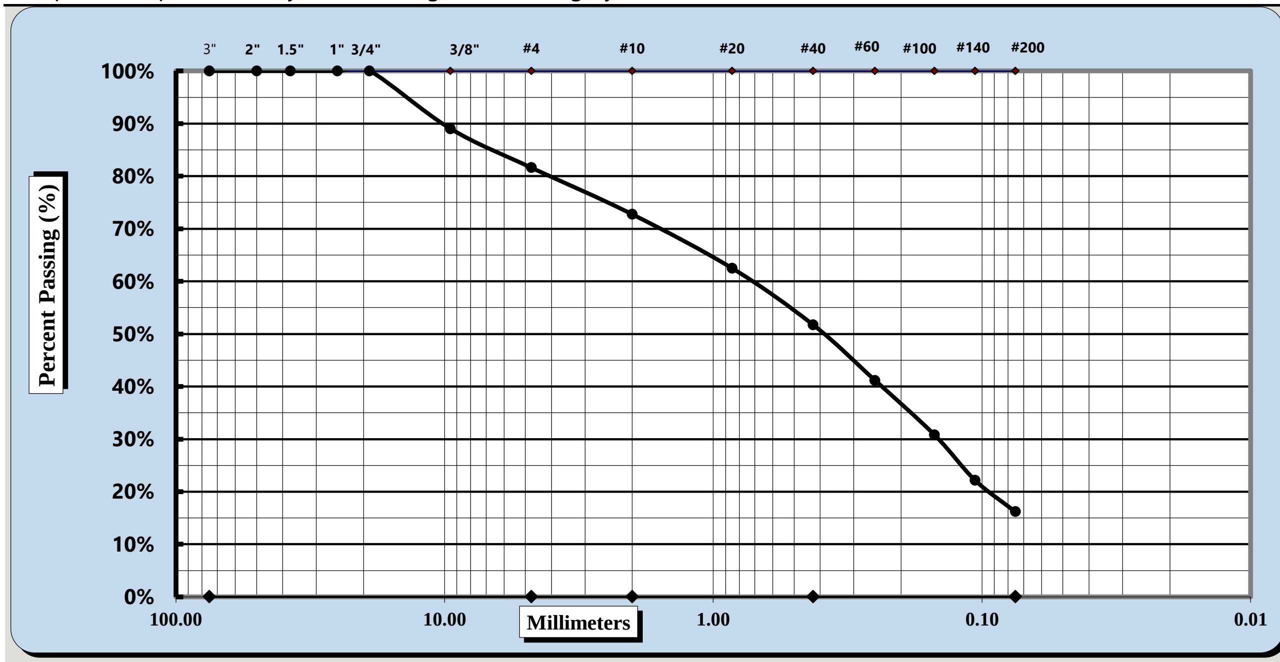
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/24/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-1	Log #:	96g	Sample Date:	4/06/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	8.1'

Sample Description: silty SAND with gravel (SM) - gray white, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	8.9%	Fine Sand	35.6%
Gravel	18.4%	Medium Sand	21.0%	Silt & Clay	16.2%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	12.0%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

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LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

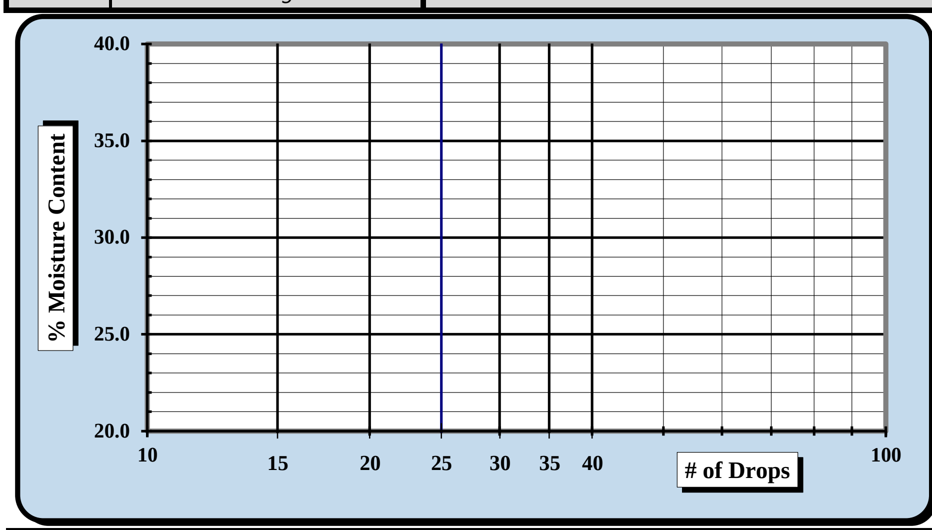
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-1	Log #:	96g	Sample Date:	4/06/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	8.1'

Sample Description: silty SAND with gravel (SM) - gray white, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	---
Plastic Limit	NP
Plastic Index	NP
Group Symbol	SM

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 16.2%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

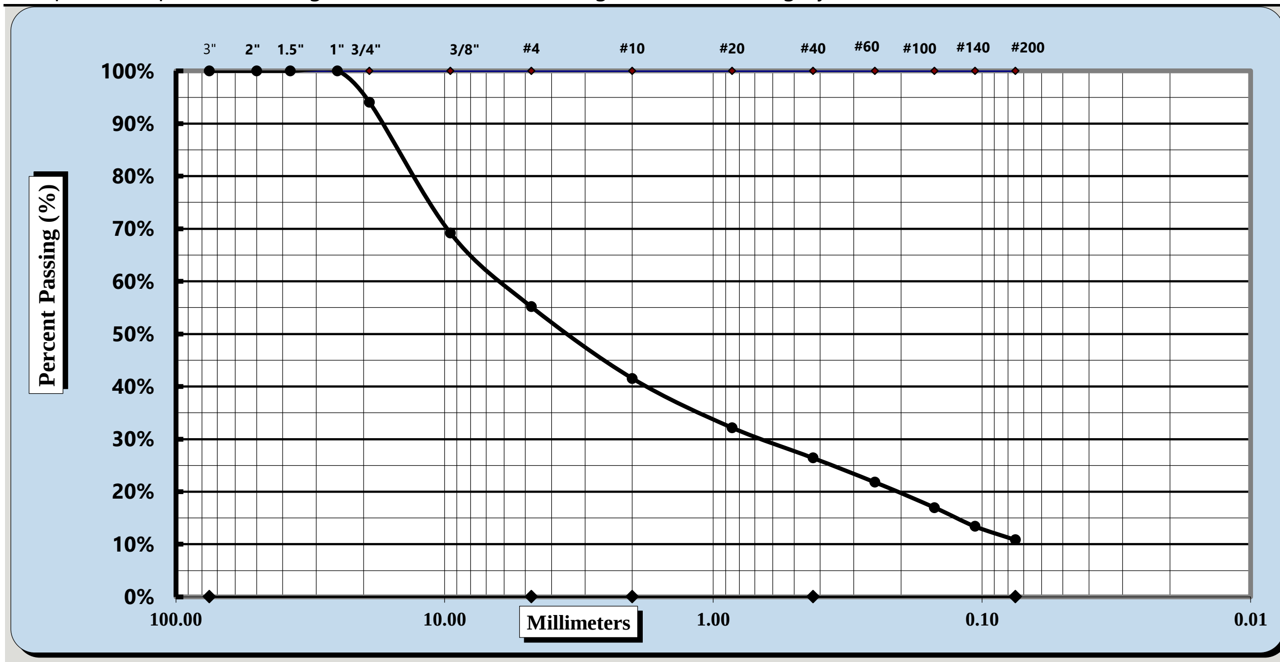
SIEVE ANALYSIS OF SOIL

Single sieve set — *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/24/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-1	Type:	Split-spoon	Depth:	0'

Sample Description: well-graded SAND with silt and gravel (SW-SM) - gray white, coarse to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	25.00 mm	Coarse Sand	13.6%	Fine Sand	15.6%
Gravel	44.8%	Medium Sand	15.1%	Silt & Clay	10.8%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 2.9%

$Cc = D_{30}^2/(D_{10} \times D_{60})$ **1.1** $Cu = D_{60}/D_{10}$ **96.9**

D10 = **0.07** D30 = **0.68** D60 = **6.30**

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ AASHTO T 89 ☐ AASHTO T 90 ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

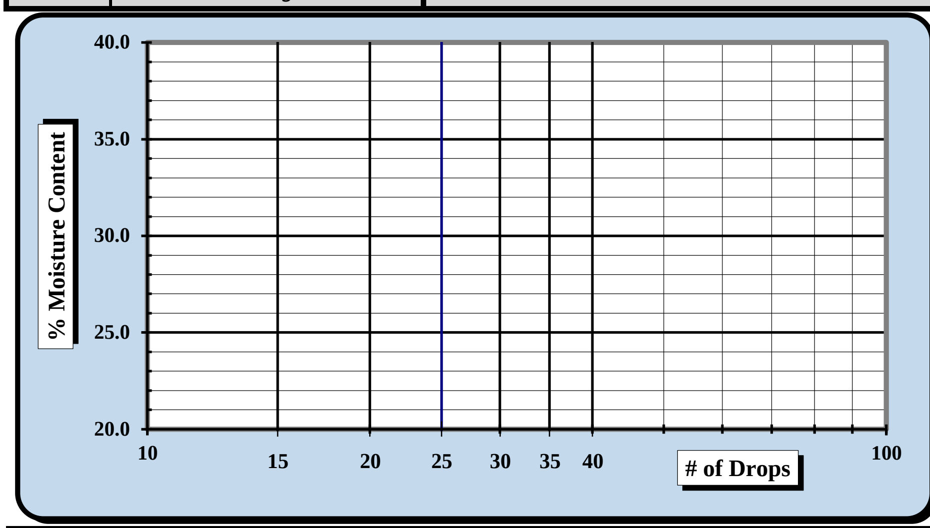
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-1	Type:	Split-spoon	Depth:	0'

Sample Description: well-graded SAND with silt and gravel (SW-SM) - gray white, coarse to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SW-SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 10.8%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

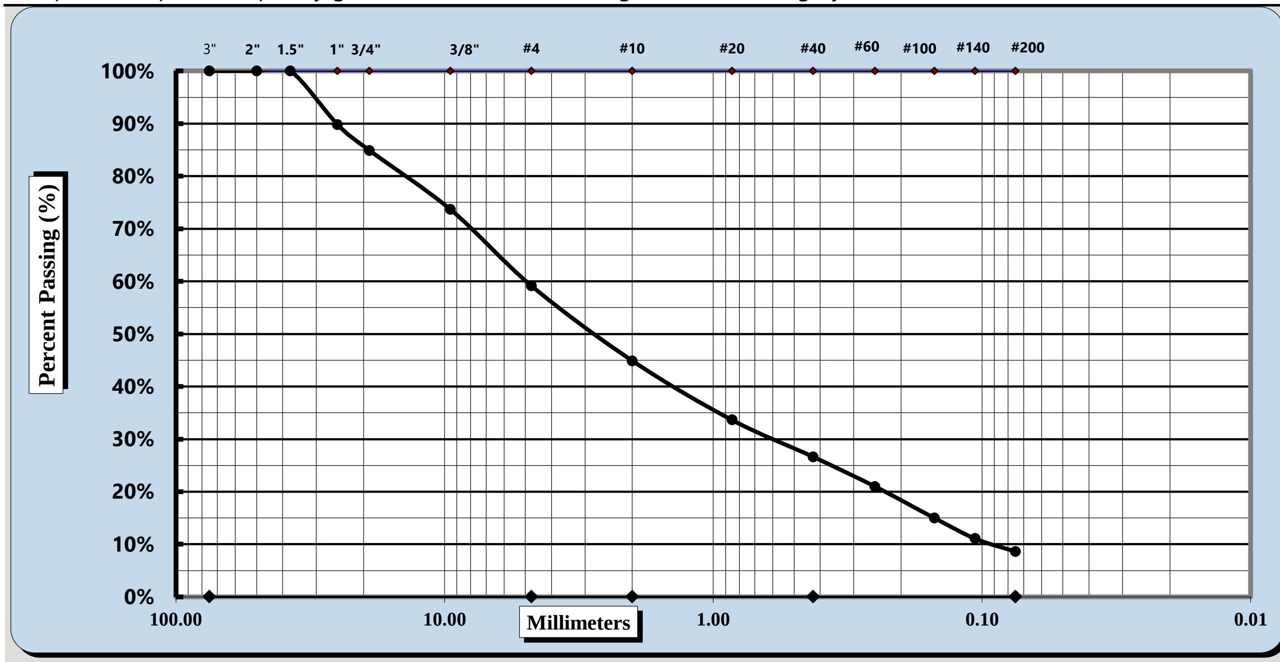
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/25/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	5'

Sample Description: poorly graded SAND with silt and gravel (SP-SM) - gray white, coarse to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	37.50 mm	Coarse Sand	14.3%	Fine Sand	18.0%
Gravel	40.9%	Medium Sand	18.2%	Silt & Clay	8.6%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 4.3%

$Cc = D_{30}^2/(D_{10} \times D_{60})$ **0.8** $Cu = D_{60}/D_{10}$ **55.6**

D10 = **0.09** D30 = **0.60** D60 = **5.00**

Notes / Deviations / References:

Frank Morris, P.E.	[signature]	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

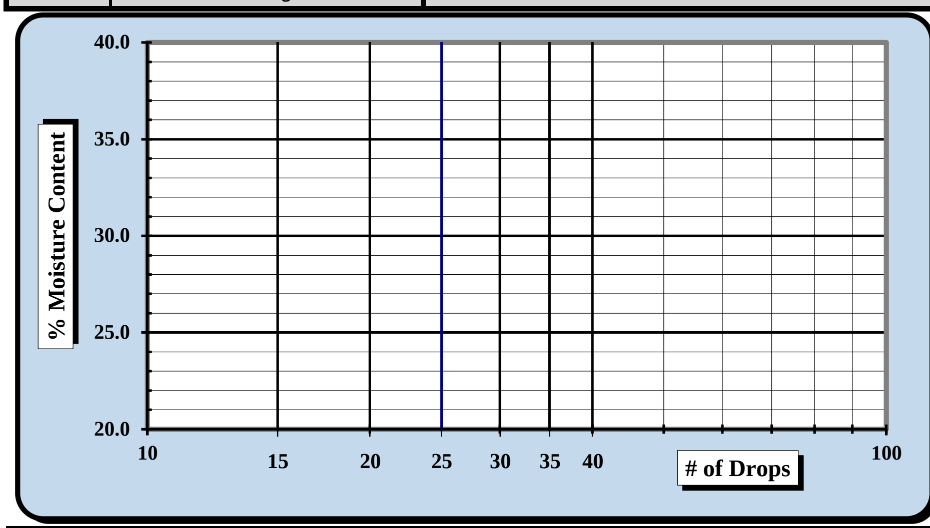
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	5'

Sample Description: poorly graded SAND with silt and gravel (SP-SM) - gray white, coarse to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SP-SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 8.6%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

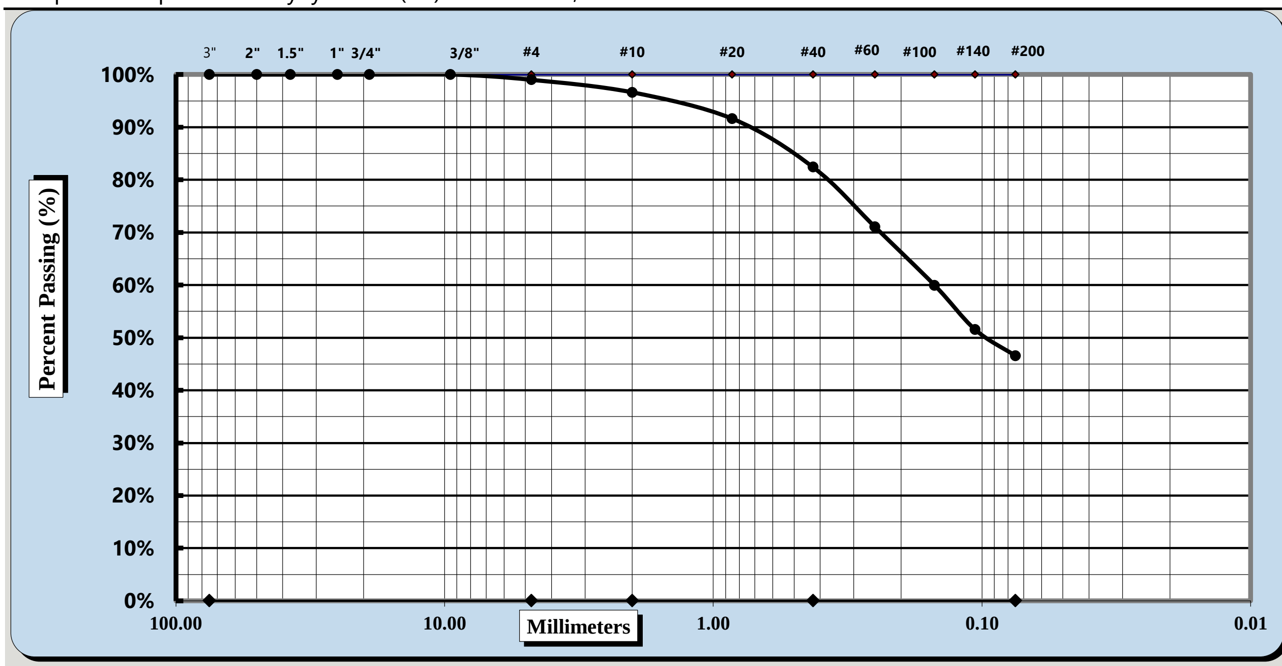
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/25/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	8.5'

Sample Description: clayey SAND (SC) - brown red, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	2.4%	Fine Sand	35.9%
Gravel	1.0%	Medium Sand	14.2%	Silt & Clay	46.5%
Liquid Limit	33	Plastic Limit	22	Plastic Index	11
		Natural Moisture	19.2%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	8.5'

Sample Description: clayey SAND (SC) - brown red, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	1	2	3				4	5	
A	Tare Weight	26.68	26.50	26.34				25.91	26.96	
B	Wet Soil Weight + A	47.02	48.11	45.14				34.08	34.16	
C	Dry Soil Weight + A	42.21	42.86	40.38				32.58	32.85	
D	Water Weight (B-C)	4.81	5.25	4.76				1.50	1.31	
E	Dry Soil Weight (C-A)	15.53	16.36	14.04				6.67	5.89	
F	% Moisture (D/E)*100	31.0%	32.1%	33.9%				22.5%	22.2%	
N	# OF DROPS	34	27	20				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							**22.4%**		

One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☐
Liquid Limit	**33**
Plastic Limit	**22**
Plastic Index	**11**
Group Symbol	**SC**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 46.5%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

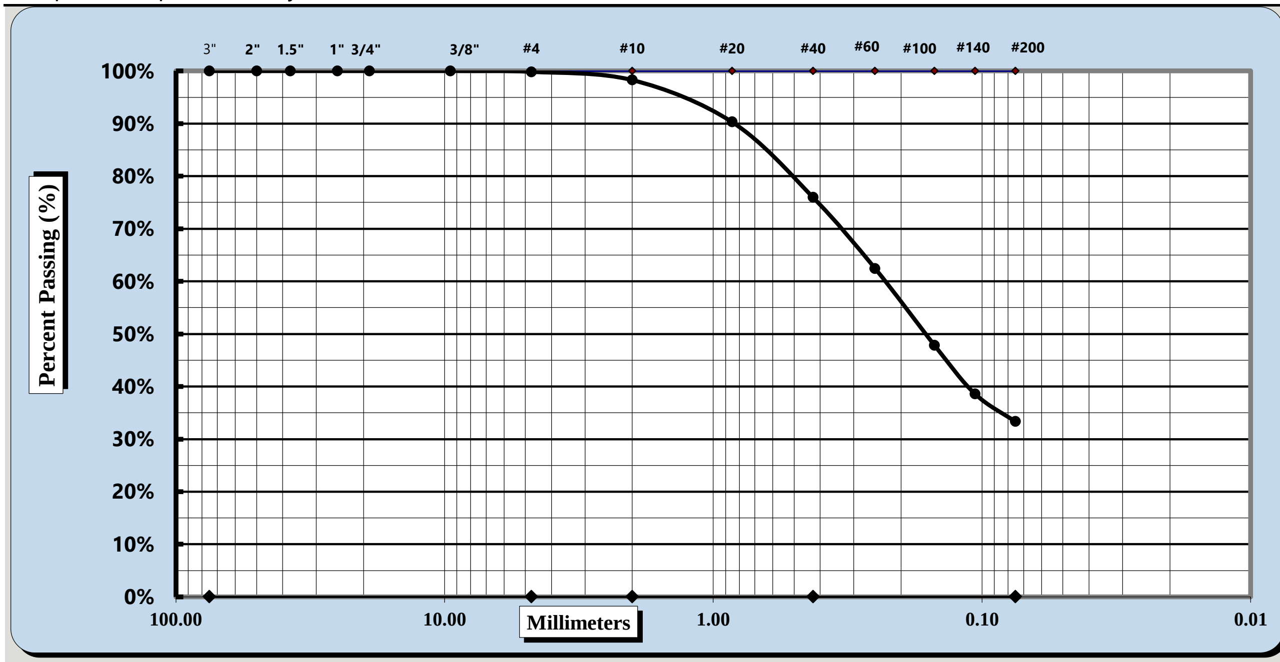
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/25/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-4	Type:	Split-spoon	Depth:	13.5'

Sample Description: silty SAND (SM) - tan brown, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	1.6%	Fine Sand	42.7%
Gravel	0.2%	Medium Sand	22.3%	Silt & Clay	33.3%
Liquid Limit	30	Plastic Limit	25	Plastic Index	5

Natural Moisture 16.7%

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

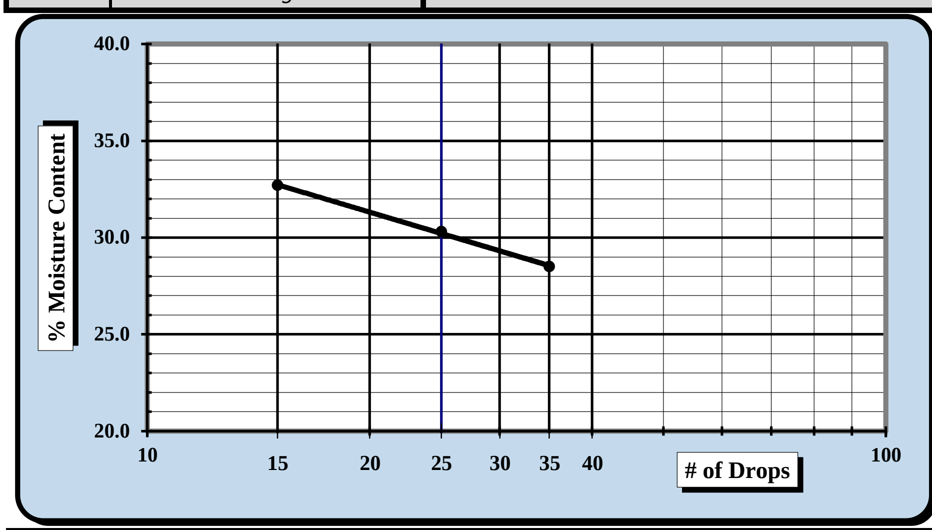
S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-4	Type:	Split-spoon	Depth:	13.5'
Sample Description:	silty SAND (SM) - tan brown, medium to fine				

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	6	7	8				9	10	
A	Tare Weight	27.75	26.28	27.32				26.82	26.75	
B	Wet Soil Weight + A	44.05	43.36	45.90				34.55	32.78	
C	Dry Soil Weight + A	40.43	39.39	41.32				33.00	31.57	
D	Water Weight (B-C)	3.62	3.97	4.58				1.55	1.21	
E	Dry Soil Weight (C-A)	12.68	13.11	14.00				6.18	4.82	
F	% Moisture (D/E)*100	28.5%	30.3%	32.7%				25.1%	25.1%	
N	# OF DROPS	35	25	15				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							**25.1%**		



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☐
Liquid Limit	**30**
Plastic Limit	**25**
Plastic Index	**5**
Group Symbol	**SM**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 33.3%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

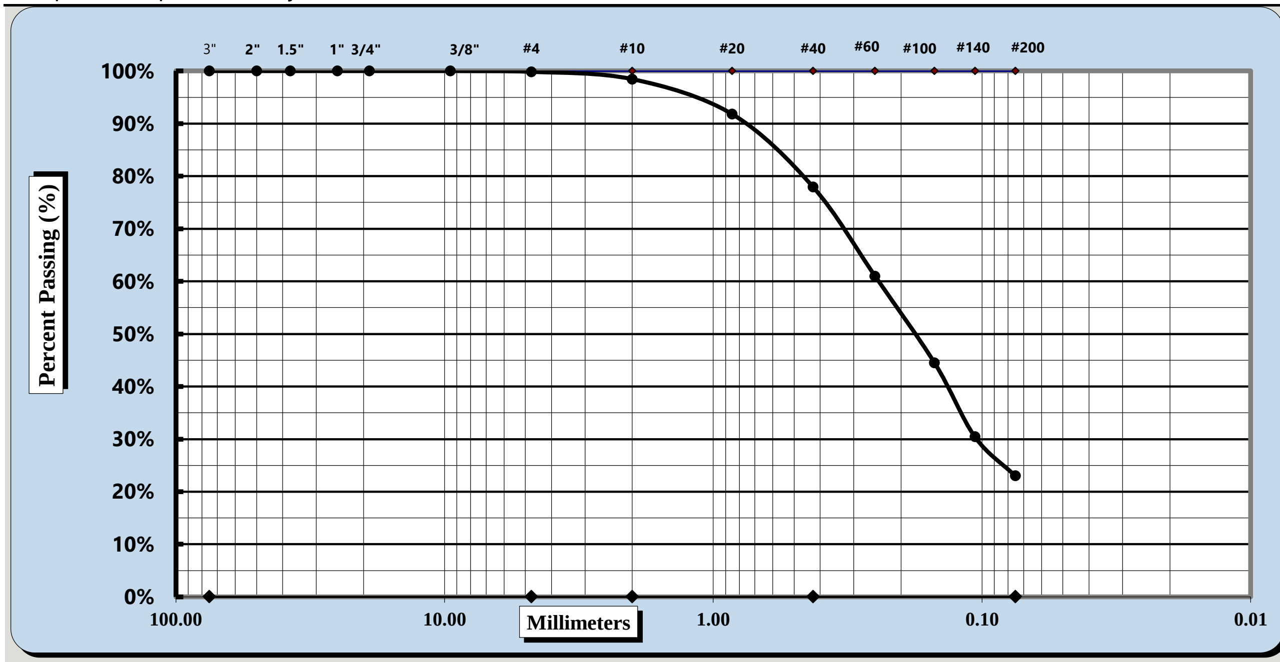
SIEVE ANALYSIS OF SOIL

Single sieve set | *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/25/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-5	Type:	Split-spoon	Depth:	18.5'

Sample Description: silty SAND (SM) - tan brown, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	1.4%	Fine Sand	54.9%
Gravel	0.2%	Medium Sand	20.5%	Silt & Clay	23.0%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 15.1%

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ AASHTO T 89 ☐ AASHTO T 90 ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

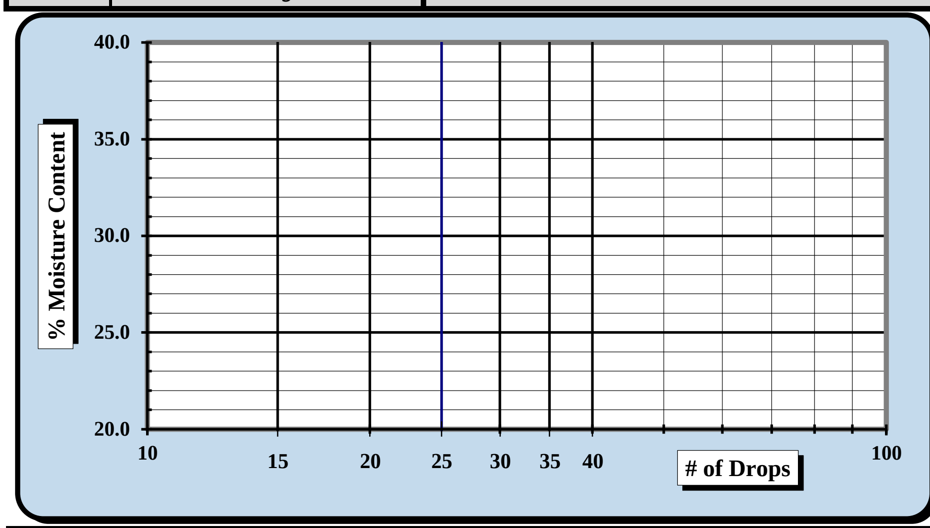
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-5	Type:	Split-spoon	Depth:	18.5'

Sample Description: silty SAND (SM) - tan brown, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	---
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 23.0%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

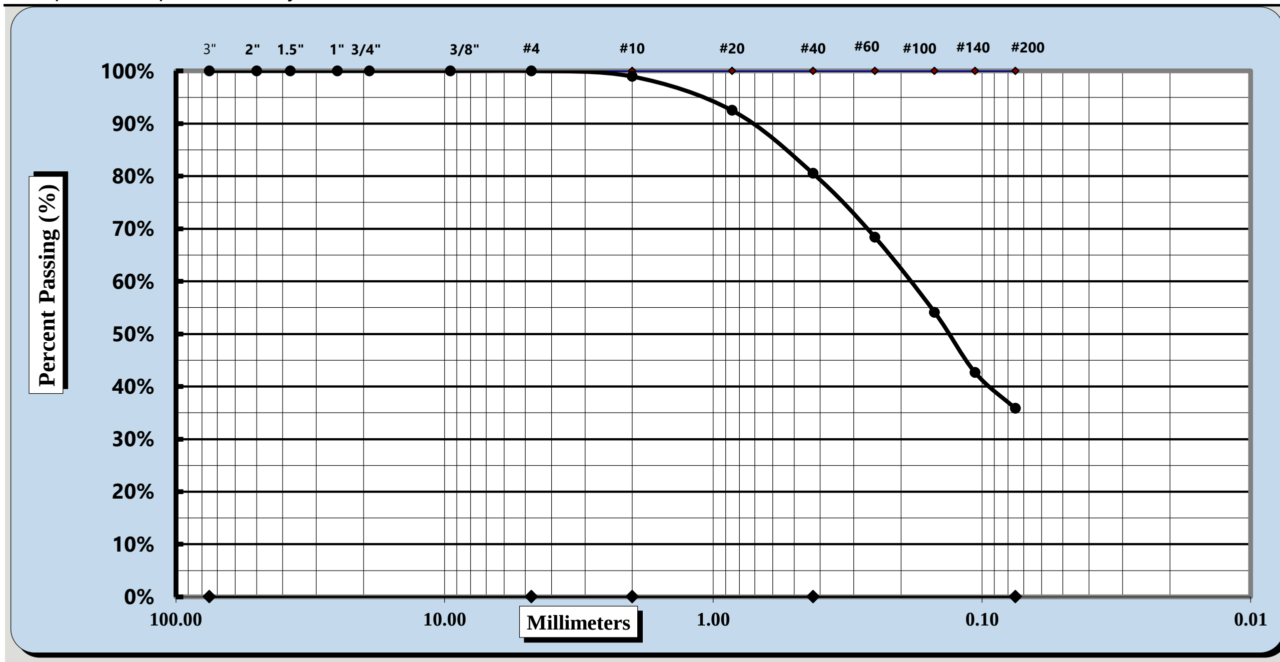
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/26/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-6	Type:	Split-spoon	Depth:	23.5'

Sample Description: silty SAND (SM) - tan red, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	1.1%	Fine Sand	44.7%
Gravel	0.0%	Medium Sand	18.4%	Silt & Clay	35.8%
Liquid Limit	32	Plastic Limit	27	Plastic Index	5
		Natural Moisture	20.9%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ AASHTO T 89 ☐ AASHTO T 90 ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

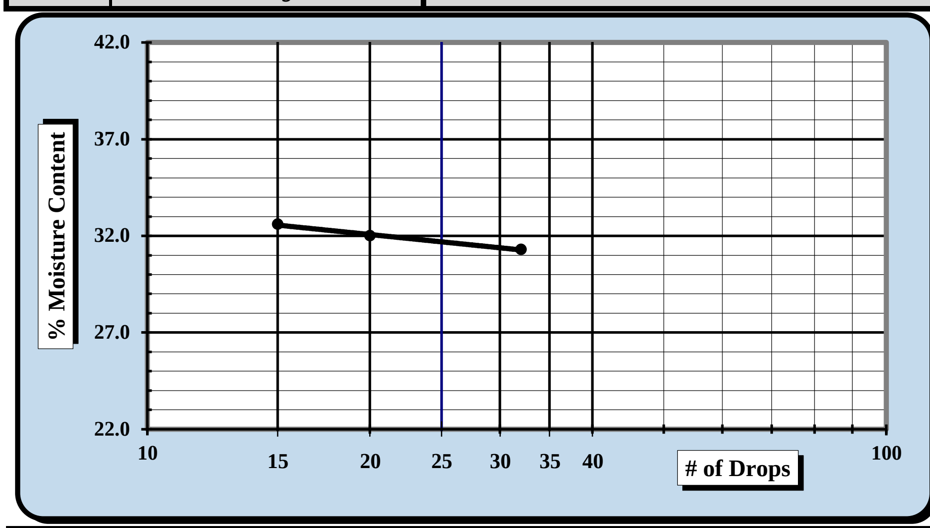
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-6	Type:	Split-spoon	Depth:	23.5'

Sample Description: silty SAND (SM) - tan red, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	11	12	13				14	15	
A	Tare Weight	26.65	26.66	26.75				26.64	27.60	
B	Wet Soil Weight + A	41.79	42.82	43.18				34.52	35.18	
C	Dry Soil Weight + A	38.18	38.90	39.14				32.85	33.59	
D	Water Weight (B-C)	3.61	3.92	4.04				1.67	1.59	
E	Dry Soil Weight (C-A)	11.53	12.24	12.39				6.21	5.99	
F	% Moisture (D/E)*100	31.3%	32.0%	32.6%				26.9%	26.5%	
N	# OF DROPS	32	20	15				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							**26.7%**		



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☐
Liquid Limit	**32**
Plastic Limit	**27**
Plastic Index	**5**
Group Symbol	**SM**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 35.8%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

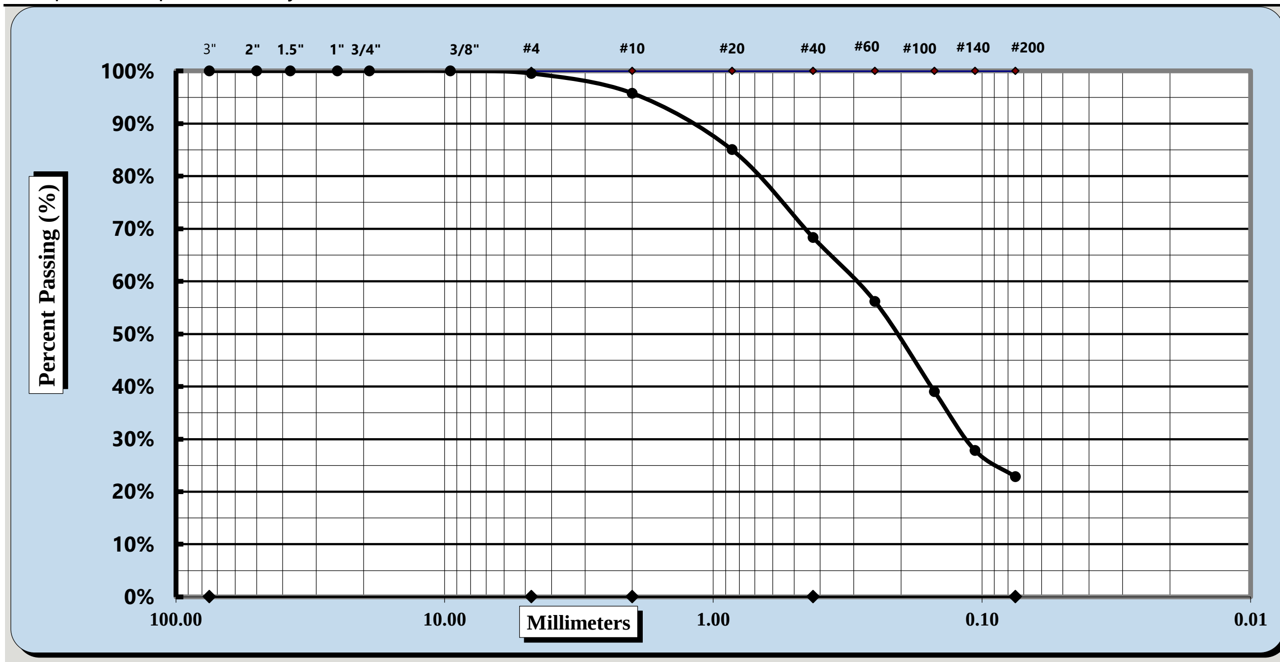
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/26/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-7	Type:	Split-spoon	Depth:	28.5'

Sample Description: silty SAND (SM) - tan brown, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	3.8%	Fine Sand	45.5%
Gravel	0.5%	Medium Sand	27.4%	Silt & Clay	22.8%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	14.4%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

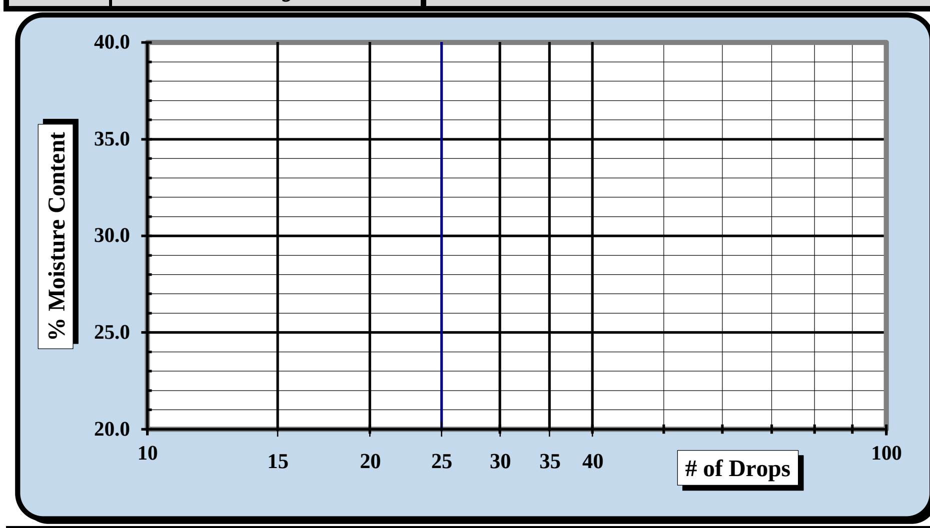
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/20/21
Sample ID:	SS-7	Type:	Split-spoon	Depth:	28.5'

Sample Description: silty SAND (SM) - tan brown, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 22.8%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

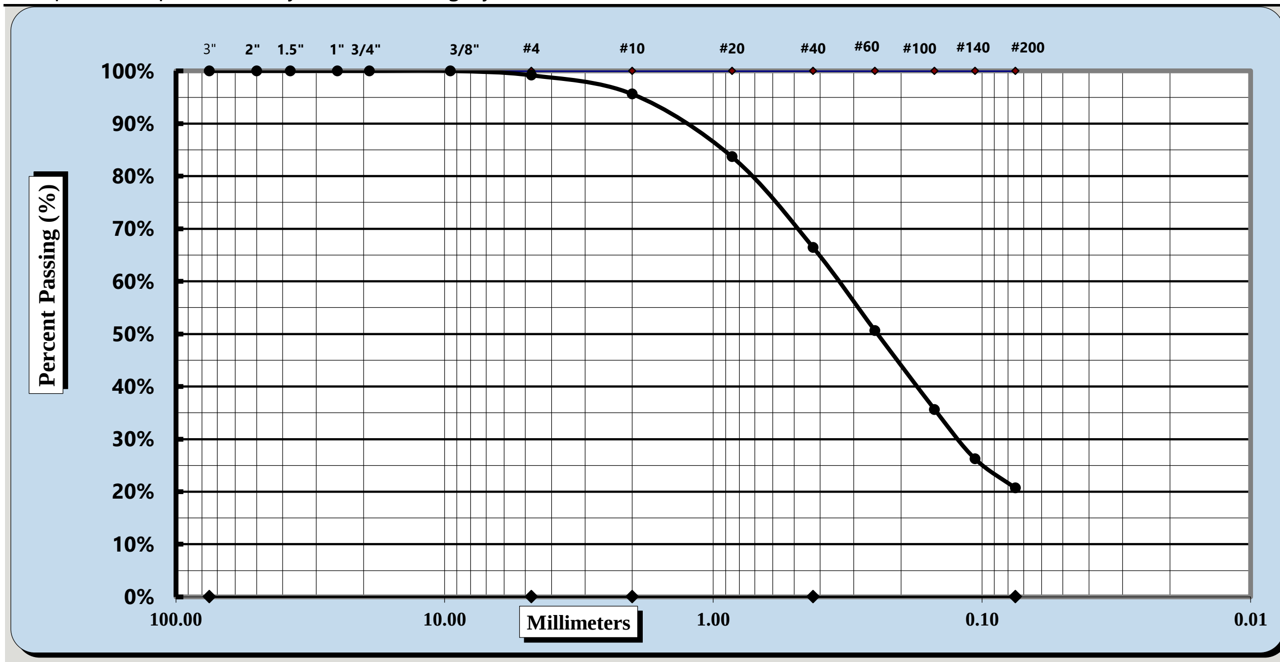
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/26/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/21/21
Sample ID:	SS-8	Type:	Split-spoon	Depth:	33.5'

Sample Description: silty SAND (SM) - gray brown, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	3.6%	Fine Sand	45.8%
Gravel	0.8%	Medium Sand	29.2%	Silt & Clay	20.7%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	22.5%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ AASHTO T 89 ☐ AASHTO T 90 ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

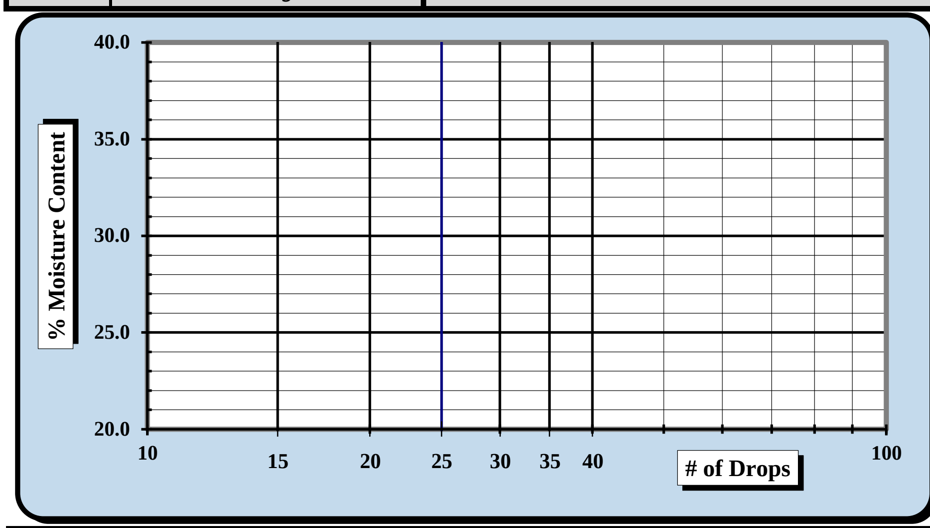
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/21/21
Sample ID:	SS-8	Type:	Split-spoon	Depth:	33.5'

Sample Description: silty SAND (SM) - gray brown, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	---
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 20.7%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

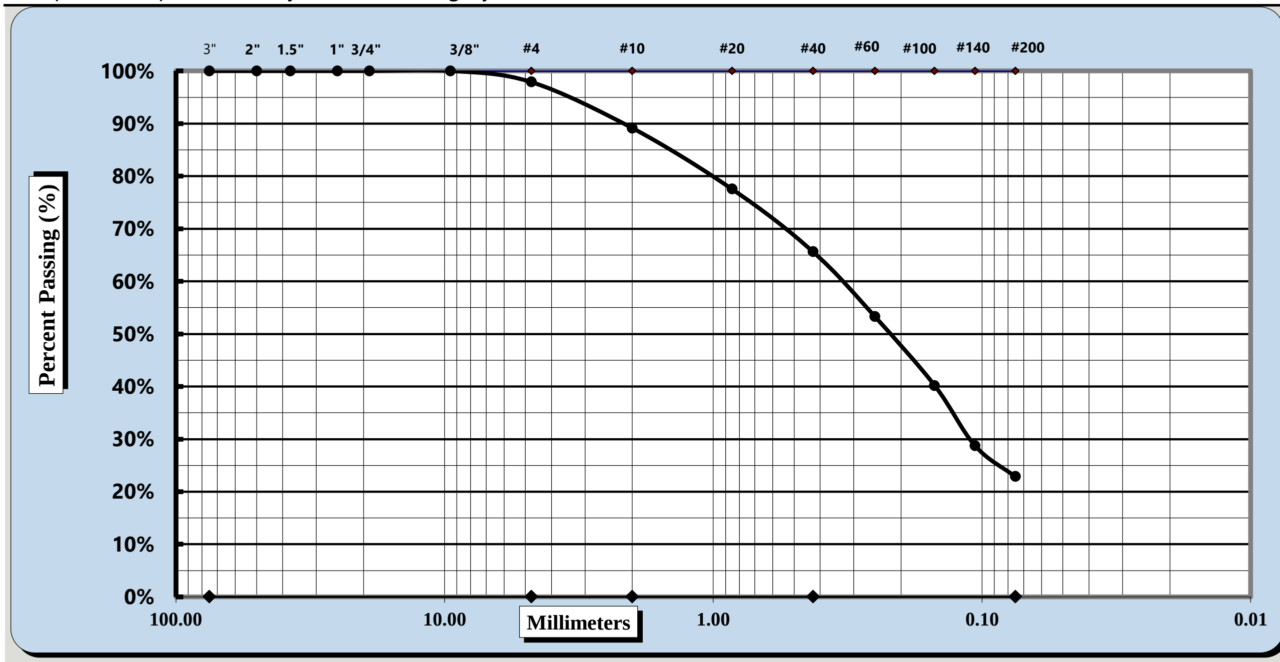
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/26/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/21/21
Sample ID:	SS-11	Type:	Split-spoon	Depth:	48.5'

Sample Description: silty SAND (SM) - gray brown, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	8.8%	Fine Sand	42.8%
Gravel	2.1%	Medium Sand	23.5%	Silt & Clay	22.9%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	26.4%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

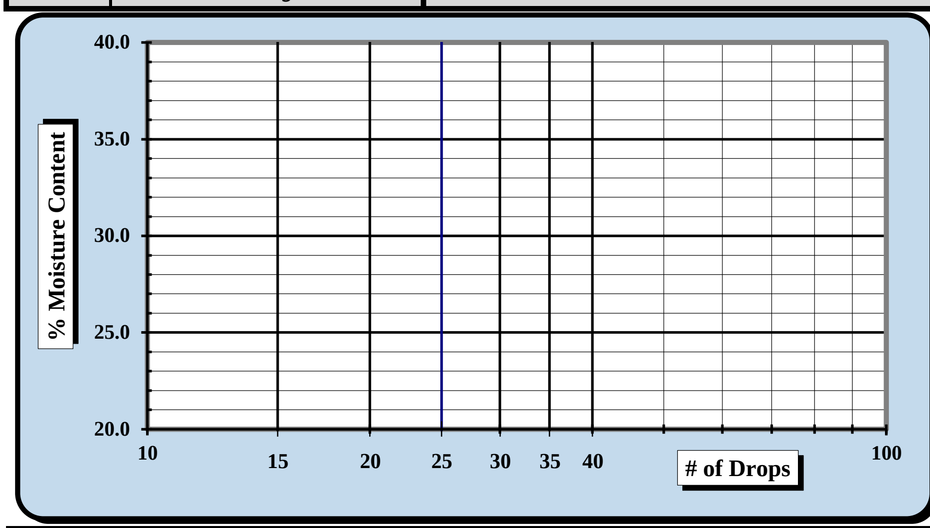
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/21/21
Sample ID:	SS-11	Type:	Split-spoon	Depth:	48.5'

Sample Description: silty SAND (SM) - gray brown, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	---
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 22.9%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

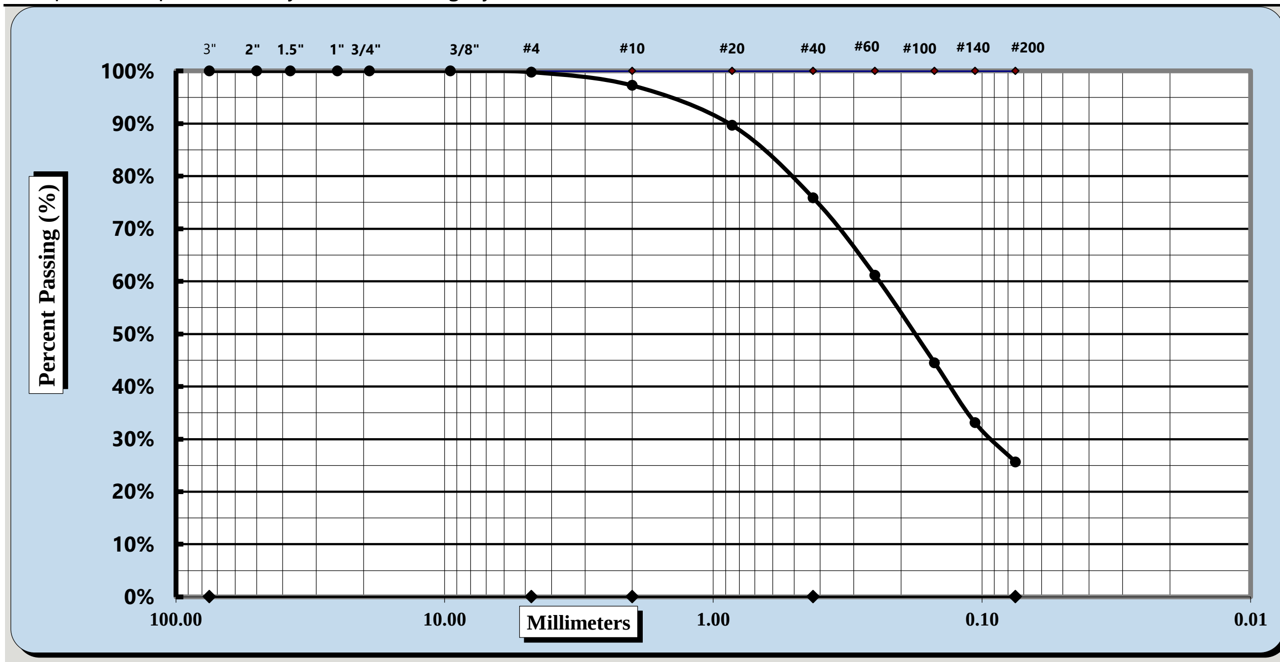
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/26/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/21/21
Sample ID:	SS-12	Type:	Split-spoon	Depth:	53.5'

Sample Description: silty SAND (SM) - gray, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	2.5%	Fine Sand	50.2%
Gravel	0.2%	Medium Sand	21.4%	Silt & Clay	25.6%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 20.4%

Notes / Deviations / References:

Frank Morris, P.E.	Frank P. Morris Jr.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

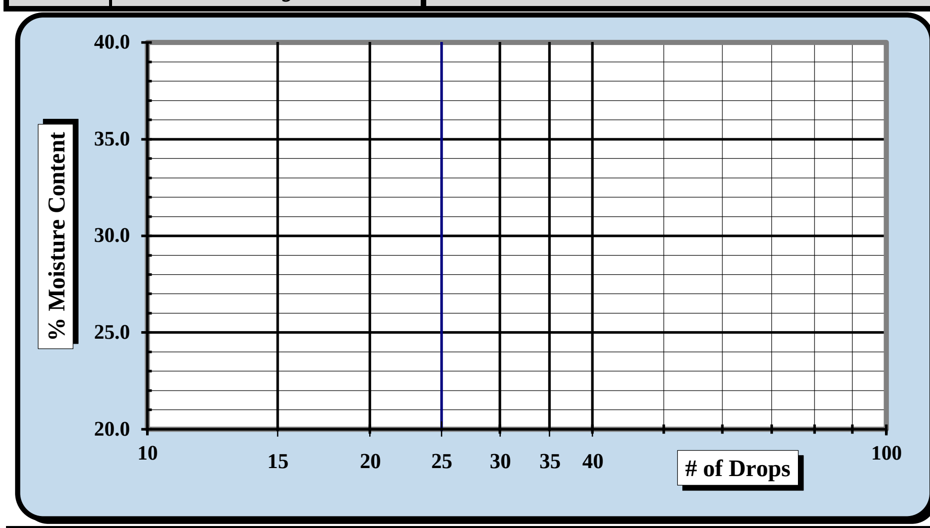
S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/21/21
Sample ID:	SS-12	Type:	Split-spoon	Depth:	53.5'
Sample Description:	silty SAND (SM) - gray, medium to fine				

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 25.6%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

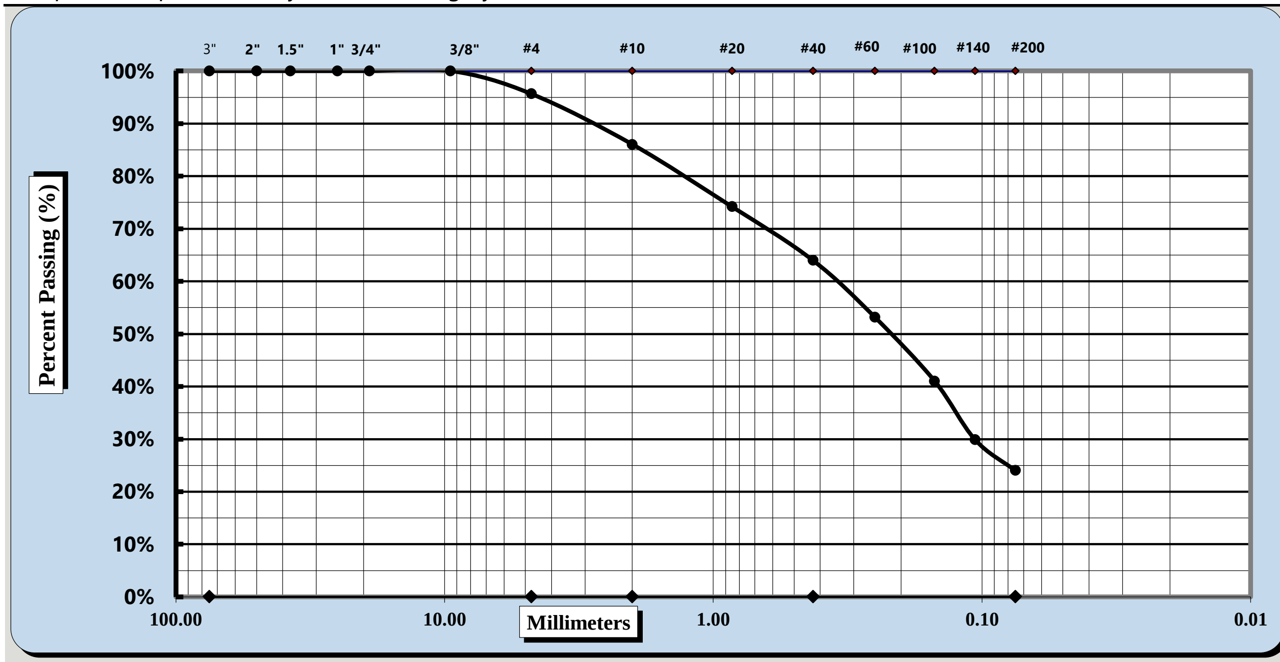
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Greenville: 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/10 - 8/26/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-2	Log #:	96g	Sample Date:	4/21/21
Sample ID:	SS-13	Type:	Split-spoon	Depth:	58.5'

Sample Description: silty SAND (SM) - gray, coarse to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	9.6%	Fine Sand	40.0%
Gravel	4.3%	Medium Sand	22.0%	Silt & Clay	24.0%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 17.5%

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

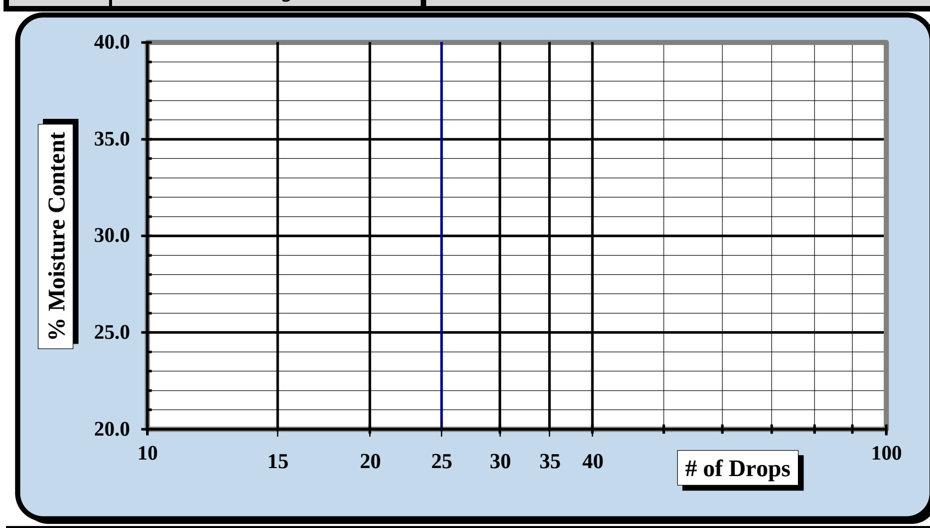
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Boring #:	B-21-2	Log #:	96g	Sample Date:	4/21/21
Sample ID:	SS-13	Type:	Split-spoon	Depth:	58.5'

Sample Description: silty SAND (SM) - gray, coarse to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	10/19/2020	Grooving tool	23119	10/15/2020
LL Apparatus	23158	2/1/2021			
Oven	13978	10/7/2020			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☒
Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 24.0%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Benjamin J. Kovaleski	8/30/21	Brian Vaughan, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

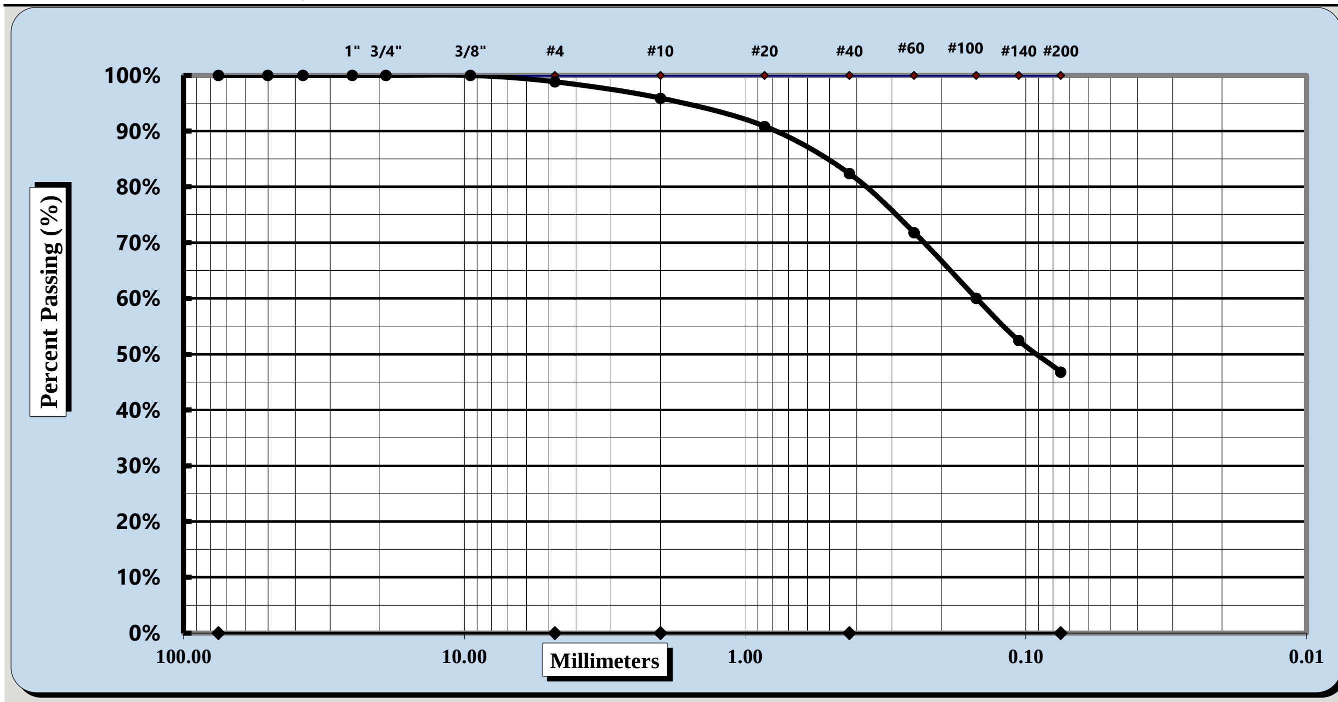
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-3	Log #:	135	Sample Date:	4/20/21
Sample ID:	SS-1	Type:	Split-spoon	Depth:	0'

Sample Description: silty SAND (SM) - red brown, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	2.9%	Fine Sand	35.6%
Gravel	1.2%	Medium Sand	13.5%	Silt & Clay	46.8%
Liquid Limit	33	Plastic Limit	25	Plastic Index	8
		Natural Moisture	16.3%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS R.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

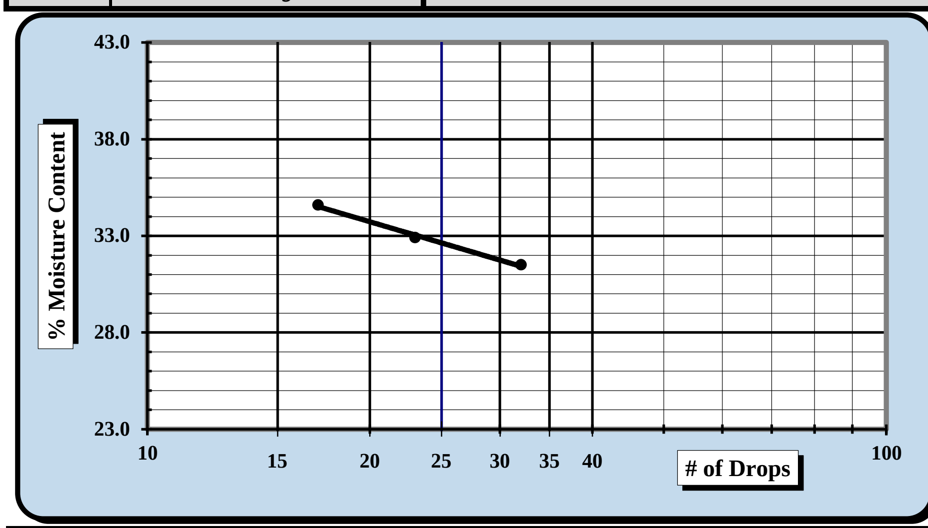
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/26/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-3	Log #:	135	Sample Date:	4/20/21
Sample ID:	SS-1	Type:	Split-spoon	Depth:	0'

Sample Description: silty SAND (SM) - red brown, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	P-1	P-2	P-3				1	2	
A	Tare Weight	16.31	15.20	16.52				12.11	12.16	
B	Wet Soil Weight + A	37.37	36.51	36.80				19.71	19.55	
C	Dry Soil Weight + A	32.33	31.23	31.59				18.22	18.08	
D	Water Weight (B-C)	5.04	5.28	5.21				1.49	1.47	
E	Dry Soil Weight (C-A)	16.02	16.03	15.07				6.11	5.92	
F	% Moisture (D/E)*100	31.5%	32.9%	34.6%				24.4%	24.8%	
N	# OF DROPS	32	23	17				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							24.6%		



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☐

Liquid Limit	**33**
Plastic Limit	**25**
Plastic Index	**8**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 46.8%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

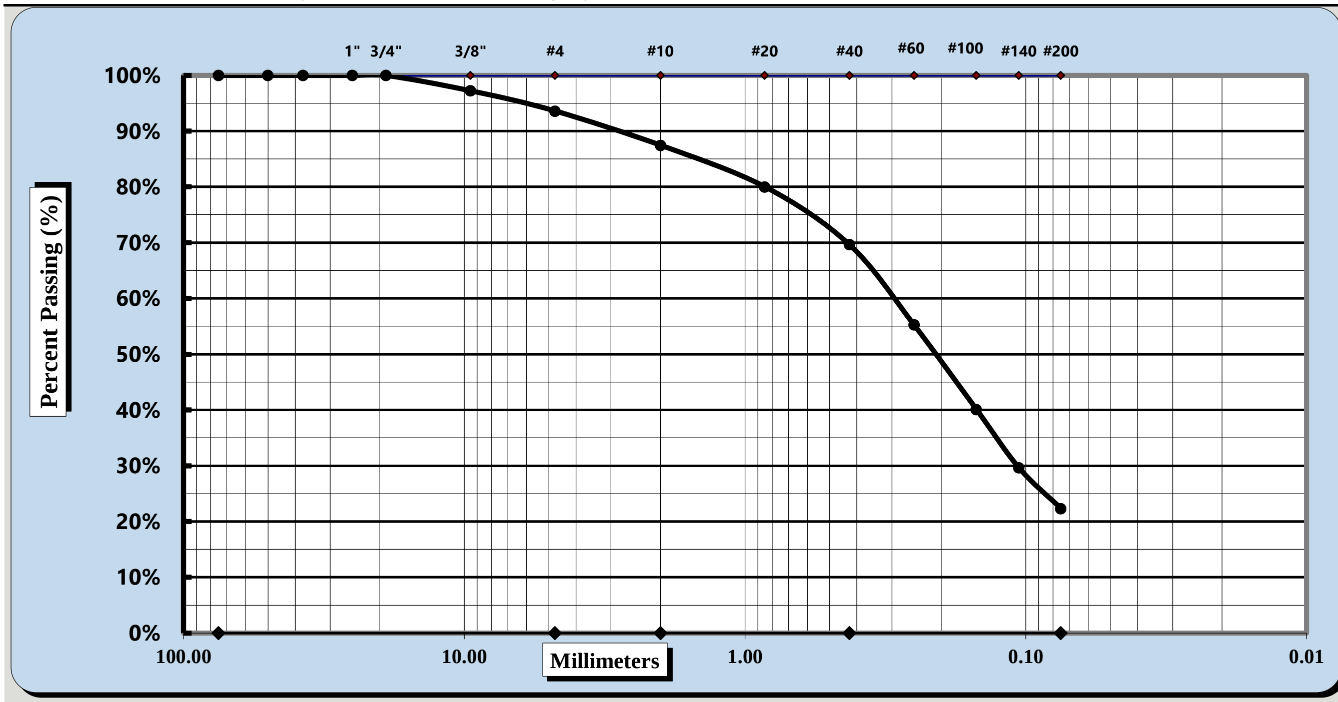
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-3	Log #:	135	Sample Date:	4/20/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	2.7'

Sample Description: silty SAND (SM) - brown gray tan, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	6.1%	Fine Sand	47.3%
Gravel	6.4%	Medium Sand	17.8%	Silt & Clay	22.3%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 13.6%

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

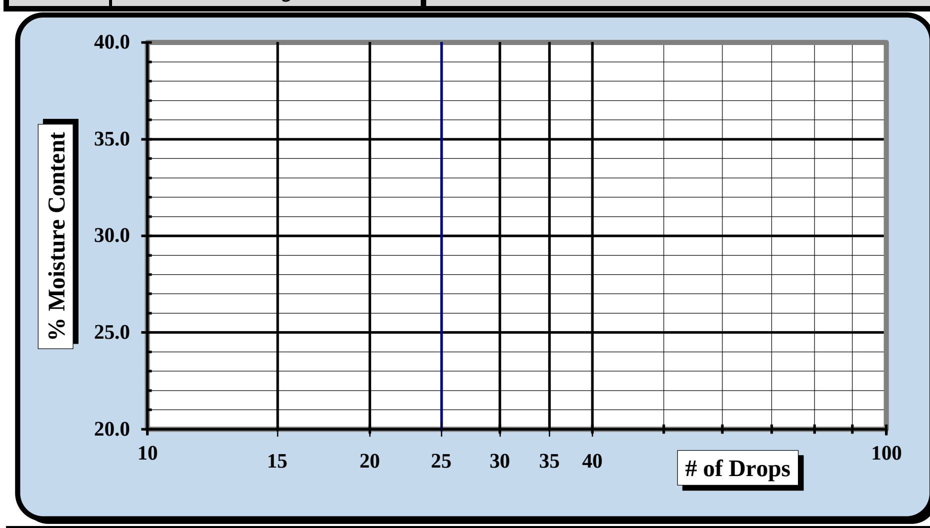
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-3	Log #:	135	Sample Date:	4/20/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	2.7'

Sample Description: silty SAND (SM) - brown gray tan, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☒
Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 22.3%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

SIEVE ANALYSIS OF SOIL

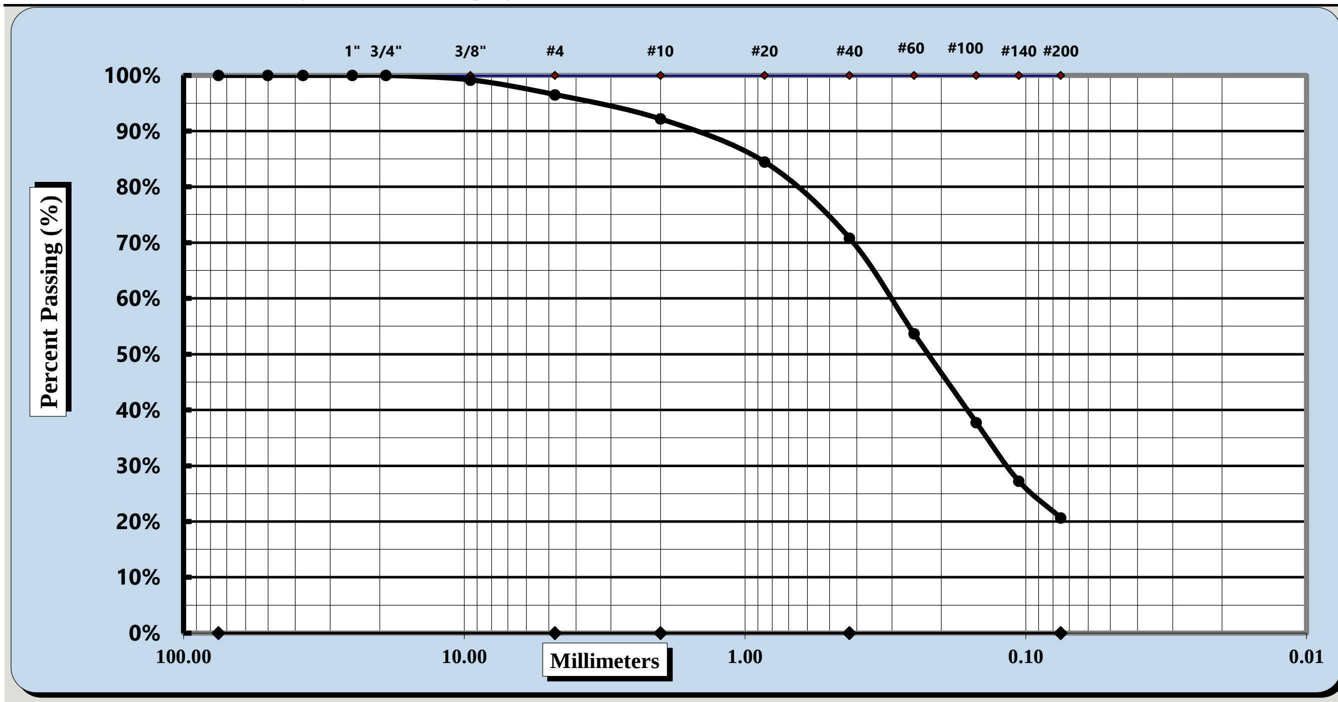
Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date(s):	8/16 - 8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-3	Log #:	135	Sample Date:	4/20/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	7.7'

Sample Description: silty SAND (SM) - gray tan, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	4.3%	Fine Sand	50.2%
Gravel	3.5%	Medium Sand	21.4%	Silt & Clay	20.6%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	18.0%		

Notes / Deviations / References:

Frank Morris, P.E.	Frank P. Morris Jr.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

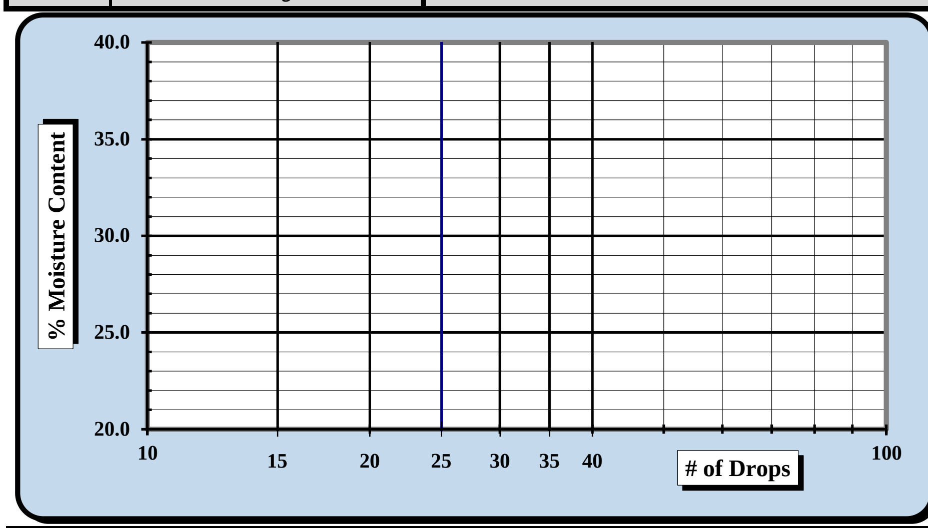
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-3	Log #:	135	Sample Date:	4/20/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	7.7'

Sample Description: silty SAND (SM) - gray tan, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 20.6%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

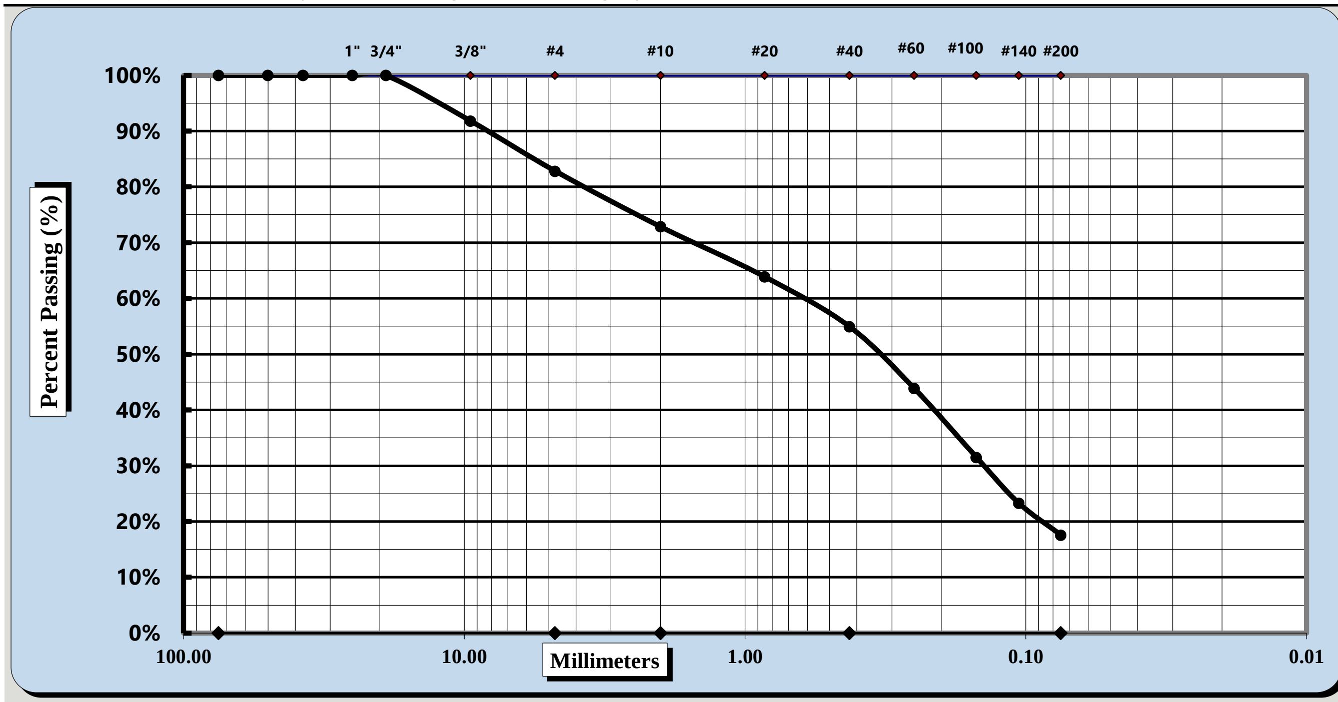
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-3	Log #:	135	Sample Date:	4/20/21
Sample ID:	SS-4	Type:	Split-spoon	Depth:	12.7'

Sample Description: silty SAND with gravel (SM) - gray, coarse to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	9.9%	Fine Sand	37.4%
Gravel	17.2%	Medium Sand	17.9%	Silt & Clay	17.6%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	13.9%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

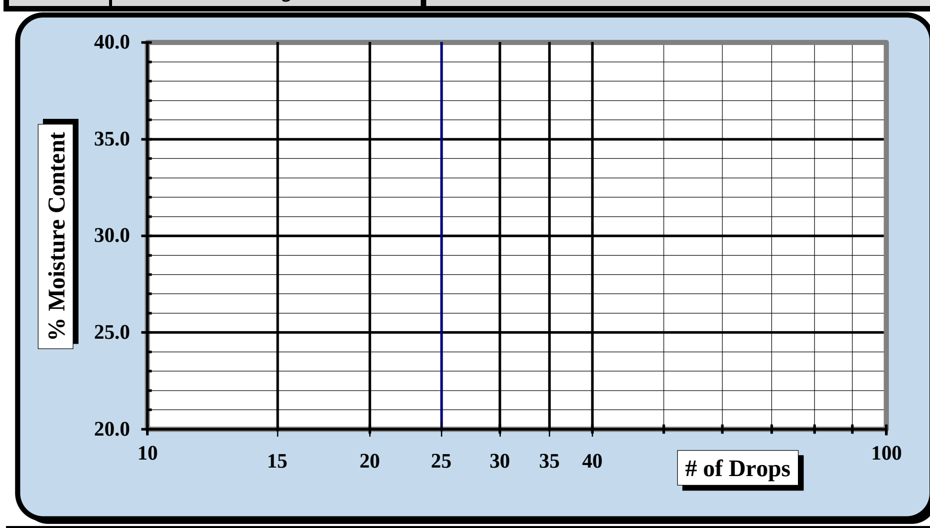
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-3	Log #:	135	Sample Date:	4/20/21
Sample ID:	SS-4	Type:	Split-spoon	Depth:	12.7'

Sample Description: silty SAND with gravel (SM) - gray, coarse to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☒
Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 17.6%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

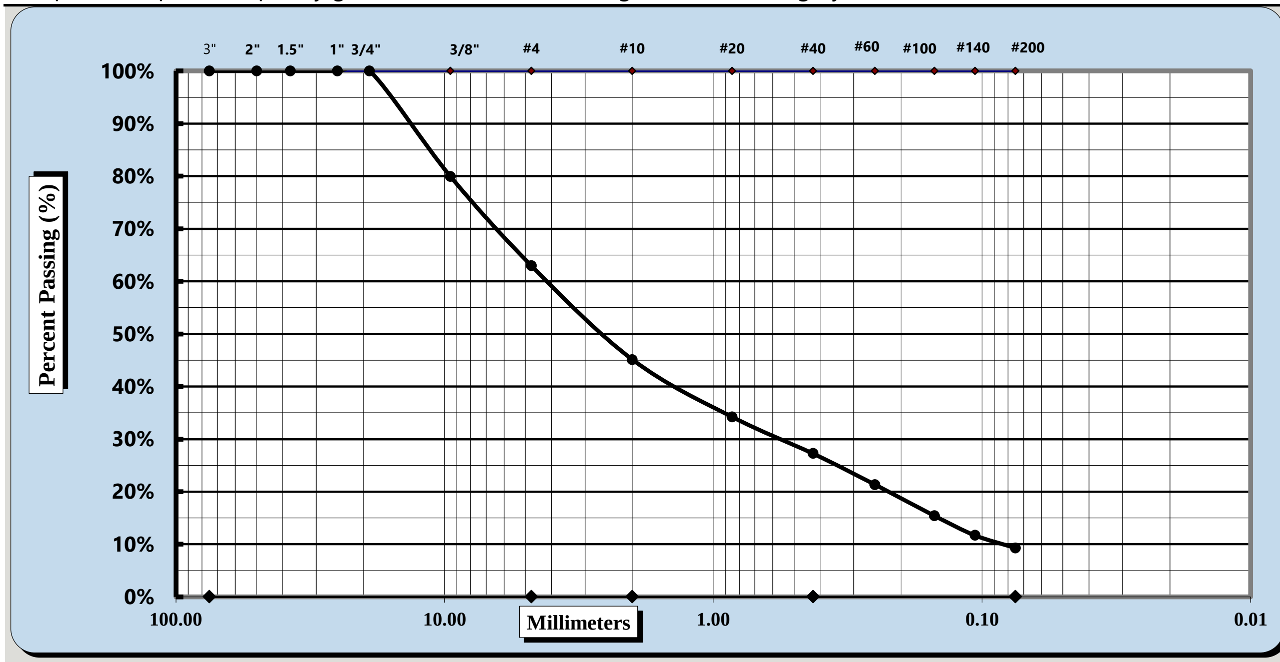
SIEVE ANALYSIS OF SOIL

Single sieve set | *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/16 - 8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		
Boring #:	B-21-4	Log #: 135	Sample Date: 4/6/21
Sample #:	SS-1	Type: Split-spoon	Depth: 0'

Sample Description: poorly graded SAND with silt and gravel (SP-SM) - gray, coarse to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B   Procedure for obtaining Specimen: Moist   Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	17.9%	Fine Sand	18.0%
Gravel	37.0%	Medium Sand	17.8%	Silt & Clay	9.3%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 3.9%

$Cc = D_{30}^2/(D_{10} \times D_{60})$ **0.9** $Cu = D_{60}/D_{10}$ **49.4**

D10 = **0.084**   D30 = **0.55**   D60 = **4.15**

Notes / Deviations / References:

Frank Morris, P.E. — *Technical Responsibility*
FRANK P. MORRIS JR. — *Signature*
Project Manager — *Position*
8/30/21 — *Date*

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

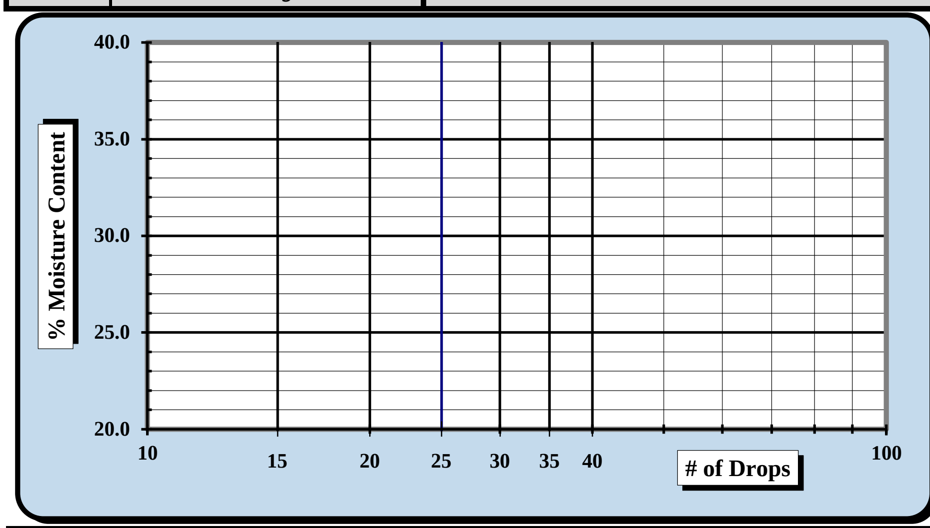
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole: B-21-4		Log #:	135	Sample Date:	4/6/21
Sample ID: SS-1		Type:	Split-spoon	Depth:	0'

Sample Description: poorly graded SAND with silt and gravel (SP-SM) - gray, coarse to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #	Tare #:	Liquid Limit						Plastic Limit		
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	---
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SP-SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 9.3%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

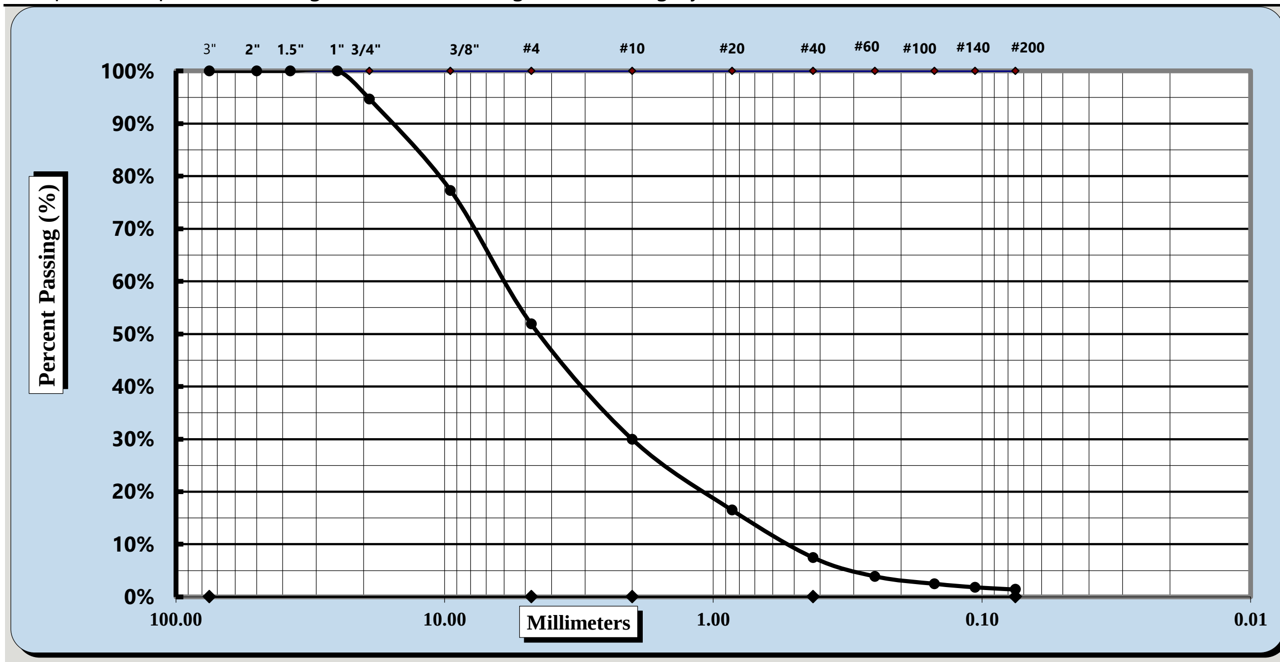
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date:	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Boring #:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample #:	SS-2	Type:	Split-spoon	Depth:	3.5'

Sample Description: well-graded SAND with gravel (SW) - gray, coarse to medium



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	25.00 mm	Coarse Sand	22.0%	Fine Sand	6.1%
Gravel	48.1%	Medium Sand	22.5%	Silt & Clay	1.4%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 5.9%

$Cc = D_{30}^2/(D_{10} \times D_{60})$ **1.3** $Cu = D_{60}/D_{10}$ **11.5**

D10 = **0.52** D30 = **2.00** D60 = **6.0**

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS, JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

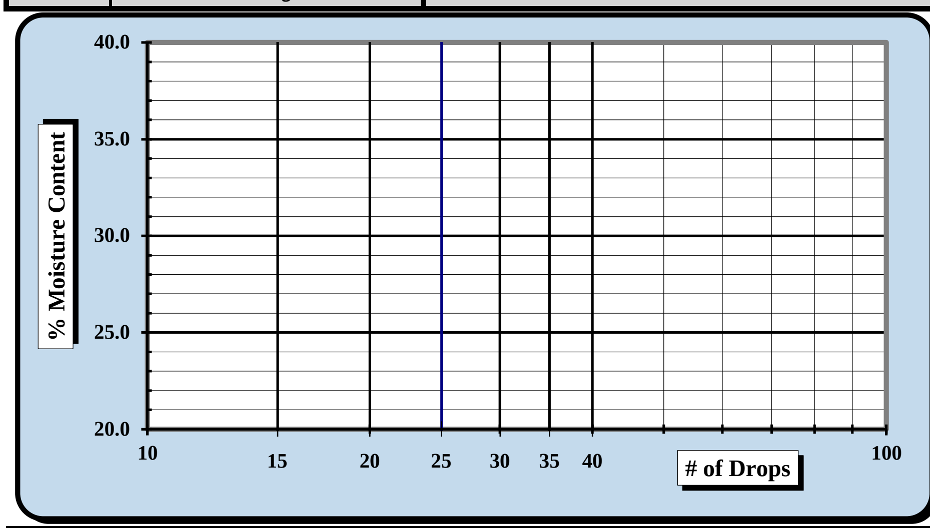
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	3.5'

Sample Description: well-graded SAND with gravel (SW) - gray, coarse to medium

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SW**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 1.4%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

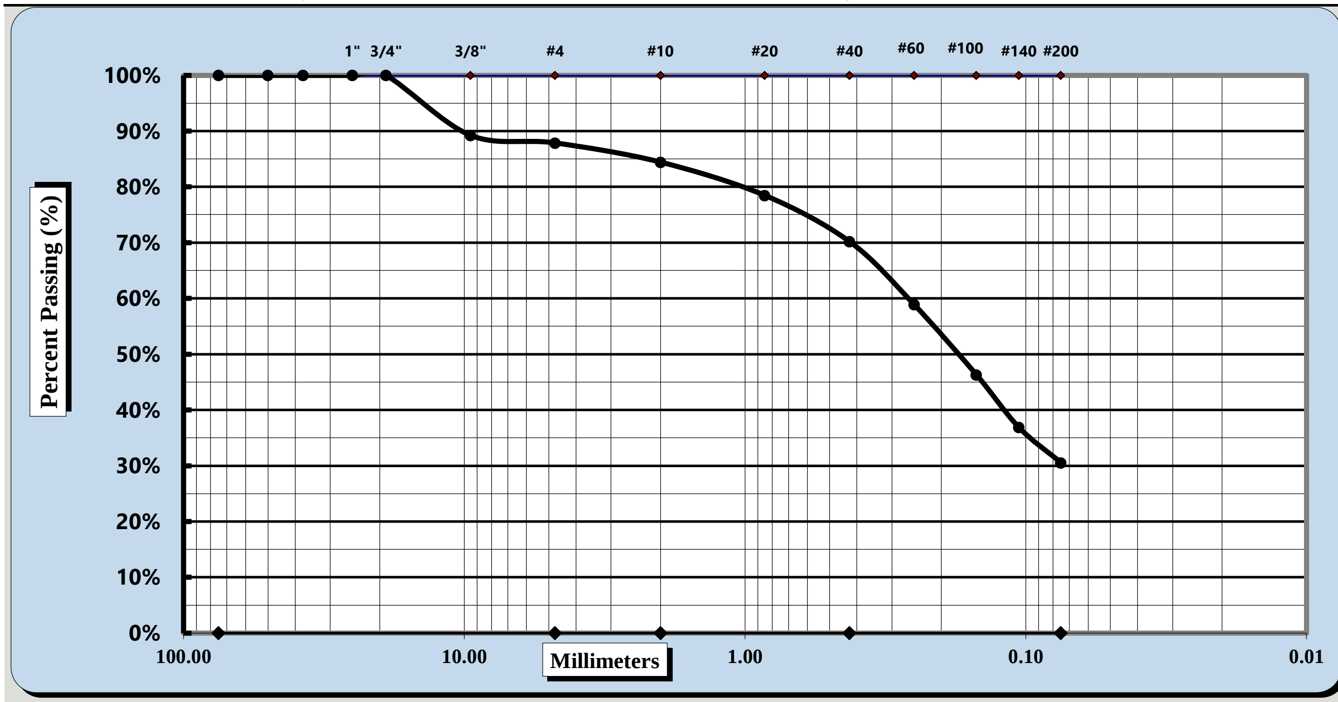
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	18.5'

Sample Description: silty SAND (SM) - brown, medium to fine with little gravel



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	3.5%	Fine Sand	39.7%
Gravel	12.1%	Medium Sand	14.2%	Silt & Clay	30.5%
Liquid Limit	28	Plastic Limit	26	Plastic Index	2
		Natural Moisture	23.4%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

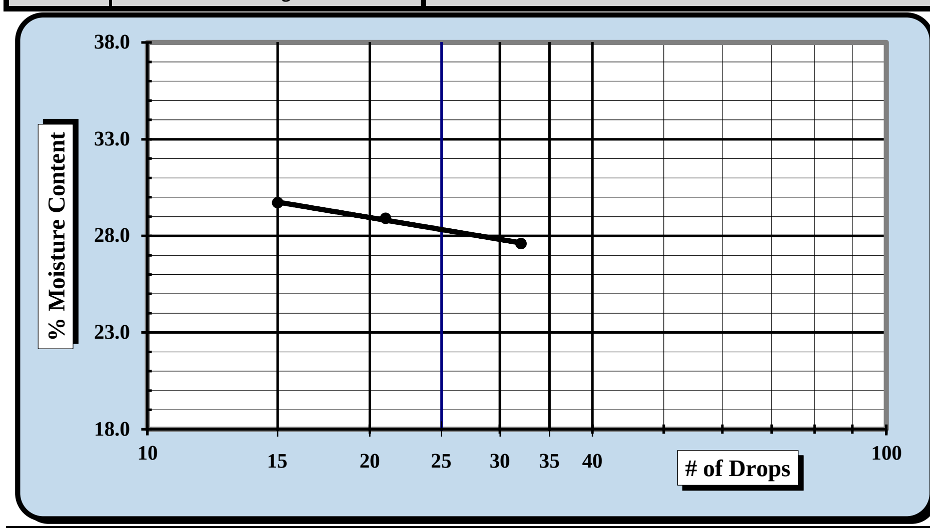
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/26/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	18.5'

Sample Description: silty SAND (SM) - brown, medium to fine with little gravel

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	Q-1	Q-2	Q-3				3	4	
A	Tare Weight	16.65	16.59	15.72				11.60	12.27	
B	Wet Soil Weight + A	40.12	41.77	40.31				18.27	18.96	
C	Dry Soil Weight + A	35.04	36.12	34.68				16.88	17.57	
D	Water Weight (B-C)	5.08	5.65	5.63				1.39	1.39	
E	Dry Soil Weight (C-A)	18.39	19.53	18.96				5.28	5.30	
F	% Moisture (D/E)*100	27.6%	28.9%	29.7%				26.3%	26.2%	
N	# OF DROPS	32	21	15				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							26.3%		



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☐
Liquid Limit	**28**
Plastic Limit	**26**
Plastic Index	**2**
Group Symbol	**SM**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 30.5%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

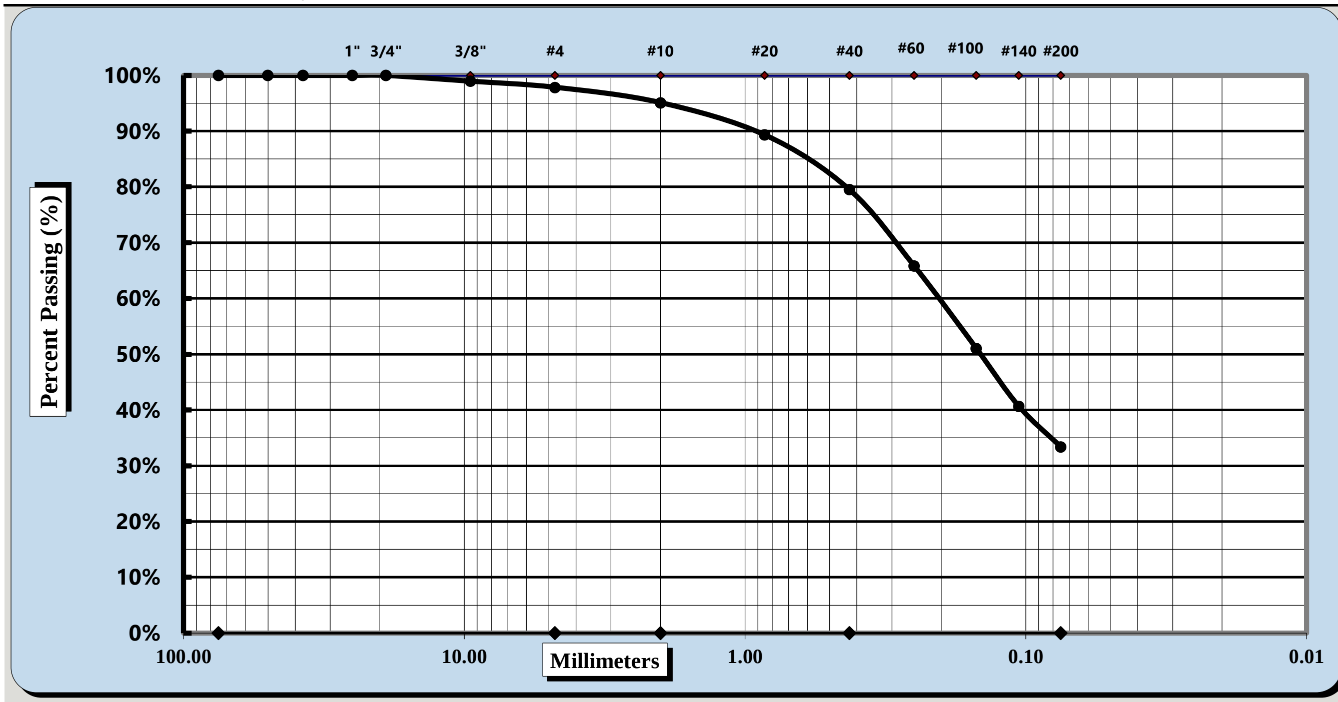
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-4	Type:	Split-spoon	Depth:	23.5'

Sample Description: silty SAND (SM) - brown, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	2.7%	Fine Sand	46.2%
Gravel	2.2%	Medium Sand	15.6%	Silt & Clay	33.4%
Liquid Limit	27	Plastic Limit	26	Plastic Index	1

Natural Moisture 23.2%

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/27/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-4	Type:	Split-spoon	Depth:	23.5'

Sample Description: silty SAND (SM) - brown, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	Y-1	Y-2	Y-3				5	6	
A	Tare Weight	16.40	16.43	16.99				12.10	12.30	
B	Wet Soil Weight + A	39.70	39.56	38.82				18.45	18.69	
C	Dry Soil Weight + A	34.77	34.53	33.96				17.14	17.36	
D	Water Weight (B-C)	4.93	5.03	4.86				1.31	1.33	
E	Dry Soil Weight (C-A)	18.37	18.10	16.97				5.04	5.06	
F	% Moisture (D/E)*100	26.8%	27.8%	28.6%				26.0%	26.3%	
N	# OF DROPS	30	22	15				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							26.2%		

One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☐
Liquid Limit	**27**
Plastic Limit	**26**
Plastic Index	**1**
Group Symbol	**SM**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 33.4%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

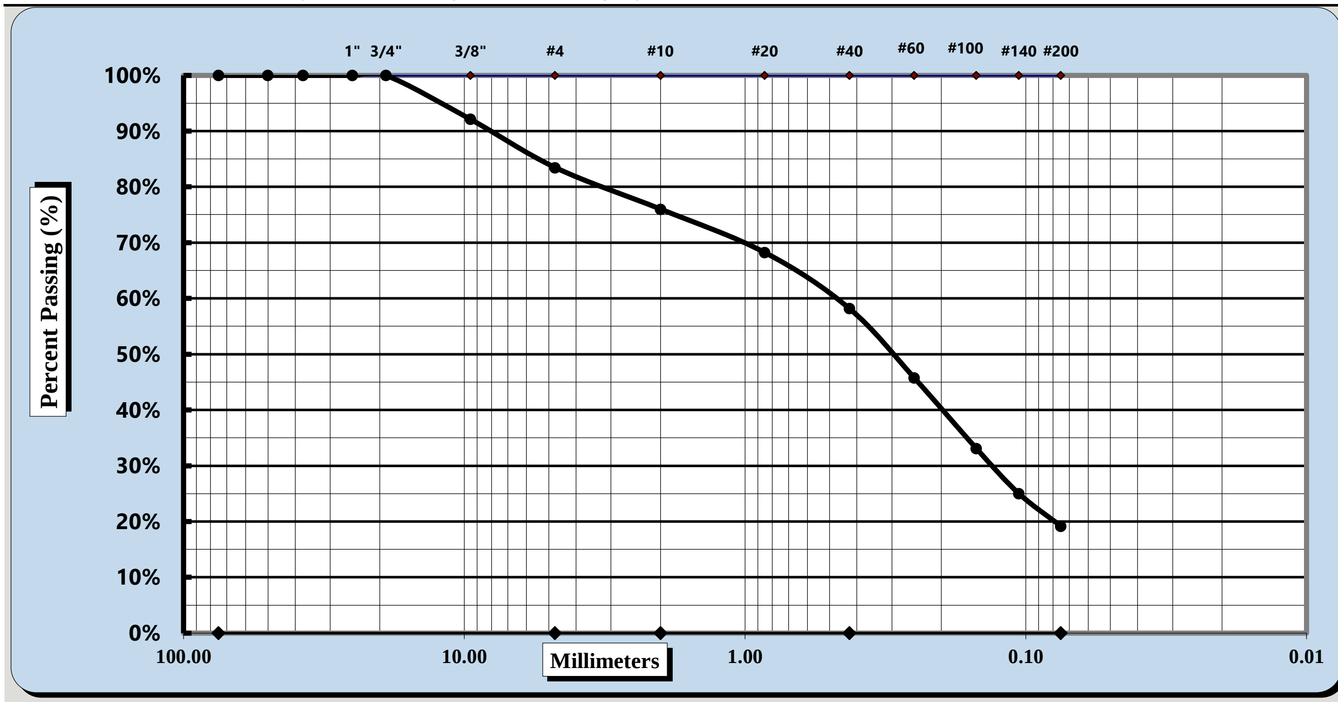
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-5	Type:	Split-spoon	Depth:	28.5'

Sample Description: silty SAND with gravel (SM) - gray tan, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	7.4%	Fine Sand	39.0%
Gravel	16.5%	Medium Sand	17.8%	Silt & Clay	19.2%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	16.6%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

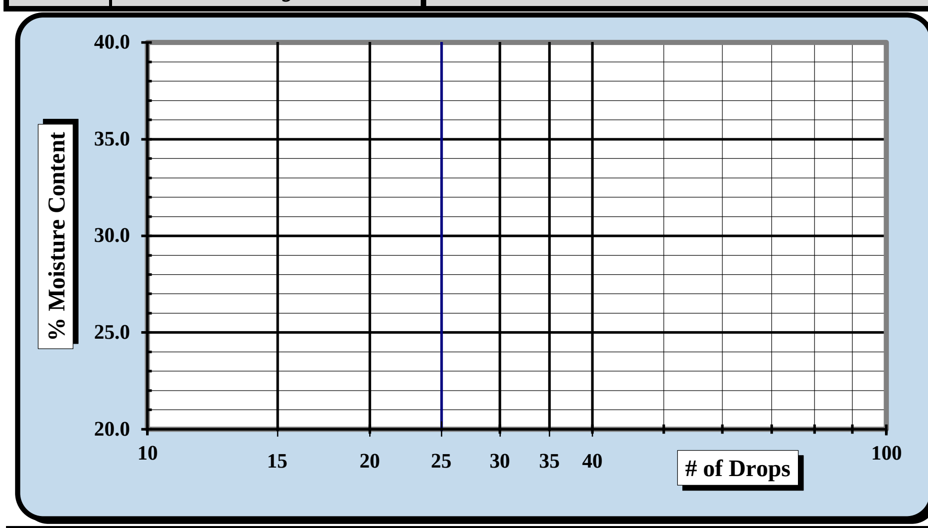
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-5	Type:	Split-spoon	Depth:	28.5'

Sample Description: silty SAND with gravel (SM) - gray tan, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 19.2%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

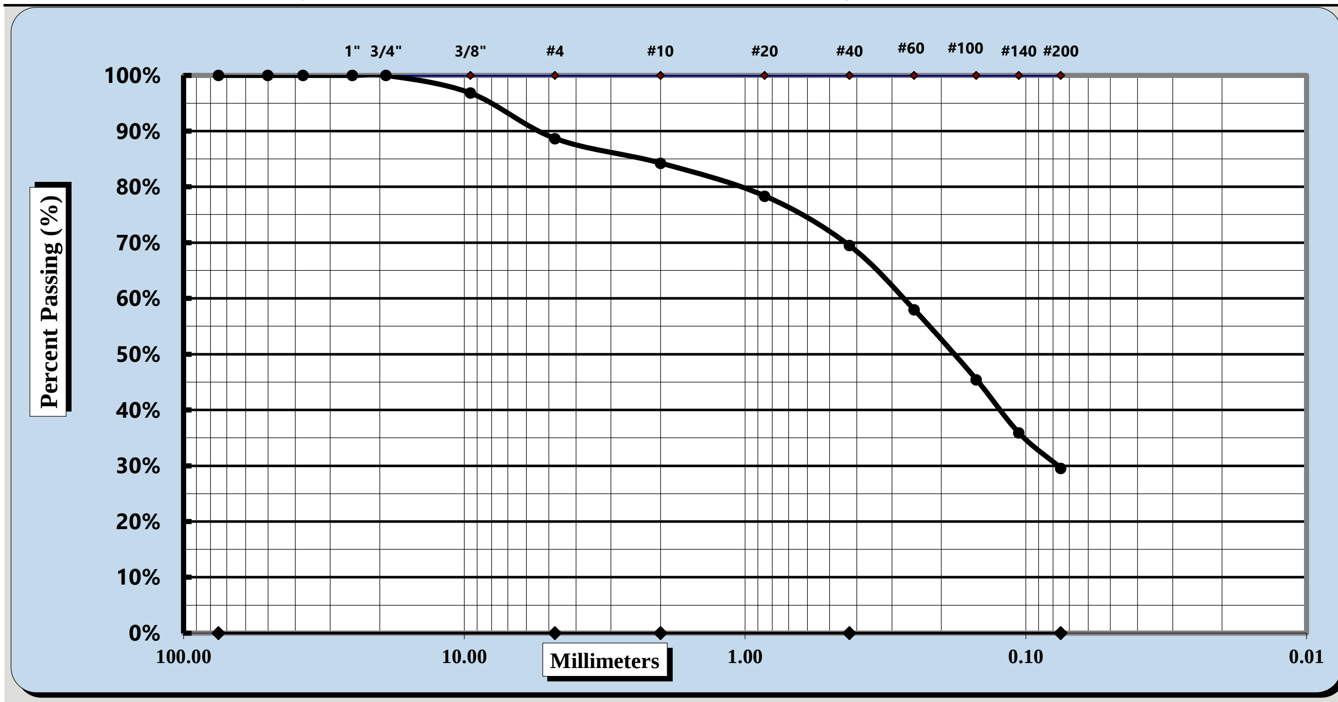
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-6	Type:	Split-spoon	Depth:	33.5'

Sample Description: silty SAND (SM) - brown, medium to fine with little gravel



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	4.4%	Fine Sand	39.9%
Gravel	11.3%	Medium Sand	14.8%	Silt & Clay	29.6%
Liquid Limit	27	Plastic Limit	25	Plastic Index	2
		Natural Moisture	20.1%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS JR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

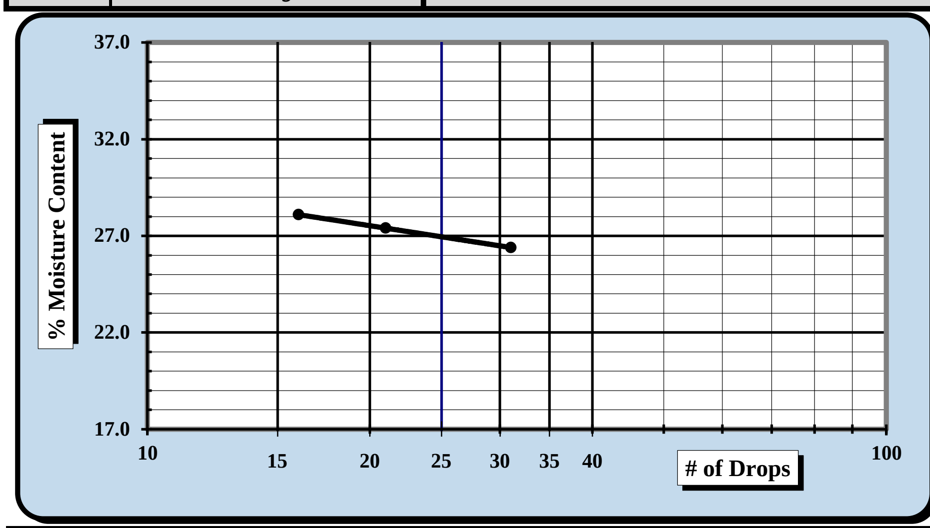
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/27/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	SS-6	Type:	Split-spoon	Depth:	33.5'

Sample Description: silty SAND (SM) - brown, medium to fine with little gravel

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	Z-1	Z-2	Z-3				7	9	
A	Tare Weight	15.90	16.58	16.77				12.00	12.23	
B	Wet Soil Weight + A	40.44	40.83	39.66				18.34	18.68	
C	Dry Soil Weight + A	35.31	35.61	34.64				17.09	17.40	
D	Water Weight (B-C)	5.13	5.22	5.02				1.25	1.28	
E	Dry Soil Weight (C-A)	19.41	19.03	17.87				5.09	5.17	
F	% Moisture (D/E)*100	26.4%	27.4%	28.1%				24.6%	24.8%	
N	# OF DROPS	31	21	16				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							24.7%		



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☐

Liquid Limit	**27**
Plastic Limit	**25**
Plastic Index	**2**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 29.6%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

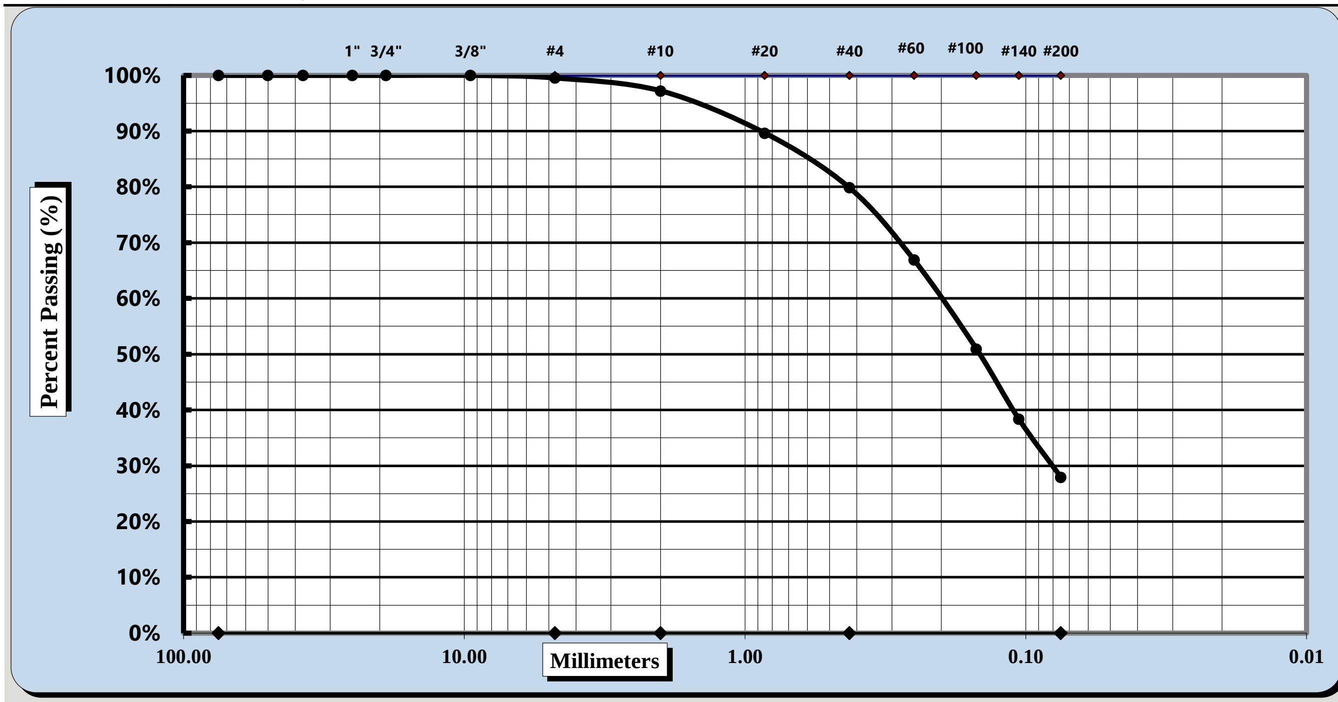
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/16 - 8/18/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	RC-1	Type:	Split-spoon	Depth:	60.7'

Sample Description: silty SAND (SM) - tan brown, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B   Procedure for obtaining Specimen: Moist   Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	2.3%	Fine Sand	52.0%
Gravel	0.5%	Medium Sand	17.3%	Silt & Clay	27.9%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	2.1%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

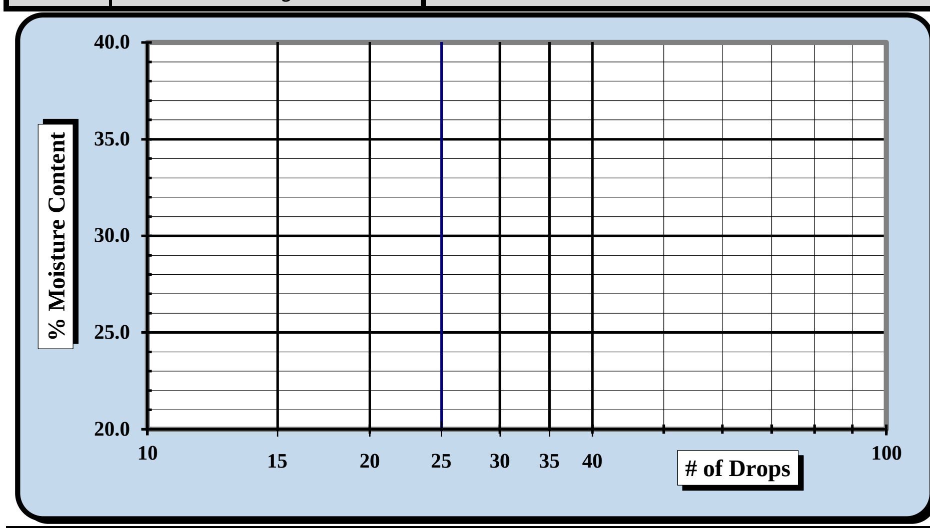
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/18/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-4	Log #:	135	Sample Date:	4/6/21
Sample ID:	RC-1	Type:	Split-spoon	Depth:	60.7'

Sample Description: silty SAND (SM) - tan brown, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☒
Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**
Multipoint Method	☑
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 27.9%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

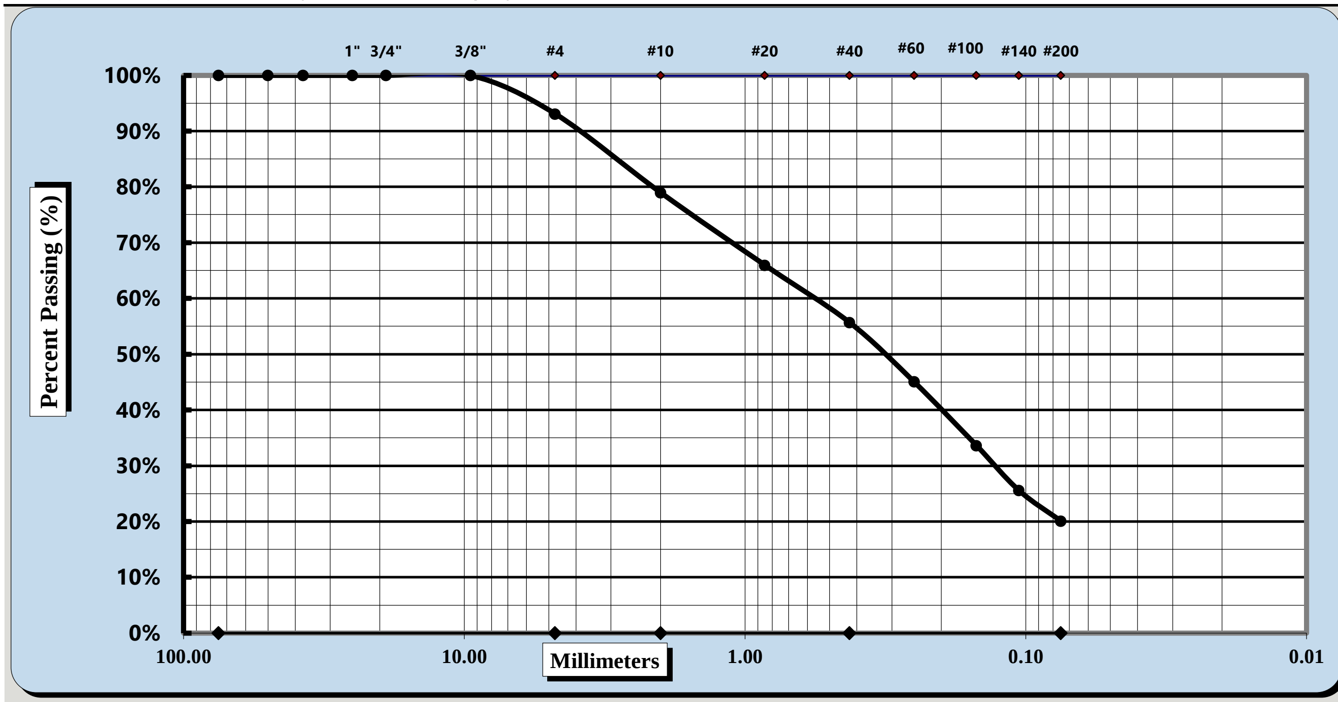
SIEVE ANALYSIS OF SOIL

Single sieve set — *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/19/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-1	Type:	Split-spoon	Depth:	2.6'

Sample Description: silty SAND (SM) - gray brown white, coarse to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B — Procedure for obtaining Specimen: Moist — Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	14.1%	Fine Sand	35.6%
Gravel	6.9%	Medium Sand	23.3%	Silt & Clay	20.1%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	14.5%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

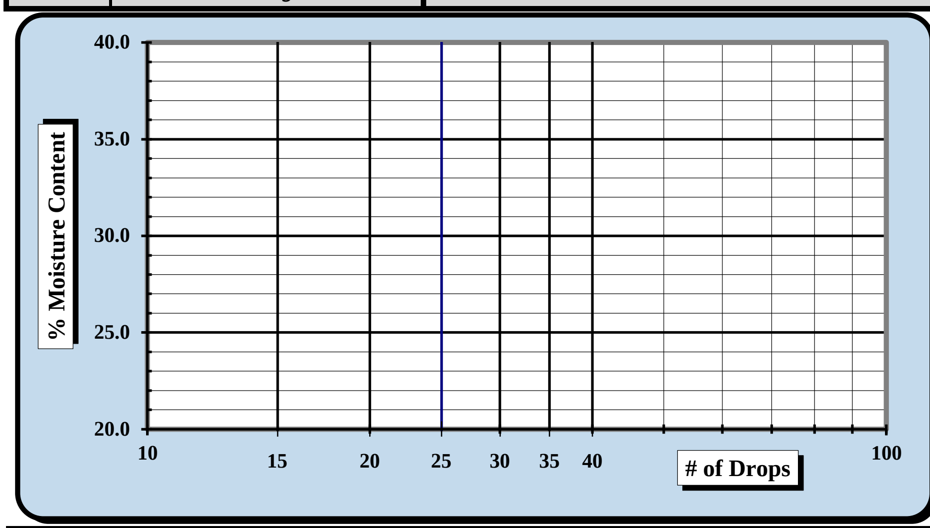
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-1	Type:	Split-spoon	Depth:	2.6'

Sample Description: silty SAND (SM) - gray brown white, coarse to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 20.1%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

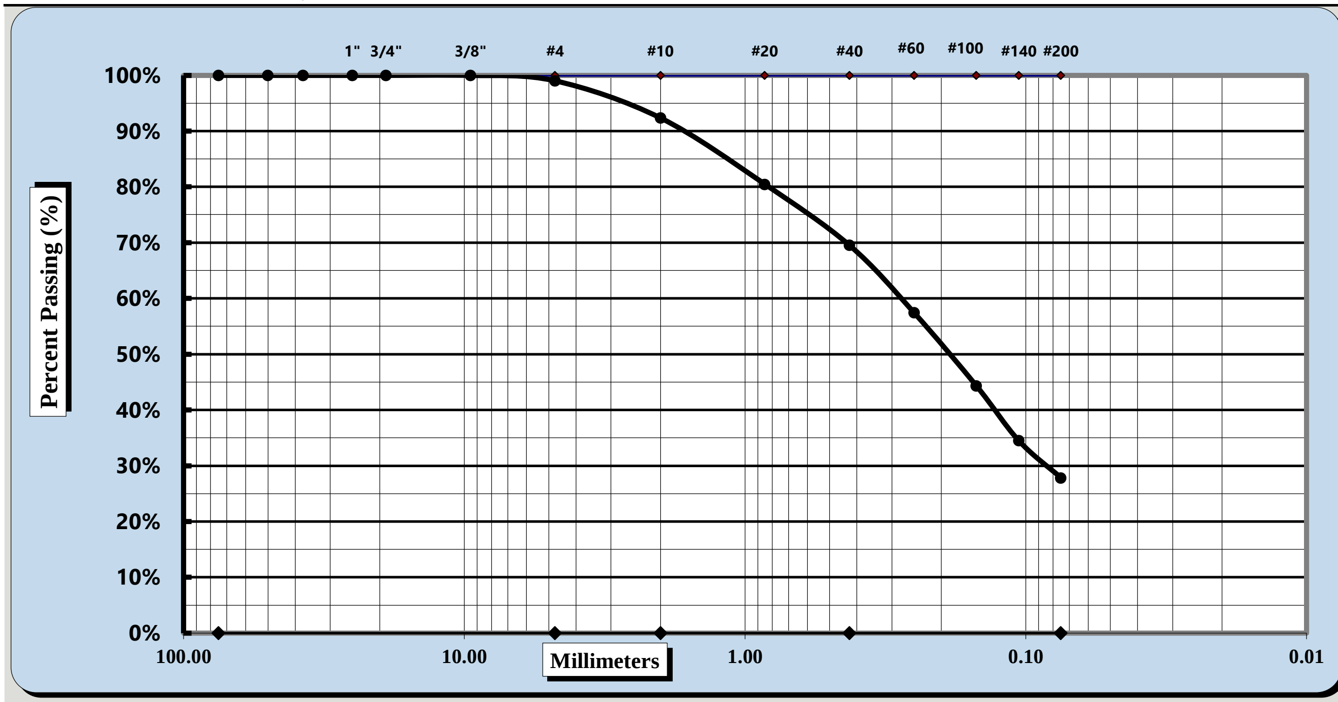
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/19/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	7.6'

Sample Description: silty SAND (SM) - brown white, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	6.6%	Fine Sand	41.7%
Gravel	1.0%	Medium Sand	22.8%	Silt & Clay	27.8%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	15.1%		

Notes / Deviations / References:

Frank Morris, P.E. — *Technical Responsibility*

[signature] — *Signature*

Project Manager — *Position*

8/30/21 — *Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

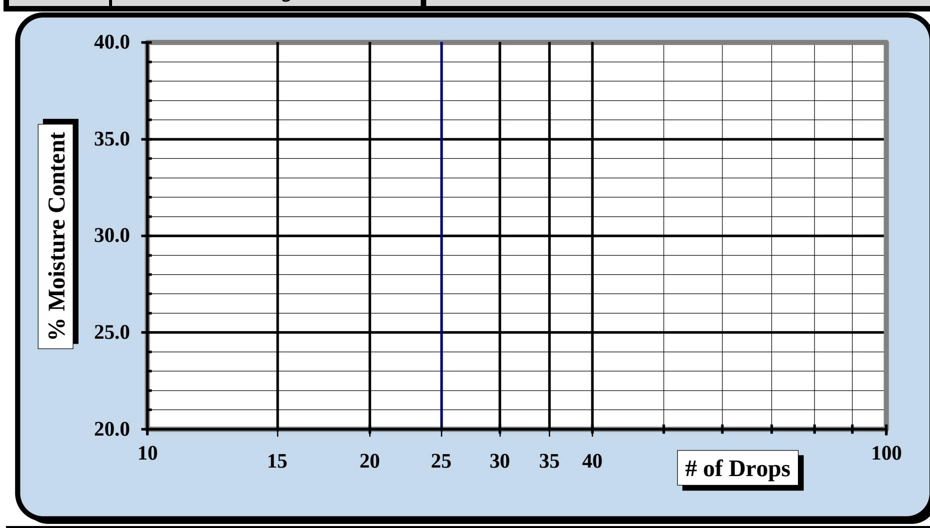
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-2	Type:	Split-spoon	Depth:	7.6'

Sample Description: silty SAND (SM) - brown white, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 27.8%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

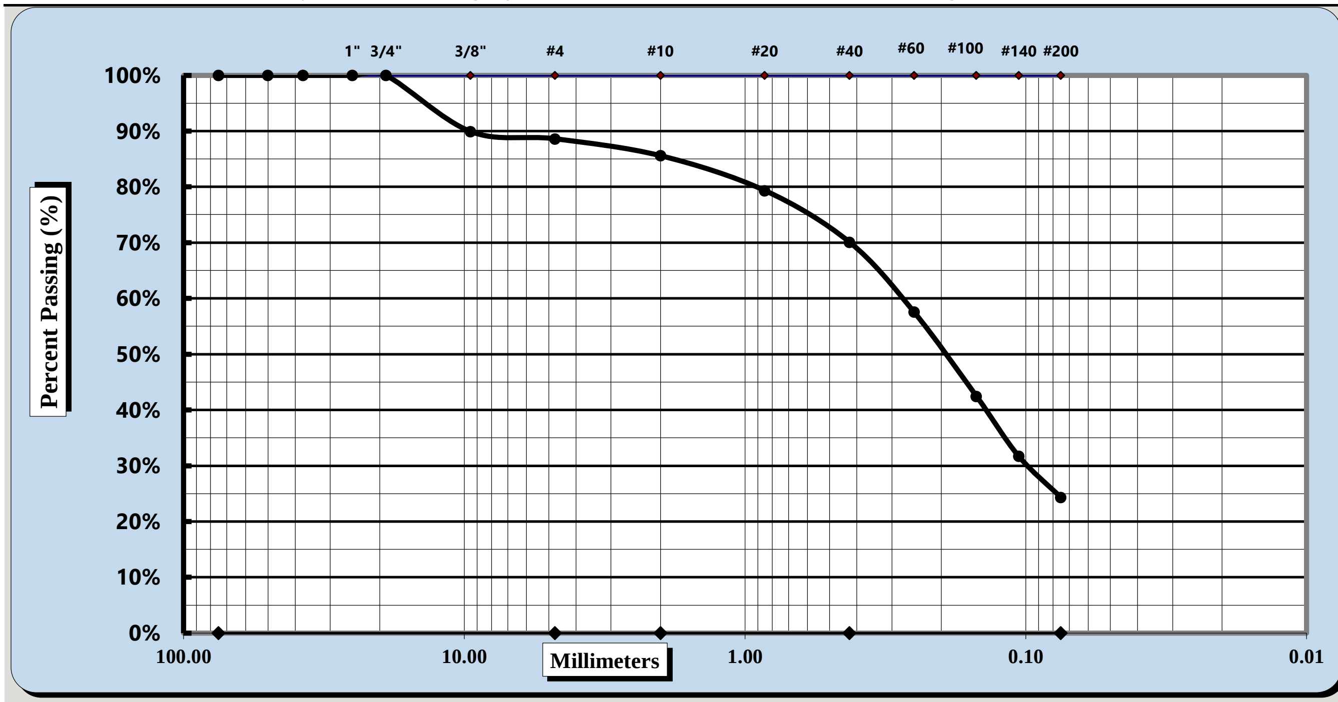
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/19/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	12.6'

Sample Description: silty SAND (SM) - gray olive white, medium to fine with little gravel



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	3.0%	Fine Sand	45.8%
Gravel	11.4%	Medium Sand	15.5%	Silt & Clay	24.3%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	13.7%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

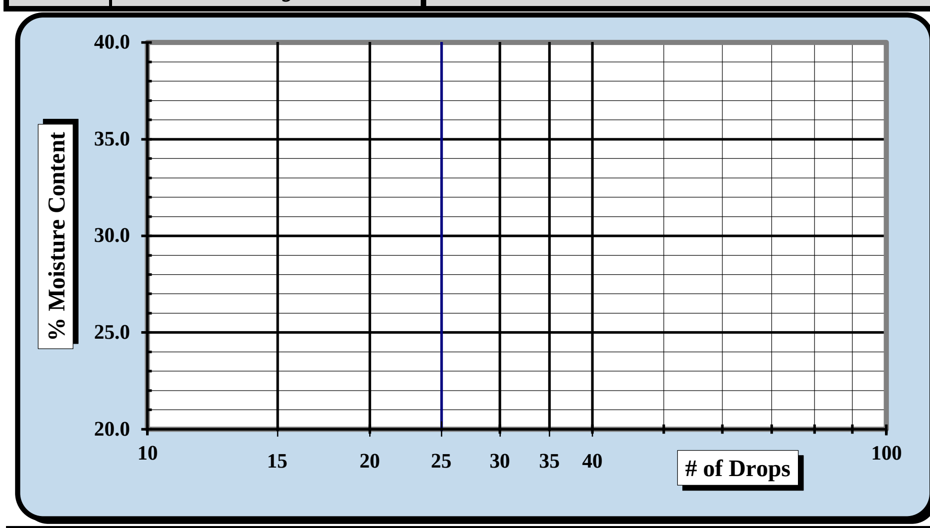
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-3	Type:	Split-spoon	Depth:	12.6'

Sample Description: silty SAND (SM) - gray olive white, medium to fine with little gravel

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 24.3%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

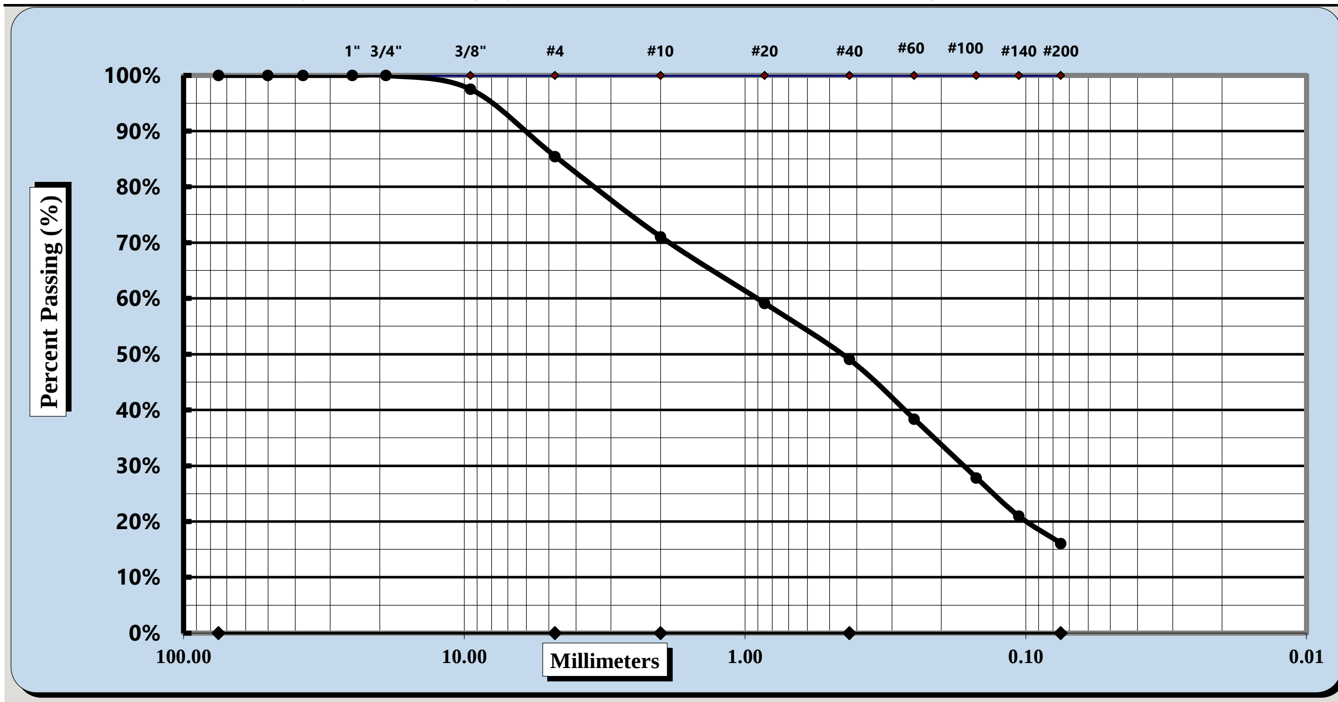
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/19/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-4	Type:	Split-spoon	Depth:	17.6'

Sample Description: silty SAND (SM) - gray olive white, coarse to fine with little gravel



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	14.4%	Fine Sand	33.0%
Gravel	14.5%	Medium Sand	22.0%	Silt & Clay	16.1%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	12.5%		

Notes / Deviations / References:

Frank Morris, P.E.	Frank P. Morris Sr.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

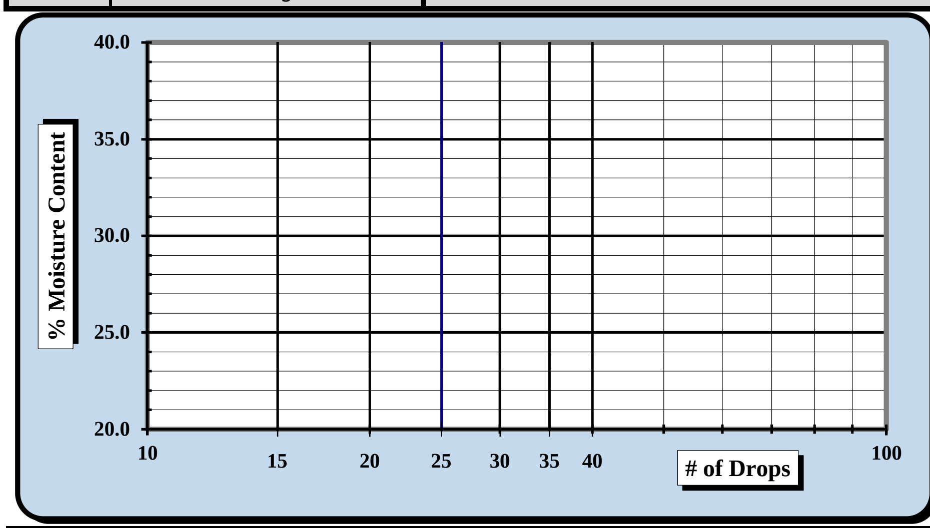
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-4	Type:	Split-spoon	Depth:	17.6'

Sample Description: silty SAND (SM) - gray olive white, coarse to fine with little gravel

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	---
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 16.1%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

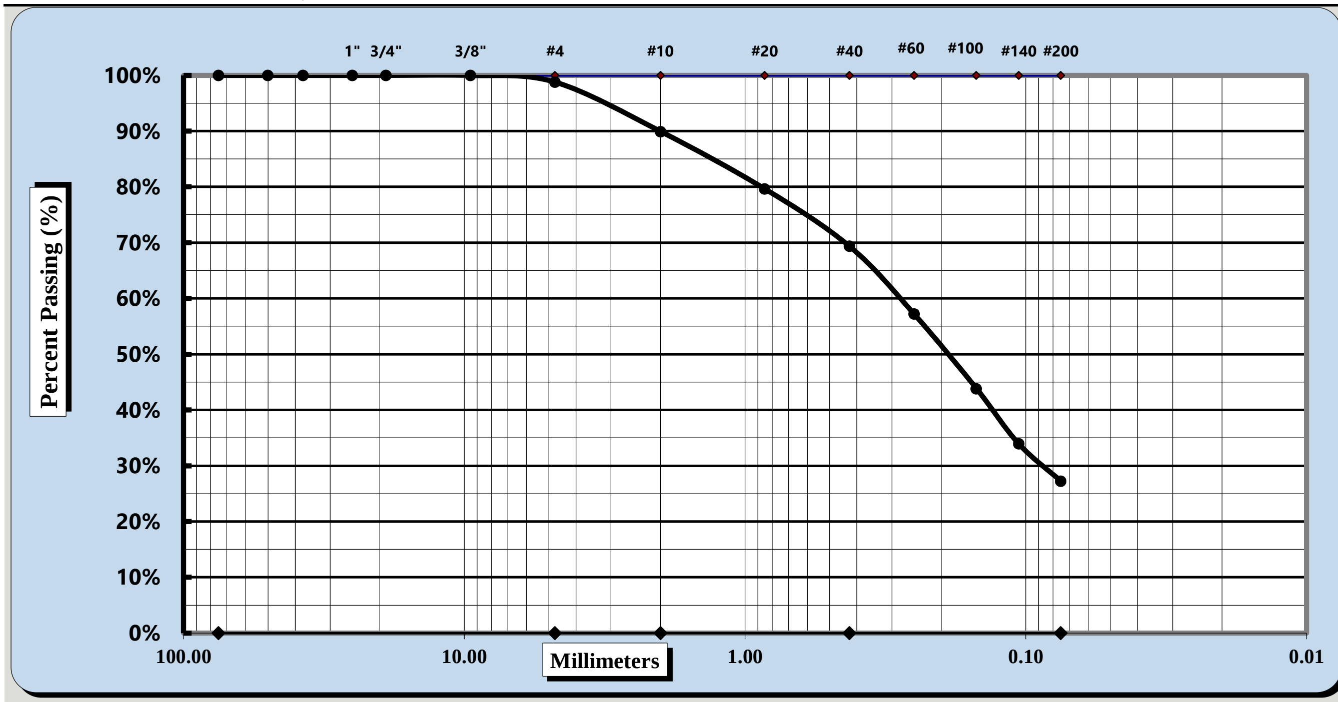
SIEVE ANALYSIS OF SOIL

Single sieve set — *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/19/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-6	Type:	Split-spoon	Depth:	27.6'

Sample Description: silty SAND (SM) - brown olive white, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B — Procedure for obtaining Specimen: Moist — Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	8.8%	Fine Sand	42.1%
Gravel	1.2%	Medium Sand	20.6%	Silt & Clay	27.3%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP

Natural Moisture 21.3%

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
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LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

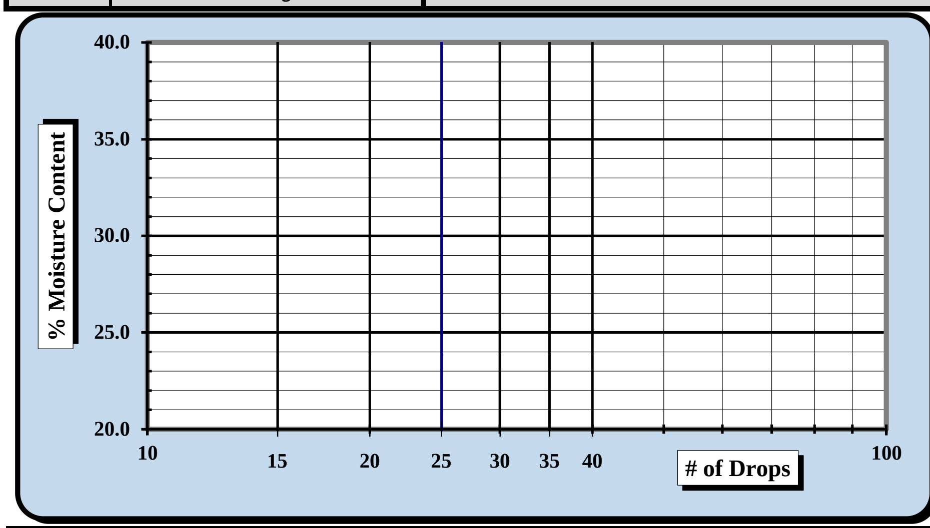
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-6	Type:	Split-spoon	Depth:	27.6'

Sample Description: silty SAND (SM) - brown olive white, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 27.3%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

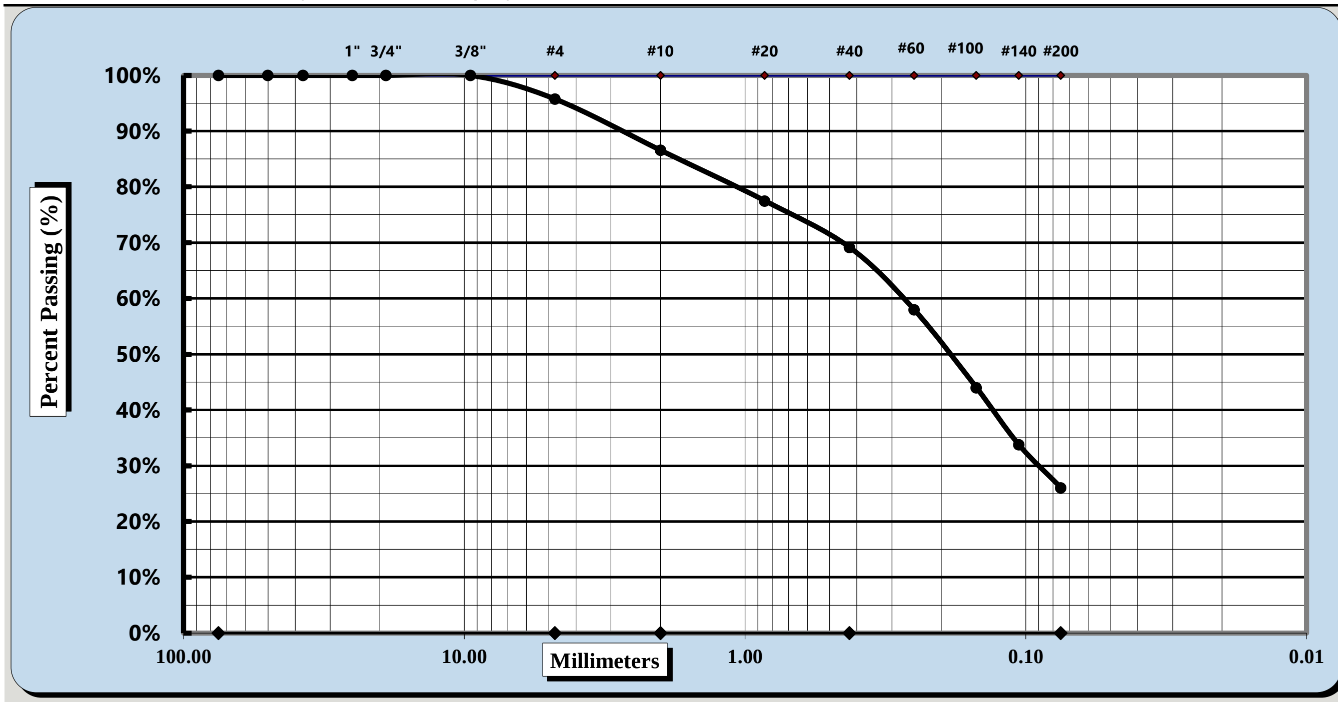
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/19/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-10	Type:	Split-spoon	Depth:	47.6'

Sample Description: silty SAND (SM) - gray olive white, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	9.2%	Fine Sand	43.1%
Gravel	4.3%	Medium Sand	17.4%	Silt & Clay	26.1%
Liquid Limit	---	Plastic Limit	NP	Plastic Index	NP
		Natural Moisture	14.4%		

Notes / Deviations / References:

Frank Morris, P.E. — *Technical Responsibility*
FRANK P. MORRIS — *Signature*
Project Manager — *Position*
8/30/21 — *Date*

Form No. TR-D4318-T89-90
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Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

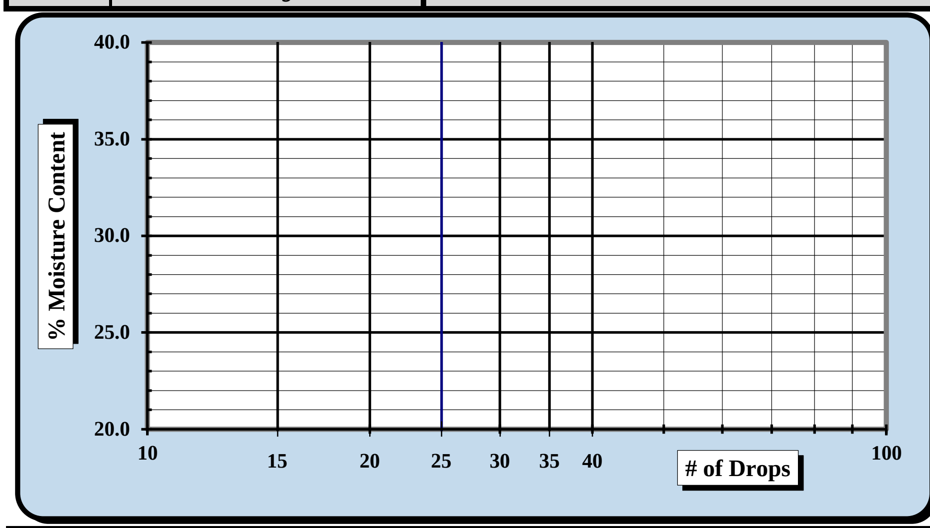
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/19/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-10	Type:	Split-spoon	Depth:	47.6'

Sample Description: silty SAND (SM) - gray olive white, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**---**
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 26.1%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

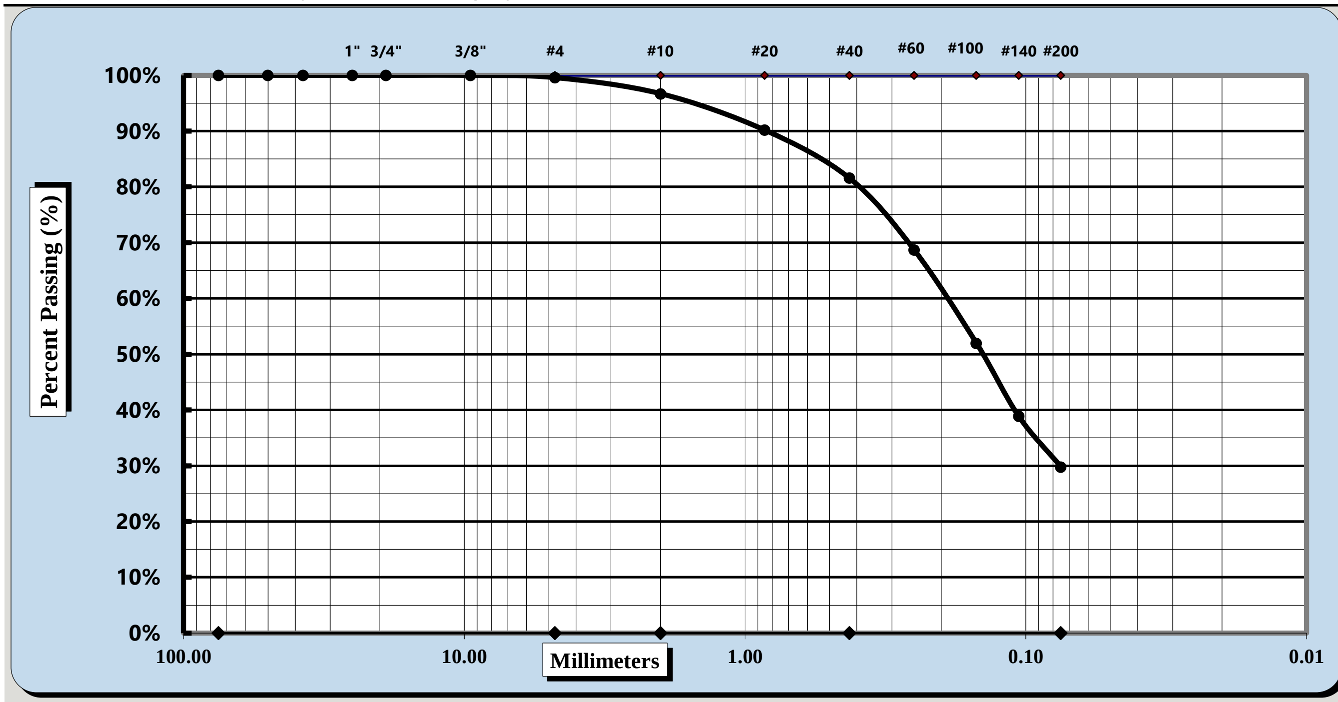
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/20/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-17	Type:	Split-spoon	Depth:	32.6'

Sample Description: silty SAND (SM) - gray olive white, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	4.75 mm	Coarse Sand	2.9%	Fine Sand	51.8%
Gravel	0.4%	Medium Sand	15.1%	Silt & Clay	29.8%
Liquid Limit	27	Plastic Limit	27	Plastic Index	NP

Natural Moisture 19.3%

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

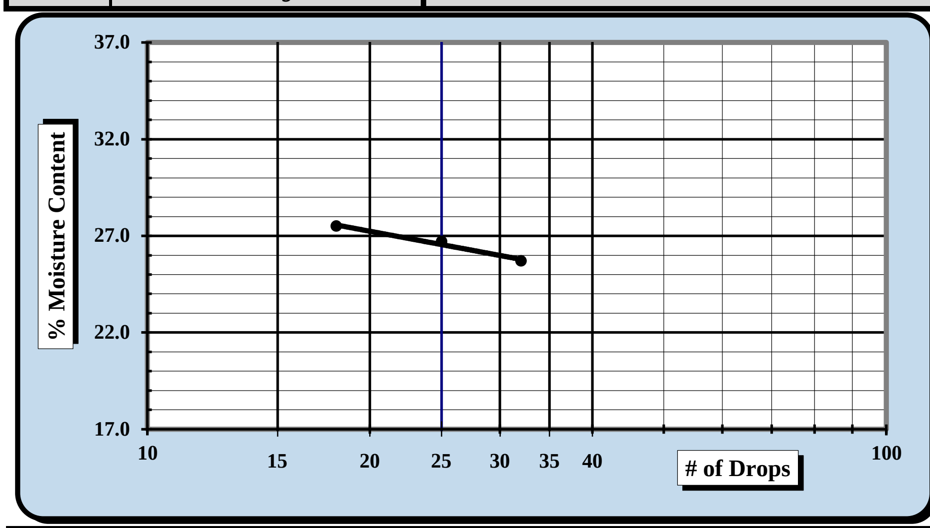
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/27/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole: B-21-5		Log #:	135	Sample Date:	6/2/21
Sample ID: SS-17		Type:	Split-spoon	Depth:	32.6'

Sample Description: silty SAND (SM) - gray olive white, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	P-4	P-5	P-6				12	13	
A	Tare Weight	16.60	16.58	15.97				11.17	12.10	
B	Wet Soil Weight + A	40.99	42.56	40.20				17.27	18.39	
C	Dry Soil Weight + A	36.01	37.08	34.97				15.95	17.05	
D	Water Weight (B-C)	4.98	5.48	5.23				1.32	1.34	
E	Dry Soil Weight (C-A)	19.41	20.50	19.00				4.78	4.95	
F	% Moisture (D/E)*100	25.7%	26.7%	27.5%				27.6%	27.1%	
N	# OF DROPS	32	25	18				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							27.4%		



One Point Liquid Limit

N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**27**
Plastic Limit	**27**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 29.8%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

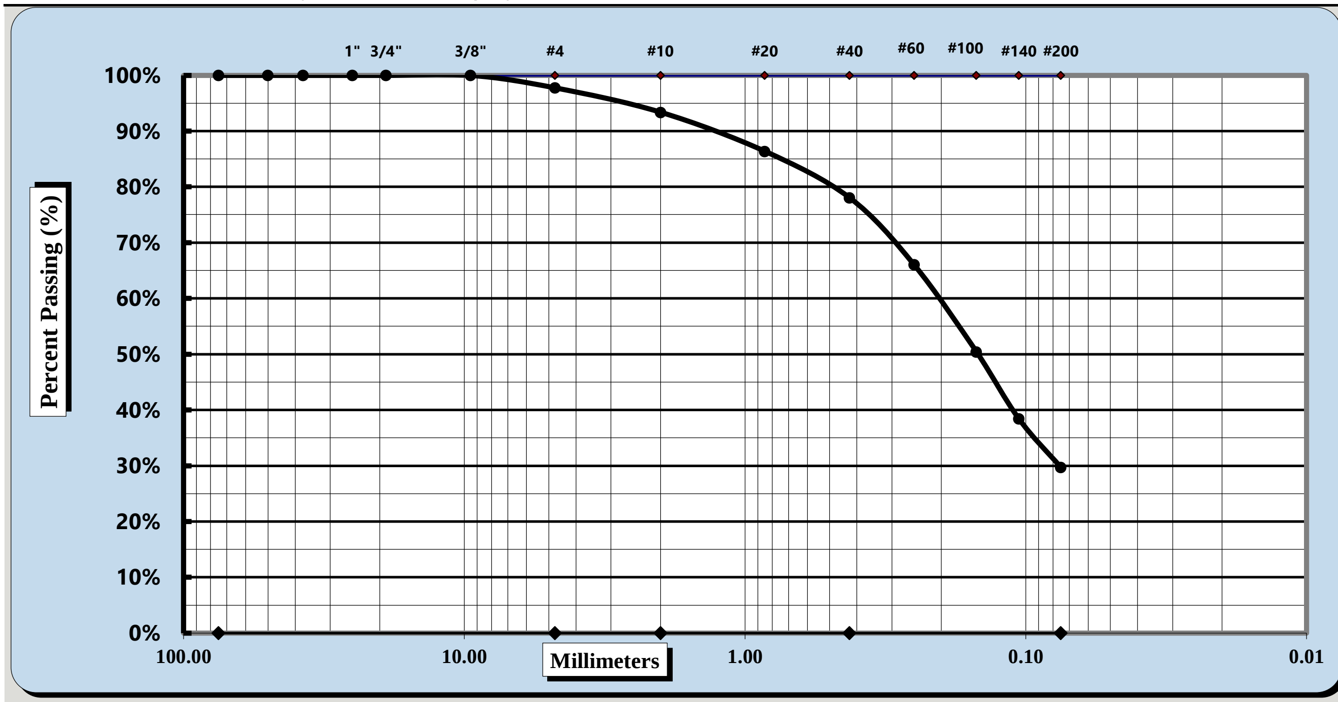
SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/20/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-18	Type:	Split-spoon	Depth:	37.6'

Sample Description: silty SAND (SM) - gray olive white, medium to fine



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B   Procedure for obtaining Specimen: Moist   Dispersion Process: Dispersant

Maximum Particle Size	9.50 mm	Coarse Sand	4.4%	Fine Sand	48.4%
Gravel	2.3%	Medium Sand	15.3%	Silt & Clay	29.7%
Liquid Limit	27	Plastic Limit	27	Plastic Index	NP
		Natural Moisture	18.7%		

Notes / Deviations / References:

Frank Morris, P.E.	FRANK P. MORRIS, SR.	Project Manager	8/30/21
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/27/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-18	Type:	Split-spoon	Depth:	37.6'

Sample Description: silty SAND (SM) - gray olive white, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	Q-4	Q-5	Q-6				17	18	
A	Tare Weight	16.67	16.82	16.80				12.12	12.12	
B	Wet Soil Weight + A	40.54	41.26	40.37				19.67	19.35	
C	Dry Soil Weight + A	35.65	36.02	35.21				18.07	17.83	
D	Water Weight (B-C)	4.89	5.24	5.16				1.60	1.52	
E	Dry Soil Weight (C-A)	18.98	19.20	18.41				5.95	5.71	
F	% Moisture (D/E)*100	25.8%	27.3%	28.0%				26.9%	26.6%	
N	# OF DROPS	35	21	15				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							26.8%		

One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	**27**
Plastic Limit	**27**
Plastic Index	**NP**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 29.7%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

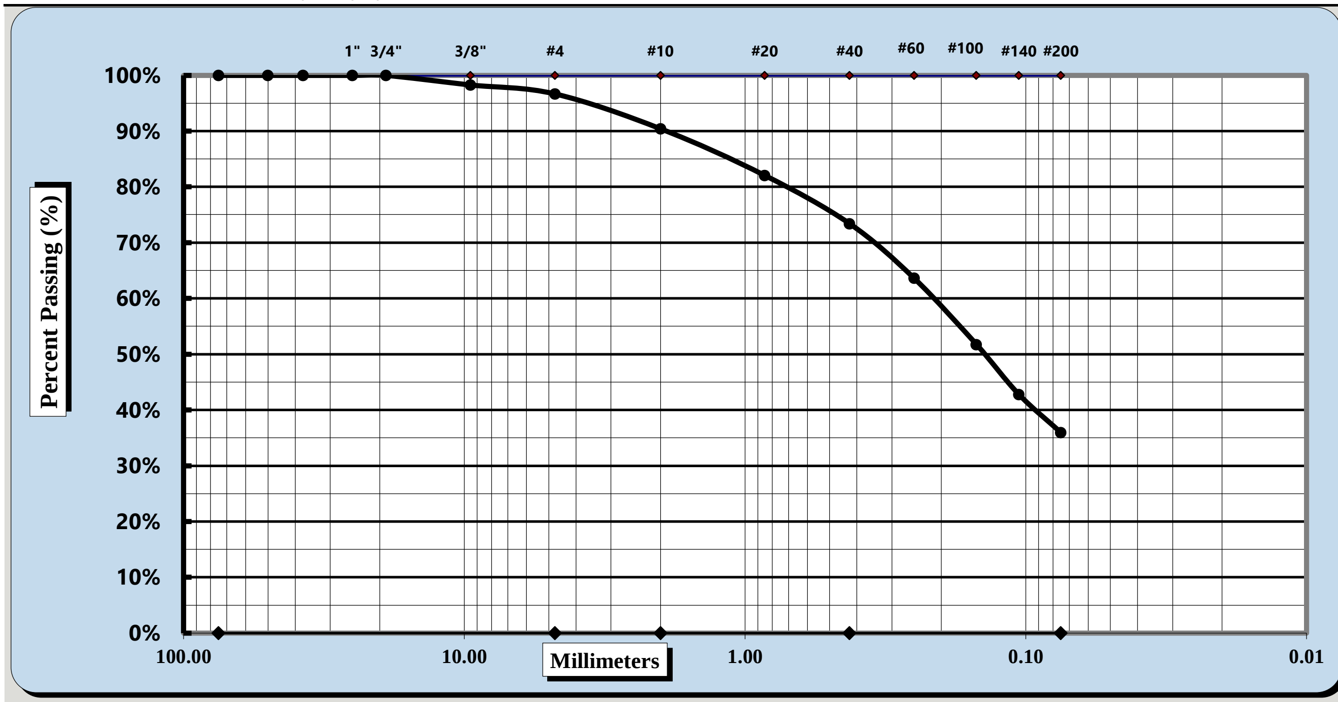
Form No TR-D6913-GR-01
Revision No. 1
Revision Date: 9/5/17

SIEVE ANALYSIS OF SOIL

Single sieve set *ASTM D 6913*

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

Project #:	213045			Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project			Test Date(s):	8/17 - 8/20/21
Client Name:	HDR				
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201				
Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-21	Type:	Split-spoon	Depth:	52.6'
Sample Description:	silty clayey SAND (SC-SM) - tan brown white, medium to fine				



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Method: B Procedure for obtaining Specimen: Moist Dispersion Process: Dispersant

Maximum Particle Size	19.00 mm	Coarse Sand	6.3%	Fine Sand	37.5%
Gravel	3.3%	Medium Sand	17.0%	Silt & Clay	36.0%
Liquid Limit	27	Plastic Limit	22	Plastic Index	5
		Natural Moisture	17.6%		

Notes / Deviations / References:

Frank Morris, P.E. — *Technical Responsibility*
FRANK P. MORRIS — *Signature*
Project Manager — *Position*
8/30/21 — *Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☒ AASHTO T 89 ☐ AASHTO T 90 ☐

S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301

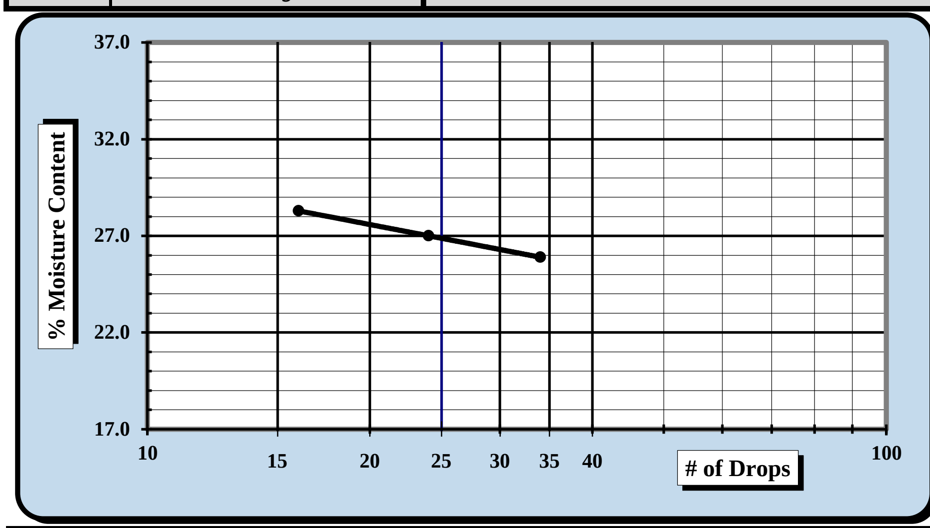
Project #:	213045	Report Date:	8/30/21
Project Name:	Bad Creek Phase 2 Feasibility Study Project	Test Date:	8/27/21
Client Name:	HDR		
Client Address:	1122 Lady Street, Suite 1100 Columbia, South Carolina 29201		

Borehole:	B-21-5	Log #:	135	Sample Date:	6/2/21
Sample ID:	SS-21	Type:	Split-spoon	Depth:	52.6'

Sample Description: silty clayey SAND (SC-SM) - tan brown white, medium to fine

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	7537	1/29/2021	Grooving tool	14185	9/28/2020
LL Apparatus	13859	9/28/2020			
Oven	7313	7/30/2021			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	Y-4	Y-5	Y-6				20	21	
A	Tare Weight	16.80	16.72	15.92				12.12	12.07	
B	Wet Soil Weight + A	41.57	41.12	40.25				18.84	18.66	
C	Dry Soil Weight + A	36.47	35.93	34.89				17.65	17.48	
D	Water Weight (B-C)	5.10	5.19	5.36				1.19	1.18	
E	Dry Soil Weight (C-A)	19.67	19.21	18.97				5.53	5.41	
F	% Moisture (D/E)*100	25.9%	27.0%	28.3%				21.5%	21.8%	
N	# OF DROPS	34	24	16				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							21.7%		



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☐

Liquid Limit	**27**
Plastic Limit	**22**
Plastic Index	**5**
Group Symbol	**SC-SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *% Passing the #200 Sieve:* 36.0%

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Matt Jacobs	8/30/21	Frank Morris, P.E.	8/30/21
Technician Name	*Date*	*Technical Responsibility*	*Date*

Appendix H

Rock Core Sample Laboratory Testing Results

Not Included - Available Upon Request

Appendix I

HDR Downhole Data Stereonets

Not Included - Available Upon Request

Attachment 3

Attachment 3 – Lower Reservoir CFD Flow Modeling Report

Bad Creek II Power Complex Feasibility Study

Volume 5: Lower Reservoir CFD Flow Modeling Report

Salem, South Carolina
September 1, 2022

Contents

Tables

Figures

Acronyms and Abbreviations

3D	three dimensional
ARL	Alden Research Laboratory
Bad Creek	Bad Creek Pumped Storage Station
Bad Creek II	Proposed Bad Creek II Power Complex
CFD	computational fluid dynamics
cfs	cubic feet per second
ft	feet/foot
ft msl	feet above mean sea level
fps	feet per second
I/O	Inlet/Outlet
URANS	Unsteady Reynolds Averaged-Navier Stokes
WSE	water surface elevation

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1 Executive Summary

As a component of the Duke Energy Carolinas, LLC (Duke Energy) Bad Creek II Power Complex (Bad Creek II) Feasibility Study scope, HDR developed a Computational Fluid Dynamic (CFD) model to quantify and evaluate potential hydraulic impacts within the Whitewater River cove of Lake Jocassee to establish velocity and flow patterns along the channel and near the east bank of the cove opposite of the discharge structure. Model simulations were carried out assuming the existing Bad Creek Pumped Storage Station (Bad Creek) and the proposed Bad Creek II were operating both simultaneously and independently under several scenarios. The modeling utilized Lake Jocassee bathymetry and the existing and proposed Bad Creek II inlet/outlet (I/O) structures to evaluate velocities and flow patterns within the Whitewater River cove to assess operational impacts. Simulations were run at elevations of 1,110 feet (ft) above mean sea level (msl) (i.e., normal full pool elevation) and 1,080 ft msl (minimum normal elevation) to calibrate the CFD model velocities and flow patterns to the 1986 physical model results reported by Alden Research Laboratory (ARL) (Larsen and White 1986) assuming the same discharge flows modeled by ARL. Bad Creek is currently undergoing upgrades to the pump-turbine units. Upgraded operations at Bad Creek as well as proposed Bad Creek II operations (and I/O structure operations) were subsequently added to the model.

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. The elevation of 1,096 ft msl was selected as an intermediate lake elevation operating scenario for the following reasons:

1. The surface water elevation threshold for implementation of protective operational measures to minimize fish entrainment is 1,099 ft msl.
2. The surface water elevation below which fish entrainment becomes elevated at Bad Creek and historically occurs less than 22 percent of the time is 1,096 ft msl.

Model results indicate 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 creates a concentrated area of high velocity flows extending downstream to the existing Bad Creek I/O structure. This effect is more pronounced at lower reservoir levels. The concentrated area of high velocity flow does not impact the east (i.e., opposite) bank of the Whitewater River cove, which is predominantly bedrock. Additional scenarios to simulate pumping operations were performed and showed distinct flow patterns specific to each I/O structure. Expansion of the existing submerged weir downstream of the I/O structure is planned during the construction of Bad Creek II; velocities in the water column above the expanded submerged weir increased as the flow depth decreased. Velocities along the eastern bank near the expanded weir were higher when compared to the simulations using existing weir.

2 Introduction

The existing Bad Creek Pumped Storage Station (Bad Creek) is part of a Duke Energy Carolinas, LLC (Duke Energy) operated system of two pumped storage stations near Salem, South Carolina. Bad Creek utilizes the Bad Creek Reservoir as the upper pool and Lake Jocassee as the lower pool. Downstream of Bad Creek is the Jocassee Pumped Storage Station, which uses Lake Jocassee as the upper pool and Lake Keowee as the lower pool.

Duke Energy is studying the viability of constructing a second pumped storage plant at Bad Creek to increase generation and pump capacity while also supporting Duke Energy's commitment to expanding intermittent renewable energy generation sources and reduce carbon dioxide emissions and achieve net-zero by 2050 (Duke Energy 2020). The proposed second powerhouse, Bad Creek II Power Complex (Bad Creek II), would operate similar to the existing Bad Creek station, using the Bad Creek Reservoir as the upper pool and Lake Jocassee as the lower pool.

As part of the Bad Creek II Feasibility Study authorized by Duke Energy, HDR Engineering, Inc. (HDR) developed a three-dimensional Computational Fluid Dynamic (CFD) model for lower reservoir modeling to complement the Upper and Lower Reservoir Operational Impact Studies. The Lower Reservoir CFD flow model supports the evaluation of a second additional inlet/outlet (I/O) structure and the potential associated impacts to the Whitewater River cove of Lake Jocassee.

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 (ARL) physical model (Larsen and White 1986), followed by phase II, which focused on evaluating the velocity and flow pattern impacts of the proposed second I/O structure at two reservoir elevations - 1,110 feet (ft) and 1,080 ft above mean sea level (msl). The second phase utilized discharge flows based on the soon to be uprated Bad Creek units, plus the assumed discharge from the conceptualized Bad Creek II project.

This report describes these simulations and the results presented provide a preliminary analysis for the Feasibility Study. Additional data or modifications to the model can be provided to support future studies.

3 CFD Model Development

3.1 Model Description

FLOW-3D is developed and supported by Flow Science, Inc. (Flow Science 2014) and is a commercially available computational model capable of solving three-dimensional (3D) Unsteady Reynolds Averaged-Navier Stokes (URANS) 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.

3.1.1 Modeling Approach

The FLOW-3D software solves fully URANS equations on structured grids and the governing equations used in the model are provided in the FLOW-3D user's guide (Flow Science 2014). Modelfitted meshes were developed for the existing Bad Creek I/O structure/reservoir and for the proposed Bad Creek II I/O structure/reservoir. A known water surface elevation (WSE) was applied to the reservoir meshes based on data supplied by Duke Energy.

PRESSURE SOLVER OPTIONS

Two numerical schemes are available for the pressure solver module with multiple options (i.e., explicit, and implicit). 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.

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 Lower Reservoir CFD flow modeling study 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.

MODEL LIMITATIONS

As with all numerical models, the CFD model is limited in the results it can accurately produce. Some hydrodynamic features are not accurately modeled with the selected solver 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.

3.2 Model Geometry

3.2.1 Existing I/O Structure and Lake Jocassee

The topography and bathymetry for the model was adapted from existing AutoCAD files and exported to a stereolithography file. Figure 1 shows the existing I/O structure and Lake Jocassee bathymetry. Figure 2 and Figure 3 show the geometry, bathymetry, and the Lake Jocassee reservoir level initial conditions of 1,110 ft and 1,080 ft msl used as initial conditions in the model, respectively. Figure 4 shows a detailed rendering of the existing I/O structure and bifurcated tunnels.

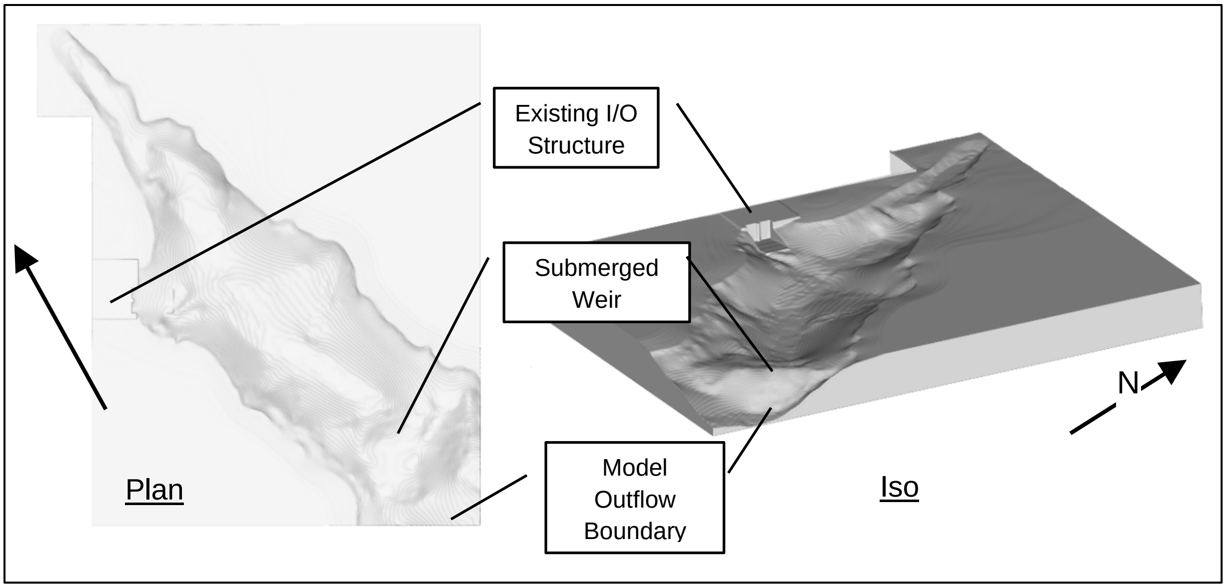

Figure 1. Existing I/O Structure and Lake Jocassee Bathymetry

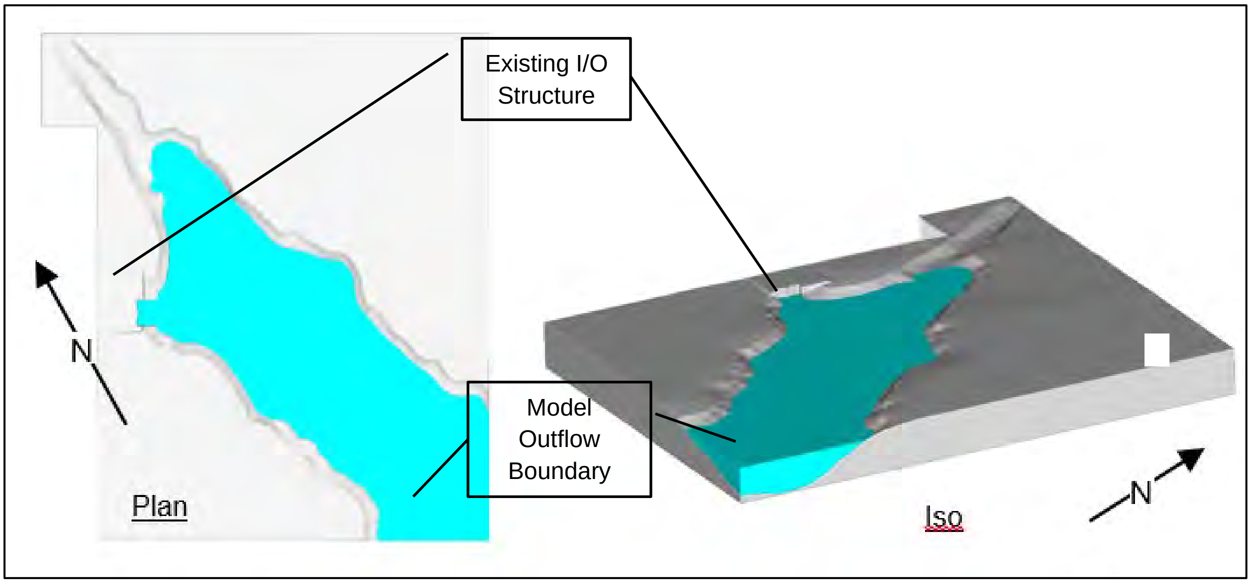

Figure 2. Existing I/O Structure and Lake Jocassee Bathymetry- Jocassee Lake Level 1,080 ft msl

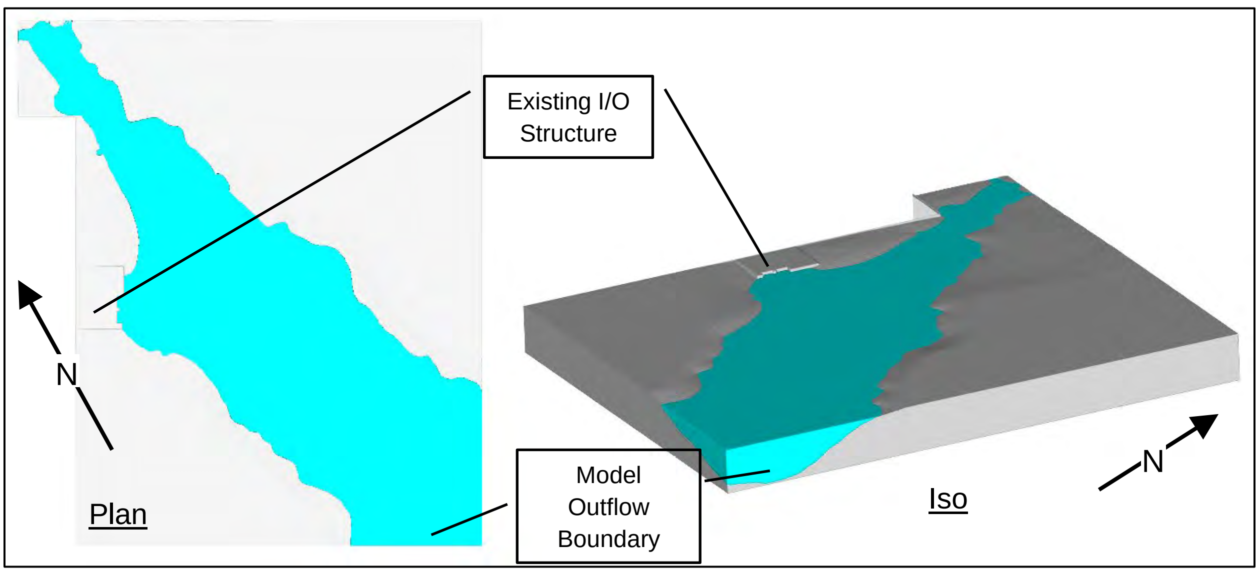

Figure 3. Existing I/O Structure and Lake Jocassee Bathymetry - Jocassee Lake Level 1,110 ft msl

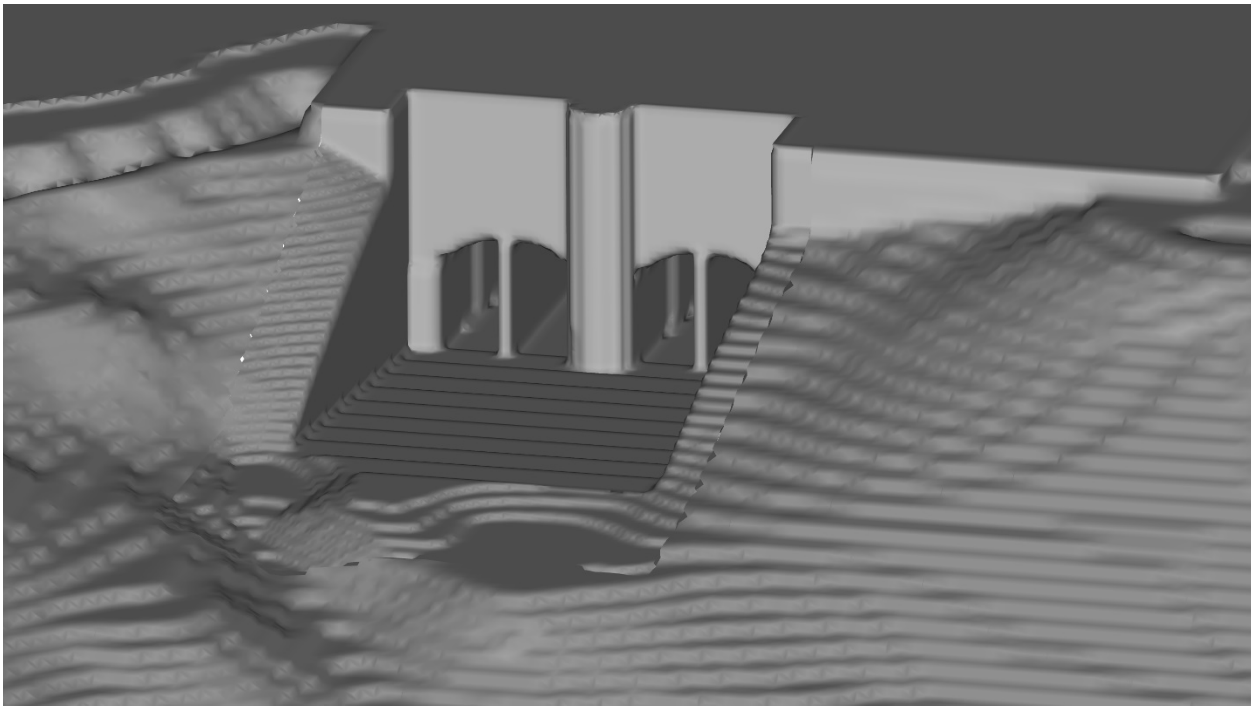

Figure 4. Existing I/O Structure Geometry and Lake Jocassee Bathymetry - detailed rendering of structure

3.2.2 Proposed I/O Structure

The existing geometry and topography were expanded, adding the geometry for the proposed I/O structure to the model. Figure 5 shows the existing and proposed I/O structure and Lake Jocassee bathymetry. Figure 6 and Figure 7 show the bathymetry and the Lake Jocassee reservoir level initial conditions of 1,110 ft and 1,080 ft msl used as initial conditions in the CFD model, respectively. Figure 8 shows a detailed rendering of the proposed I/O structure and bifurcated tunnels.

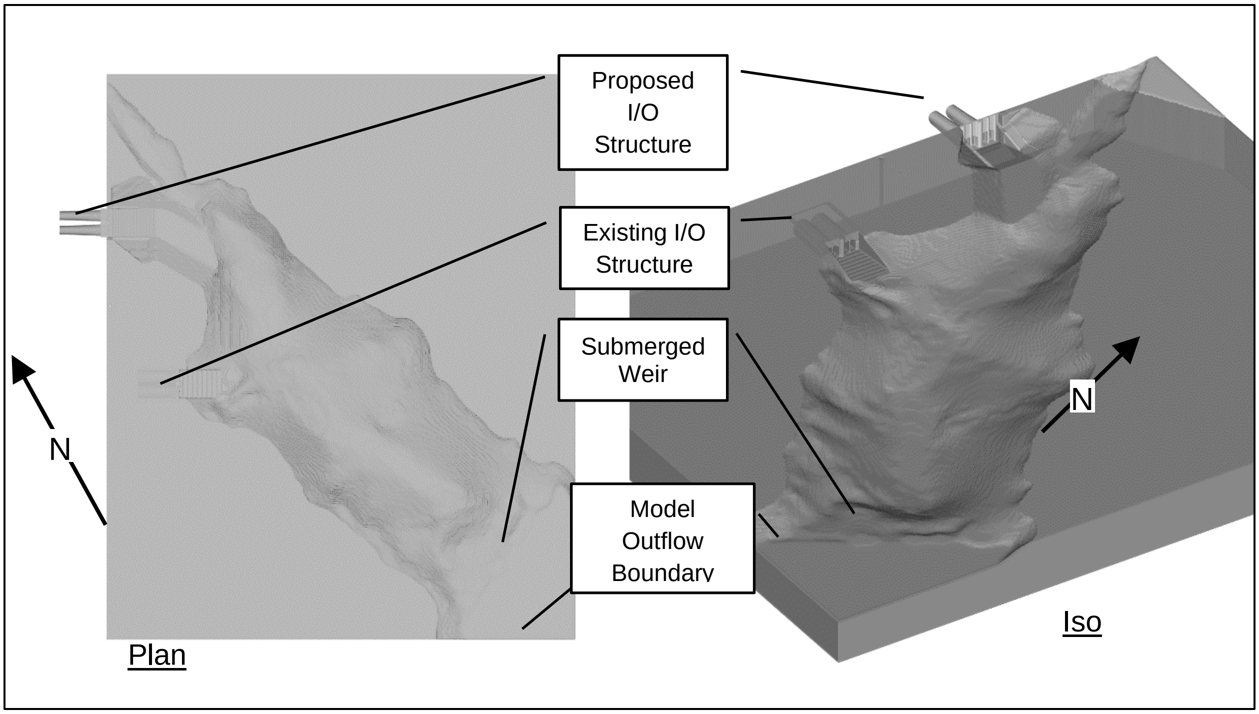

Figure 5. Existing and Proposed I/O Structure and Lake Jocassee Topography

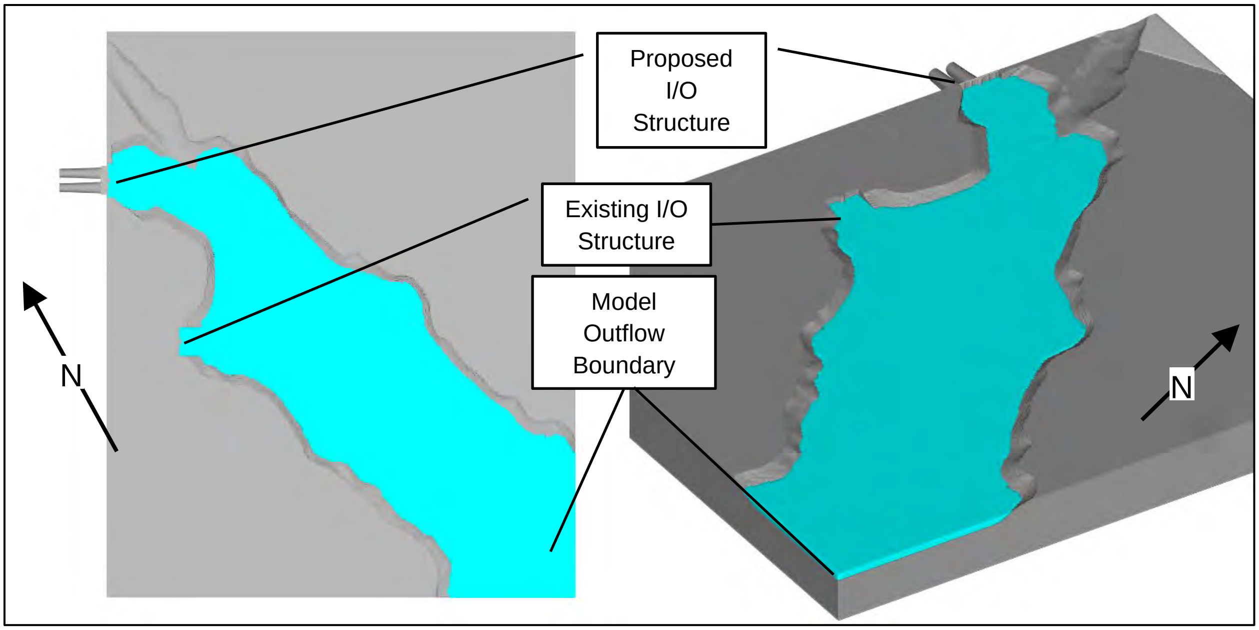

Figure 6. Existing and Proposed I/O and Lake Jocassee Bathymetry - Jocassee Lake Level 1,080 ft msl

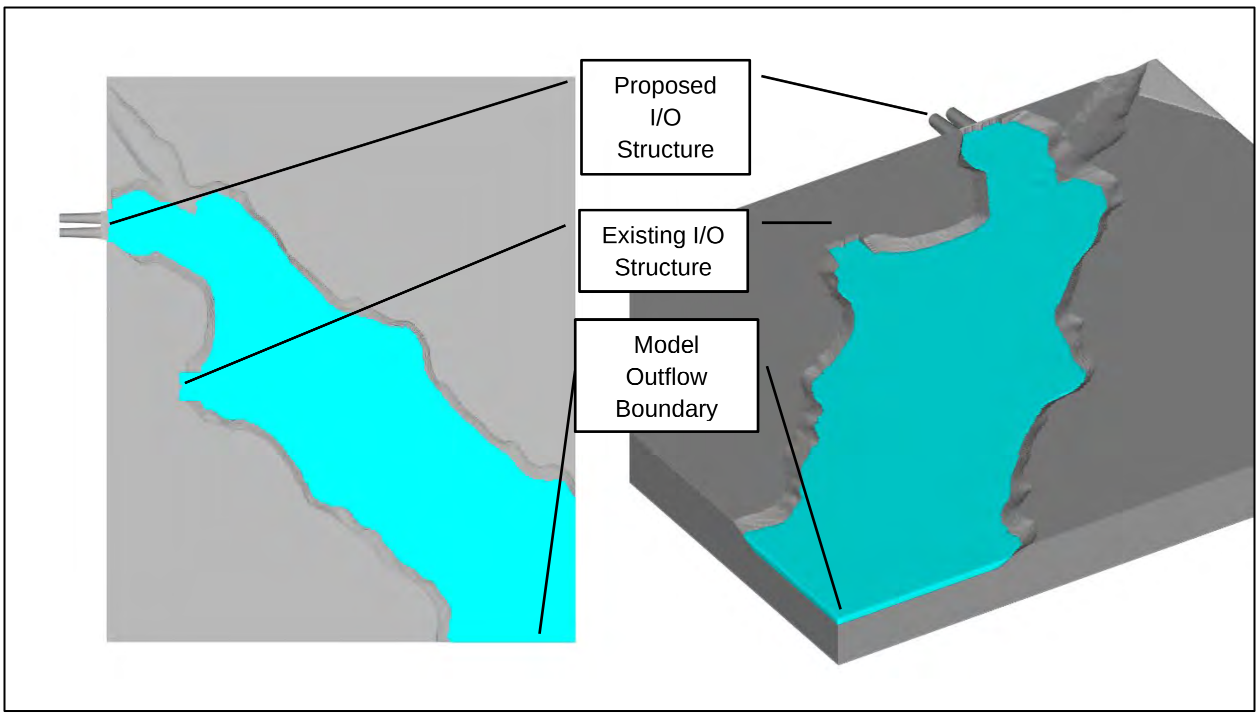

Figure 7. Proposed I/O Structure and Lake Jocassee Bathymetry - Jocassee Lake Level 1,110 ft msl

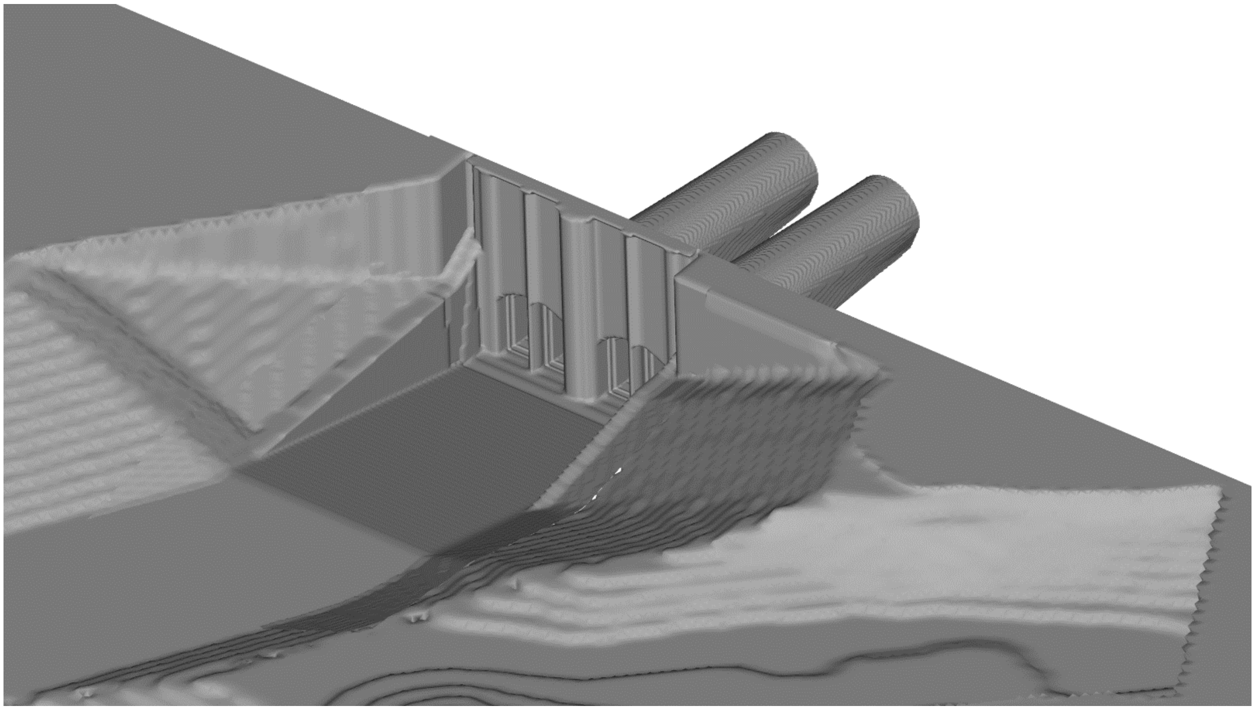

Figure 8. Proposed I/O Structure Geometry and Lake Jocassee Bathymetry – detailed rendering of structure

3.3 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.

3.3.1 Existing Configuration

The computational mesh block used for the existing Bad Creek configuration was 4-ft by 4-ft by 4-ft (length by width by height). The block was modified in the vertical direction +/- 8 ft from the anticipated free surface elevation (i.e., 1,110 ft or 1,080 ft msl) to help resolve the free surface and aid with the computational runtime. Mesh planes were added in the horizontal direction to align the computational mesh with important project features such as the I/O structure.

3.3.2 Proposed Configuration

The computational mesh for the proposed Bad Creek II powerhouse was largely unchanged from the existing configuration. The mesh block remained 4-ft by 4-ft by 4-ft (length by width by height) and contained the vertical modification in the vicinity of the free surface. Additional mesh planes were added to align the mesh with the proposed I/O structure.

3.4 Model Scenarios

3.4.1 Model Scenarios

Model simulations were run until the monitored flow (see Section 3.5 for description of methods used to monitor the model simulations) converged with the target flow; Table 1 lists the model scenarios. Three categories of simulations were performed: generation, pumping, and construction. Cases (i.e., simulations) 1 and 2 are verification of model parameters and performance. Cases 3, 4, and 5 evaluate the hydraulic interactions between the existing and proposed I/O structures in the turbine (or generation) mode. The hydraulic interactions of the existing and proposed I/O structures during pump back were evaluated in Cases 6, 7, and 8. Cases 9 through 12 represent mid construction operations of the existing powerhouse in both the pump and turbine mode after the rock spoil from construction of Bad Creek II has been placed in the reservoir.

Table 1. Simulation Conditions

Simulation	Reservoir WSE (ft msl)	Flow (cfs)	Notes
Case 1 (Turbine Mode)	1,110	Unit 1: 4,000 Unit 2: 4,000 Unit 3: 4,000 Unit 4: 4,000	• Existing I/O structure configuration, Lake Jocassee at normal full reservoir elevation. • Original ARL unit characteristics.
Case 2 (Turbine Mode)	1,080	Unit 1: 4,000 Unit 2: 4,000 Unit 3: 4,000 Unit 4: 4,000	• Existing I/O structure configuration, Lake Jocassee at normal minimum reservoir elevation. • Original ARL unit characteristics

Simulation	Reservoir WSE (ft msl)	Flow (cfs)	Notes
Case 3 (Turbine Mode)	1,110	Unit 1: 4,940 Unit 2: 4,940 Unit 3: 4,940 Unit 4: 4,940 Unit 5: 4,860 Unit 6: 4,860 Unit 7: 4,860 Unit 8: 4,860	• Proposed I/O structure configuration, Lake Jocassee at normal full reservoir elevation during generation. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.
Case 4 (Turbine Mode)	1,080	Unit 1: 4,940 Unit 2: 4,940 Unit 3: 4,940 Unit 4: 4,940 Unit 5: 4,860 Unit 6: 4,860 Unit 7: 4,860 Unit 8: 4,860	• Proposed I/O structure configuration, Lake Jocassee at normal minimum reservoir elevation during generation. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.
Case 5 (Turbine Mode)	1,096	Unit 1: 4,940 Unit 2: 4,940 Unit 3: 4,940 Unit 4: 4,940 Unit 5: 4,860 Unit 6: 4,860 Unit 7: 4,860 Unit 8: 4,860	• Proposed I/O structure configuration, Lake Jocassee at assumed intermediate reservoir elevation during generation. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.
Case 6 (Pump Mode)	1,110	Unit 1: 4,060 Unit 2: 4,060 Unit 3: 4,060 Unit 4: 4,060 Unit 5: 4,120 Unit 6: 4,120 Unit 7: 4,120 Unit 8: 4,120	• Proposed I/O structure configuration, Lake Jocassee at normal maximum reservoir elevation during pumping. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.
Case 7 (Pump Mode)	1,080	Unit 1: 4,060 Unit 2: 4,060 Unit 3: 4,060 Unit 4: 4,060 Unit 5: 4,120 Unit 6: 4,120 Unit 7: 4,120 Unit 8: 4,120	• Proposed I/O structure configuration, Lake Jocassee at normal minimum reservoir elevation during pumping. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.
Case 8 (Pump Mode)	1,096	Unit 1: 4,060 Unit 2: 4,060 Unit 3: 4,060 Unit 4: 4,060 Unit 5: 4,120 Unit 6: 4,120 Unit 7: 4,120 Unit 8: 4,120	• Proposed I/O structure configuration, Lake Jocassee at assumed intermediate reservoir elevation during pumping. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.
Case 9 (Turbine Mode)	1,110	Unit 1: 4,940 Unit 2: 4,940 Unit 3: 4,940 Unit 4: 4,940 Unit 5: 0 Unit 6: 0 Unit 7: 0 Unit 8: 0	• Proposed I/O structure configuration, Lake Jocassee at normal full reservoir elevation during generation. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.

Simulation	Reservoir WSE (ft msl)	Flow (cfs)	Notes
Case 10 (Turbine Mode)	1,080	Unit 1: 4,940 Unit 2: 4,940 Unit 3: 4,940 Unit 4: 4,940 Unit 5: 0 Unit 6: 0 Unit 7: 0 Unit 8: 0	• Proposed I/O structure configuration, Lake Jocassee at normal minimum reservoir elevation during generation. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.
Case 11 Pump Mode)	1,110	Unit 1: 4,060 Unit 2: 4,060 Unit 3: 4,060 Unit 4: 4,060 Unit 5: 0 Unit 6: 0 Unit 7: 0 Unit 8: 0	• Proposed I/O structure configuration, Lake Jocassee at normal minimum reservoir elevation during pumping. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.
Case 12 (Pump Mode)	1,080	Unit 1: 4,060 Unit 2: 4,060 Unit 3: 4,060 Unit 4: 4,060 Unit 5: 0 Unit 6: 0 Unit 7: 0 Unit 8: 0	• Proposed I/O structure configuration, Lake Jocassee at normal minimum reservoir elevation during pumping. • Units 1-4 belong to the existing I/O structure and 5-8 belong to the proposed I/O structure. • Units 1-4 reflect upgraded unit characteristics.

Note: cfs = cubic feet per second

3.4.2 Boundary Conditions

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

MASS-MOMENTUM SOURCES

Mass-momentum sources were used to define the I/O structure discharge tunnels. The source allows flow to be added or removed from the model domain.

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 normal full and normal minimum Lake Jocassee levels, respectively.

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.

3.5 Model Evaluation

Analysis of completed model runs focused on the flow patterns and velocities. 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.

3.5.1 Flux Surfaces

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

3.5.2 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 determine if the model reached a reportable solution.

3.6 Evaluation Criteria

The three categories (generation, pumping, and construction) of simulation were evaluated using several different criteria. The details of the evaluation are listed below.

3.6.1 Model Verification Criteria

The CFD model assumptions and performance were compared against previous physical model results. The exact location and orientation of the physical model data were not explicitly detailed in the documentation (Larsen and White 1986), so a qualitative analysis was performed to verify the model could replicate the general flow patterns and velocity magnitude of the physical model study.

3.6.2 Generation Scenario Criteria

The focus of the generation simulations was the hydraulic impact along the east bank of Lake Jocassee. A specific velocity threshold or criteria was not established for potential bank erosion or recreational flows in the Whitewater River cove. The east bank velocities were compared to the verification simulations and existing site knowledge to determine potential hydraulic impacts.

3.6.3 Pumping Scenario Criteria

The flow patterns and velocities in the Whitewater River cove and near the proposed I/O structure were qualitatively evaluated. The velocity magnitude north of the submerged weir was identified as a potential concern and maximum values were reported in this area. The hydraulic approach conditions for the proposed I/O structure were analyzed for hydraulic efficiency and distribution of approaching flow.

3.6.4 Construction Scenarios Criteria

The flow patterns and velocities in the Whitewater River cove and near the expanded weir structure were qualitatively evaluated. The velocity magnitude north of the submerged weir was identified as a potential concern and maximum values were reported in this area. The hydraulic approach conditions for the existing I/O structure were analyzed for hydraulic efficiency and distribution of approaching flow. Simulations for only the proposed structure were not performed as the initial hydraulics did not indicate the hydraulics Lake Jocassee would not produce hydraulic variables in excess of previously simulated flows.

4 Results

The hydraulics for both the existing and proposed I/O structures were simulated to target outflow convergence to establish flow and velocity patterns for the Whitewater River cove channel and east bank velocity analysis.

4.1 Existing Bad Creek Configuration and Model Verification - Cases 1 & 2

The CFD model was verified against the ARL physical model (Larsen and White 1986) using Cases 1 and 2 (see Table 3-1). Flow patterns and bank line velocities were described by the physical model. Figure 9 through Figure 12 shows the comparison between CFD model and physical model flow patterns and east bank velocities for the reservoir at the normal full pool (i.e., 1,110 ft msl) and normal minimum (i.e., 1,080 ft msl) reservoir levels at Lake Jocassee, respectively. The model showed a reasonable comparison to the physical modeled data. While the existing I/O structure outflow predicted by the physical model is higher than that predicted by the CFD model resulting in more recirculation (which in turn has a more pronounced effect on the flow pattern), the overall flow patterns predicted by the physical model, including major patterns of recirculation and velocity magnitudes, are captured in the CFD model. This was noted in both the normal minimum and normal full Lake Jocassee elevation scenarios.

East bank velocities along the I/O structure centerline predicted by the physical model range between about 0.5 feet per second (fps) and 2.25 fps at reservoir level 1,110 ft msl. At the minimum normal reservoir elevation of 1,080 ft msl, the velocities are slightly lower ranging from 0.5 fps to 1.3 fps. As shown on Figure 10 and Figure 12, similar bank velocities were also captured by the CFD model. For the purposes of this study, it is assumed the velocities measured in the ARL physical model are representative of the existing east bank conditions. The point velocities shown in the physical model results were reproduced by the flow simulated in the CFD model. To HDR's knowledge, flows from the existing structure have not caused erosion along the east bank.

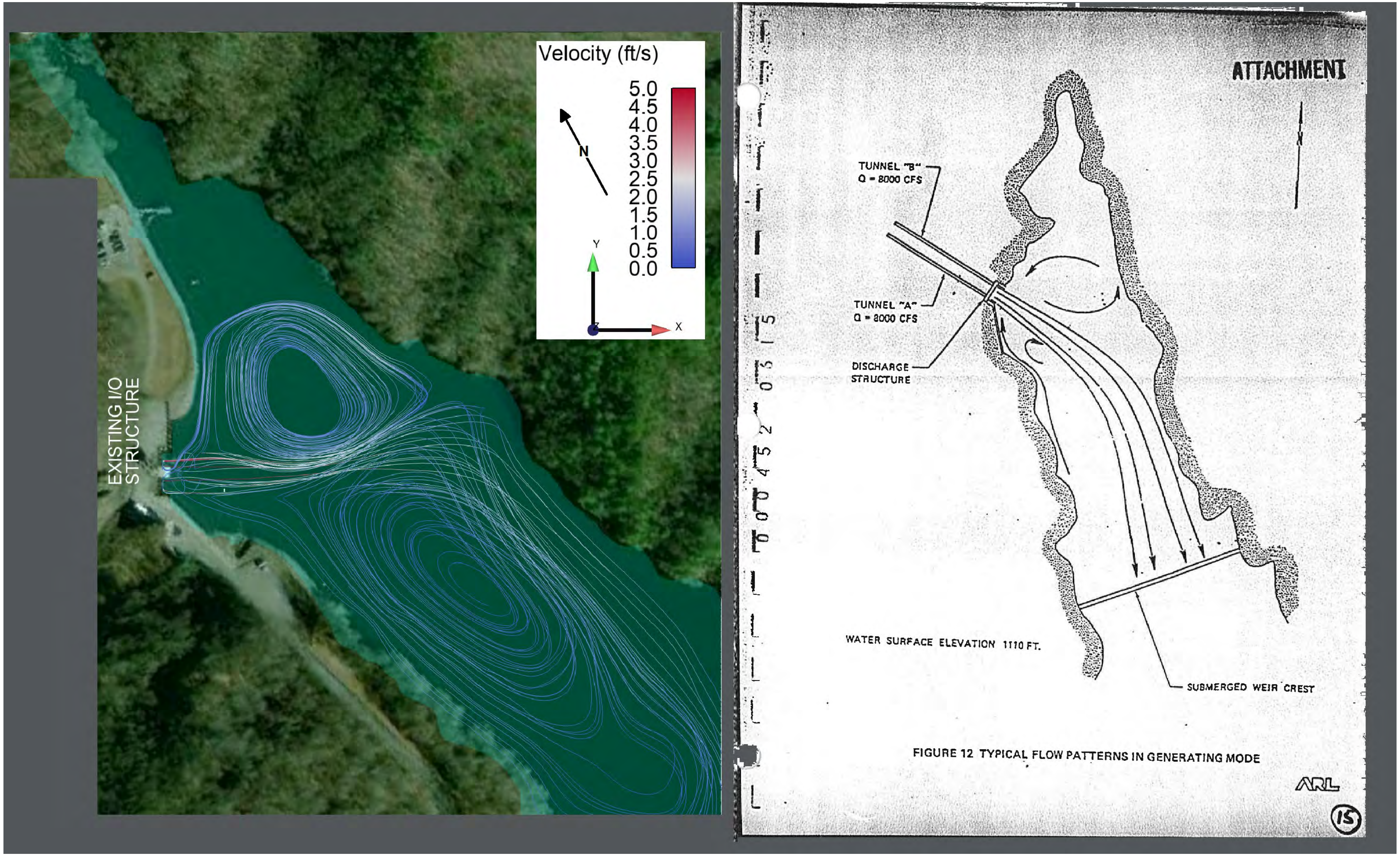

Figure 9. General Flow Pattern Comparison - CFD Model Case 1 Results vs ARL Physical Model Results - Lake Jocassee Normal Full Reservoir: 1,110 ft msl

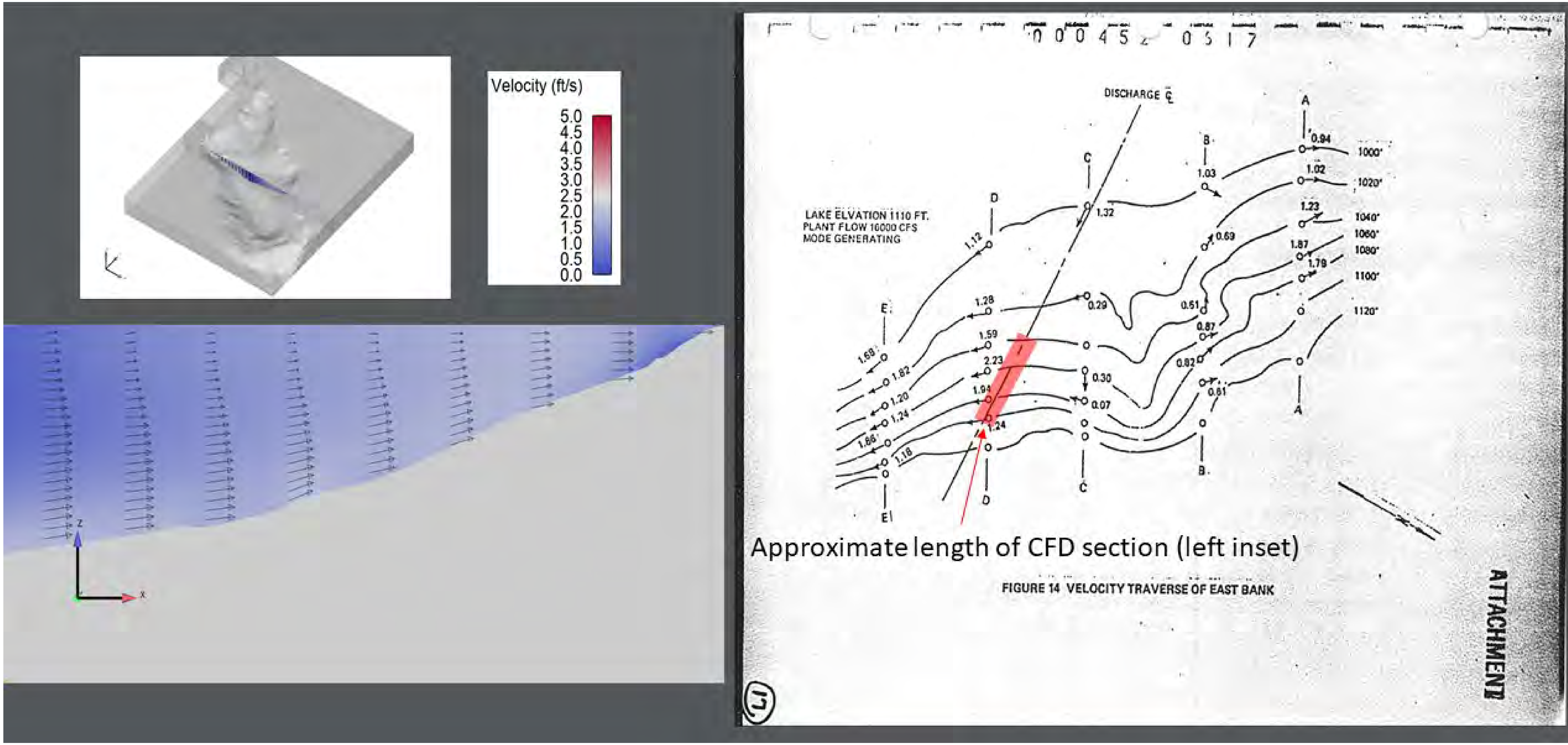

Figure 10. East Bank Velocity and Flow Pattern Comparison - CFD Model Case 1 Results vs ARL Physical Model Results - Lake Jocassee Normal Full Reservoir: 1,110 ft msl

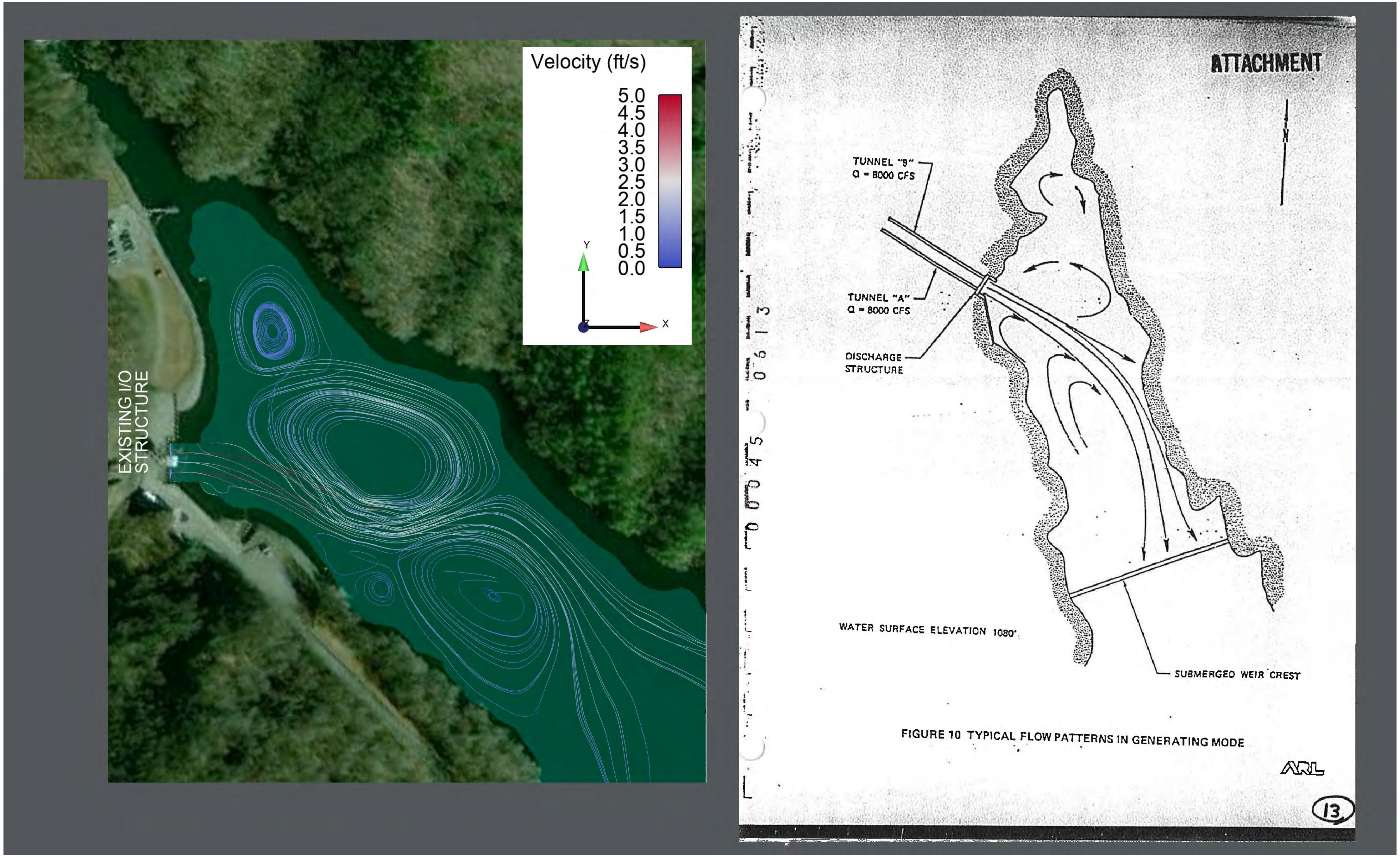

Figure 11. General Flow Pattern Comparison - CFD Model Case 2 Results vs ARL Physical Model Results - Lake Jocassee Normal Minimum Reservoir: 1,080 ft msl

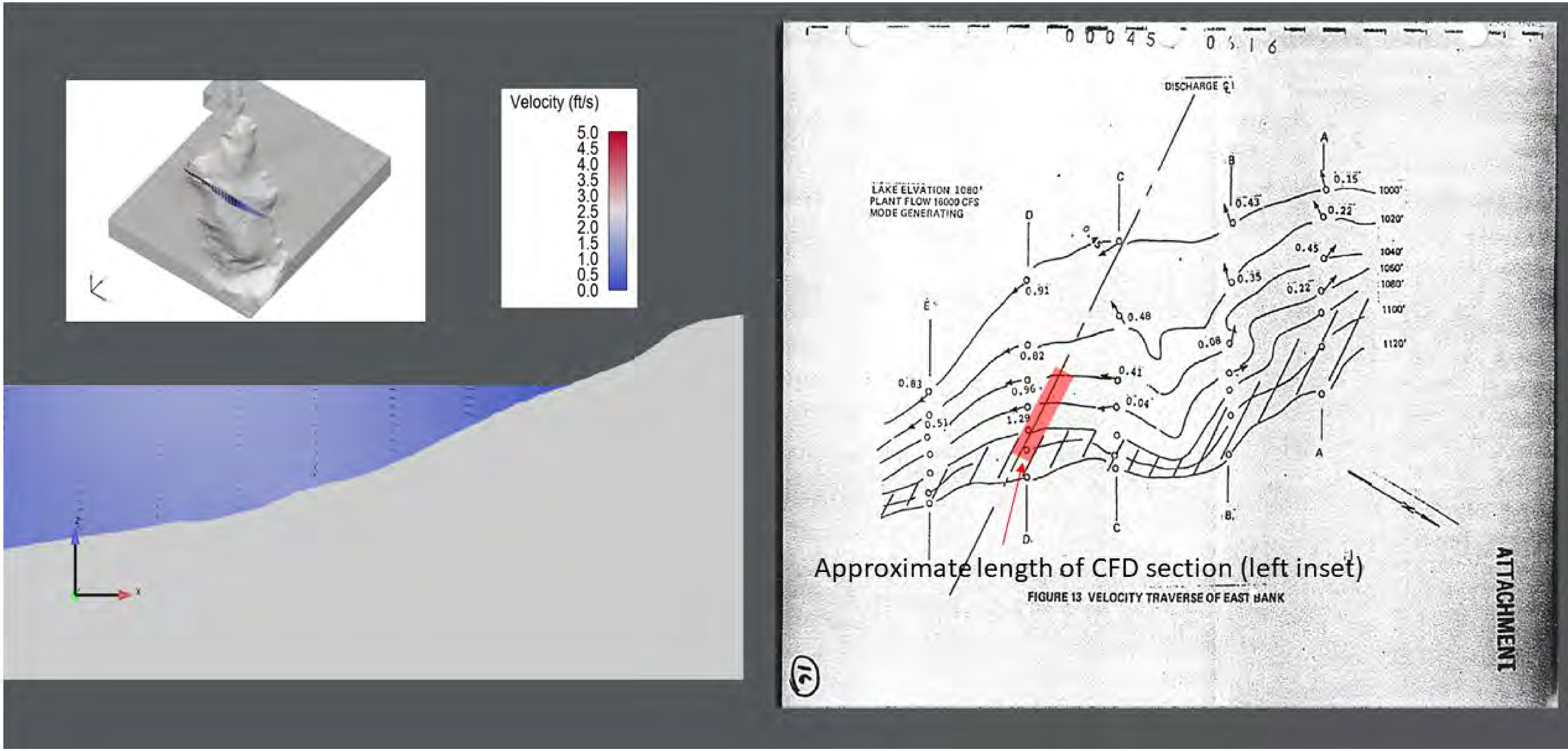

Figure 12. East Bank Velocity and Flow Pattern Comparison - CFD Model Case 2 Results vs ARL Physical Model Results - Lake Jocassee Normal Minimum Reservoir: 1,080 ft msl

4.2 Proposed Configuration - Cases 3 through 5 (Turbine Mode)

After model verification (see Section 4.1), the proposed Bad Creek II I/O structure configuration was modeled for both reservoir elevations and assuming full generation at both I/O structures (combined 39,200 cubic feet per second [cfs]) to determine impacts to the channel and east bank of the Lake Jocassee Whitewater River cove. Turbine flows for the uprated Bad Creek units were used in these scenarios.

4.2.1 Case 3: Lake Jocassee Normal Full Reservoir Elevation 1,110 ft msl

Results of the proposed configuration at normal full reservoir elevation are presented on Figure 13 through Figure 21. Figure 13 shows the plan view of the streamlines at normal full pool elevation. Flow from the proposed I/O structure forces flow from the existing I/O structure to the center of the reservoir, lowering the velocities along the east bank.

Figure 14 through Figure 17 show slices of the velocity vectors at four elevations within the water column: 1,040 ft msl, 1,050 ft msl, 1,080 ft msl, and at the surface (i.e., 1,110 ft msl). The flow patterns at each depth are relatively similar throughout the water column. The water velocities within the concentrated flows from the I/O structures increase with depth.

The effect of adding the proposed I/O structure to the model is distinct; the area of high velocity along the east bank moved approximately 600 ft to the north and velocity peaks at approximately 2.5 fps. Recirculation patterns were reduced in size as the velocity flow from the proposed I/O structure forced more of the flow to the center of the channel. The peak magnitude of the velocity along the east bank was approximately equal to the velocities measured in the ARL physical model. The change in location of the peak velocities should not affect bank conditions/erosion assuming the geology of the east bank is consistent upstream (i.e., north) of the existing structure (i.e., predominantly bedrock).

Figure 18 through Figure 21 show model slices of velocity vectors and magnitudes through the two existing and two proposed I/O structure tunnels centerlines, respectively (note that these figures represent a cross-sectional view across the Whitewater River channel (i.e., a view from west to east looking downstream from the I/O structure). These slices show peak velocities on the east bank below 2.5 fps along tunnel centerlines.

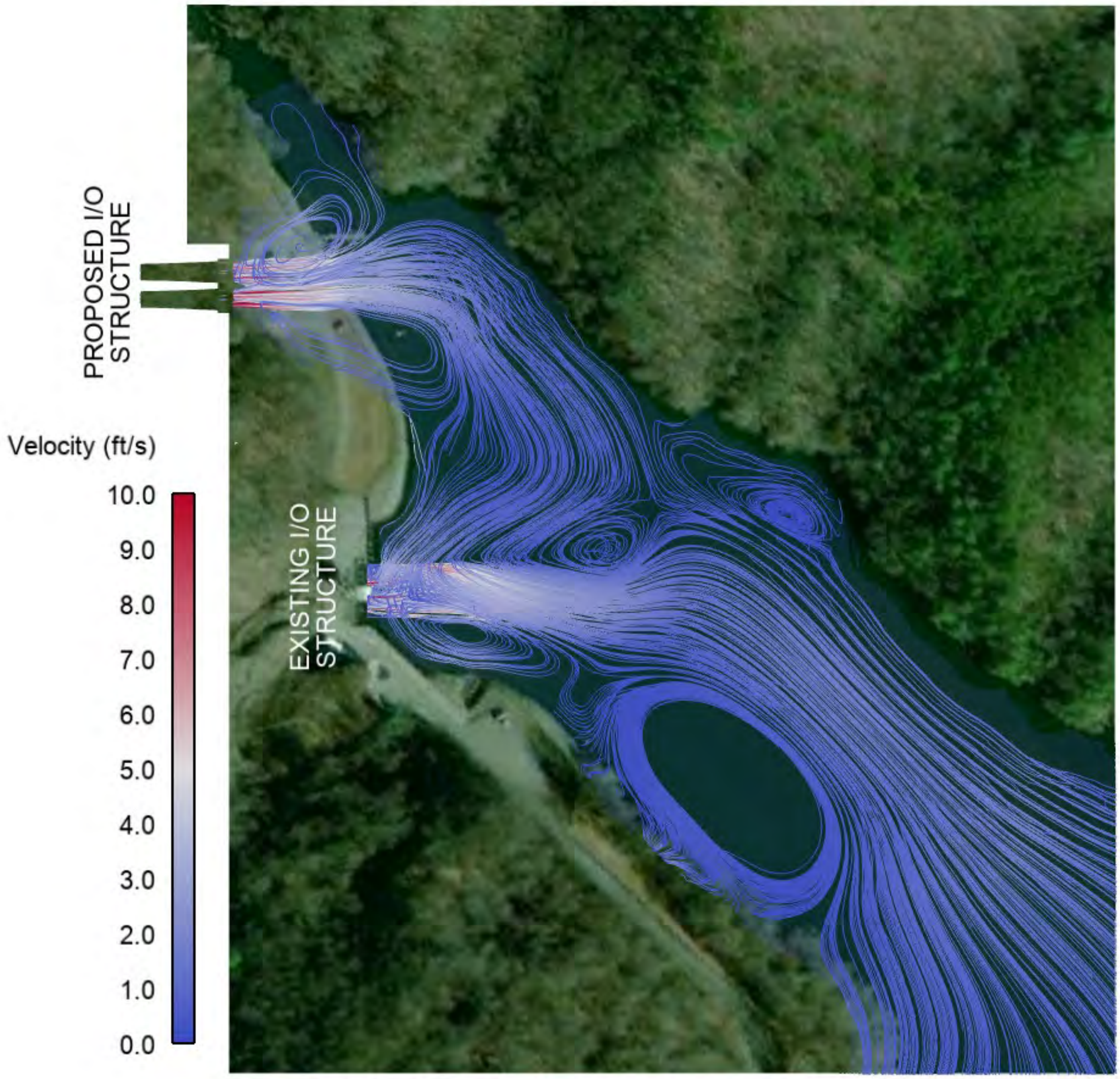

Figure 13. Case 3 (generation - maximum reservoir elevation) Velocity Streamlines at Normal Full Pool Elevation

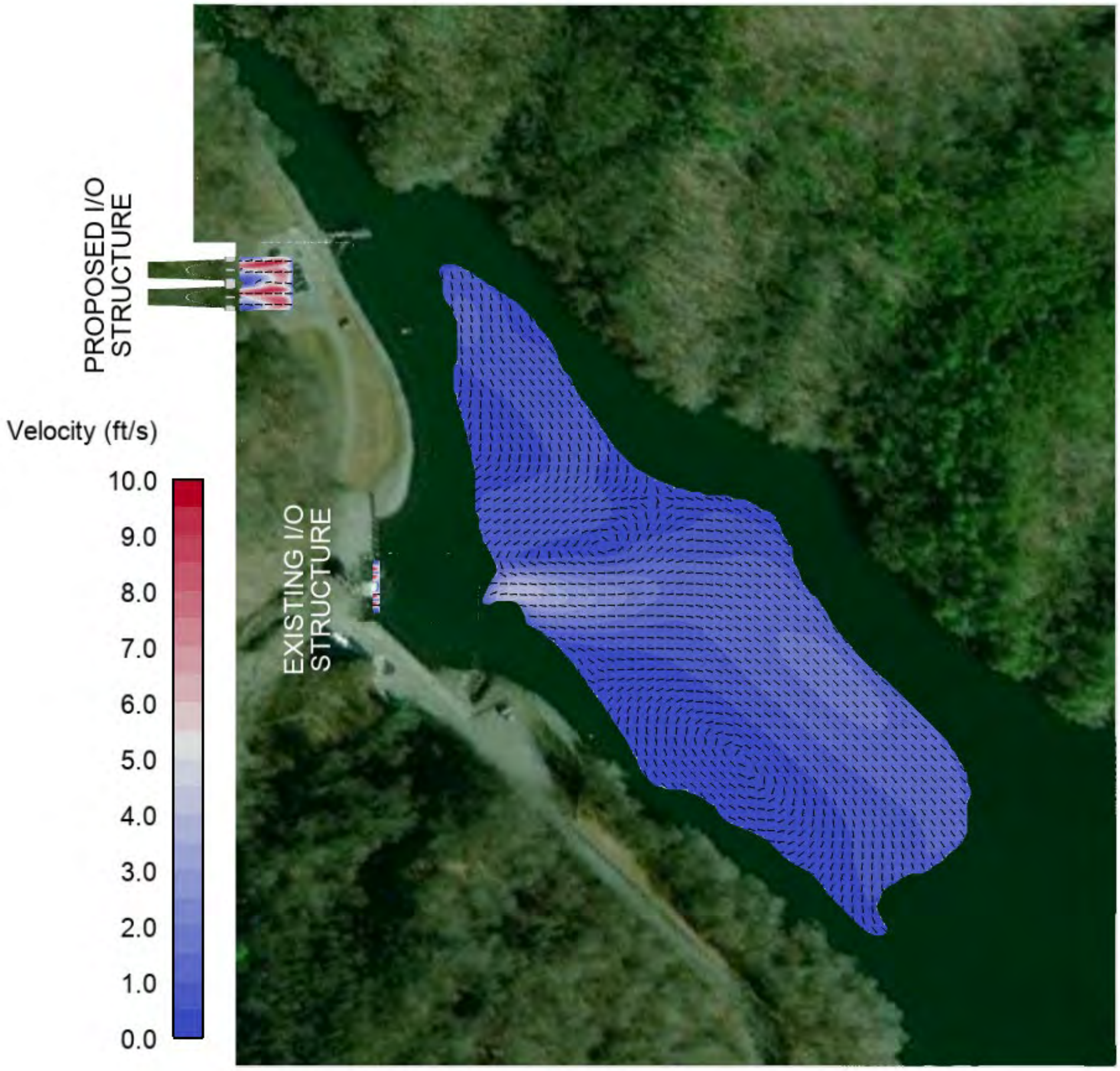

Figure 14. Case 3 (generation - maximum reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

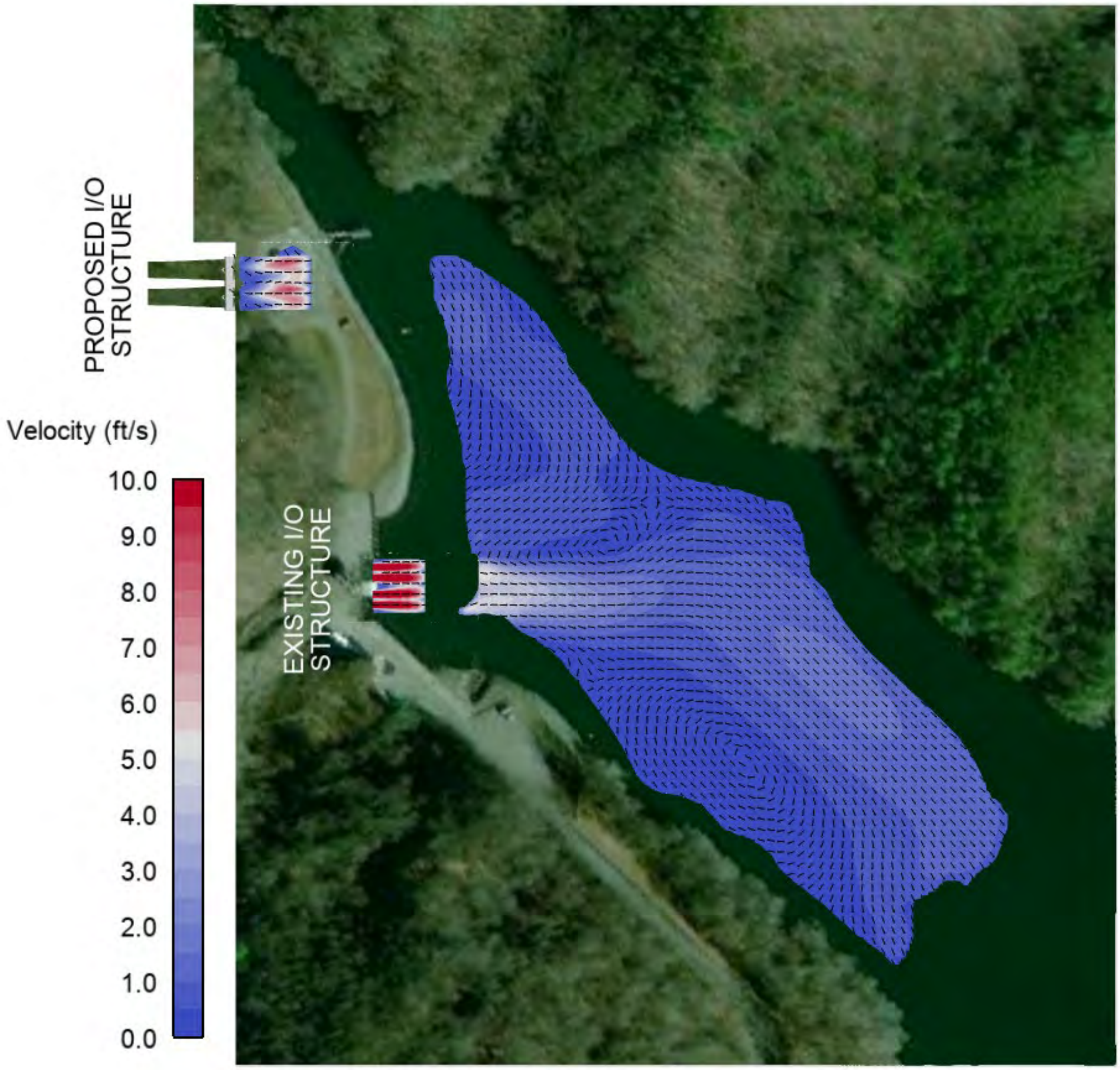

Figure 15. Case 3 (generation - maximum reservoir elevation) Velocity Vectors at Elevation 1,050 ft

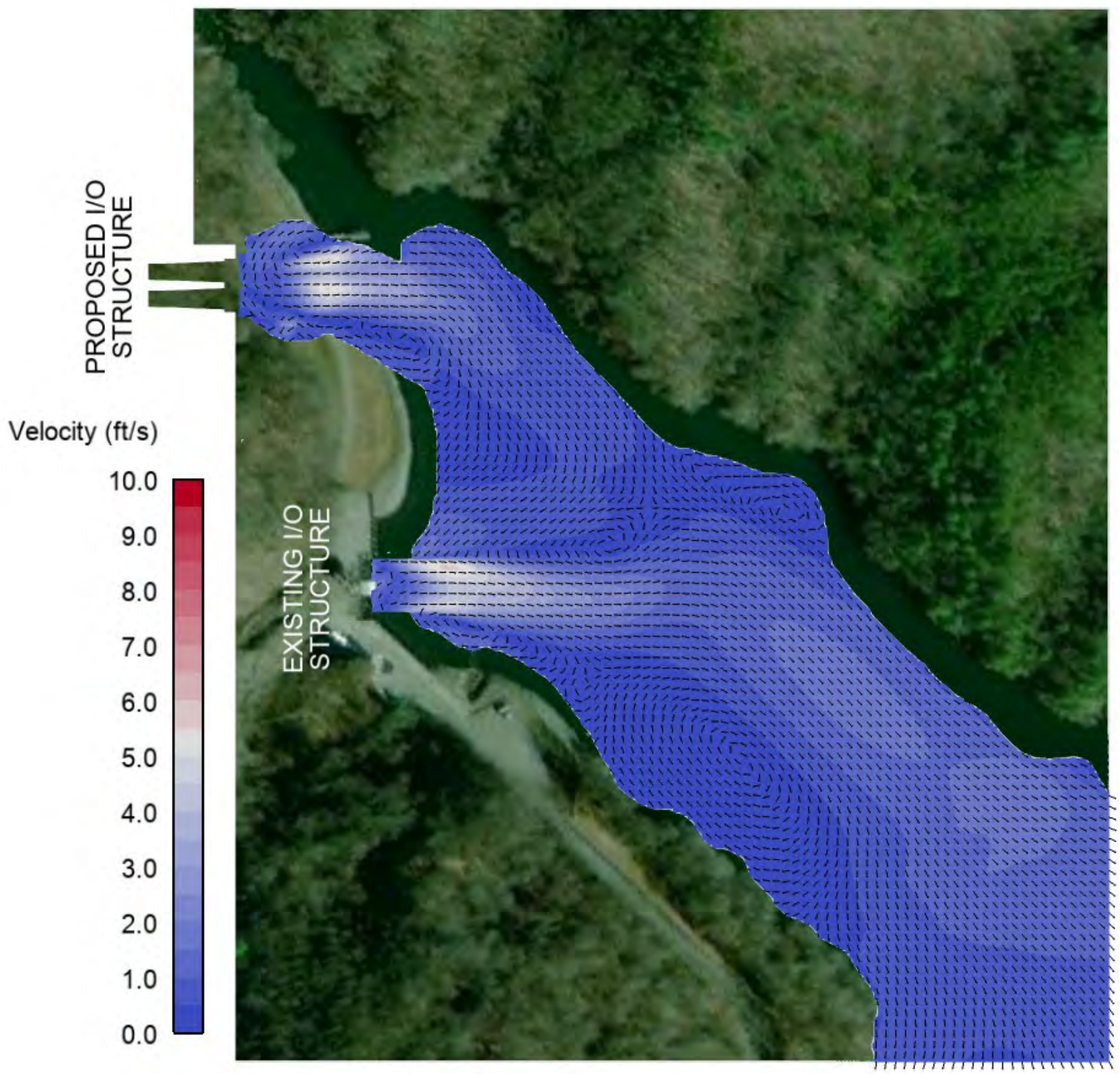

Figure 16. Case 3 (generation - maximum reservoir elevation) Velocity Vectors at Elevation 1,080 ft

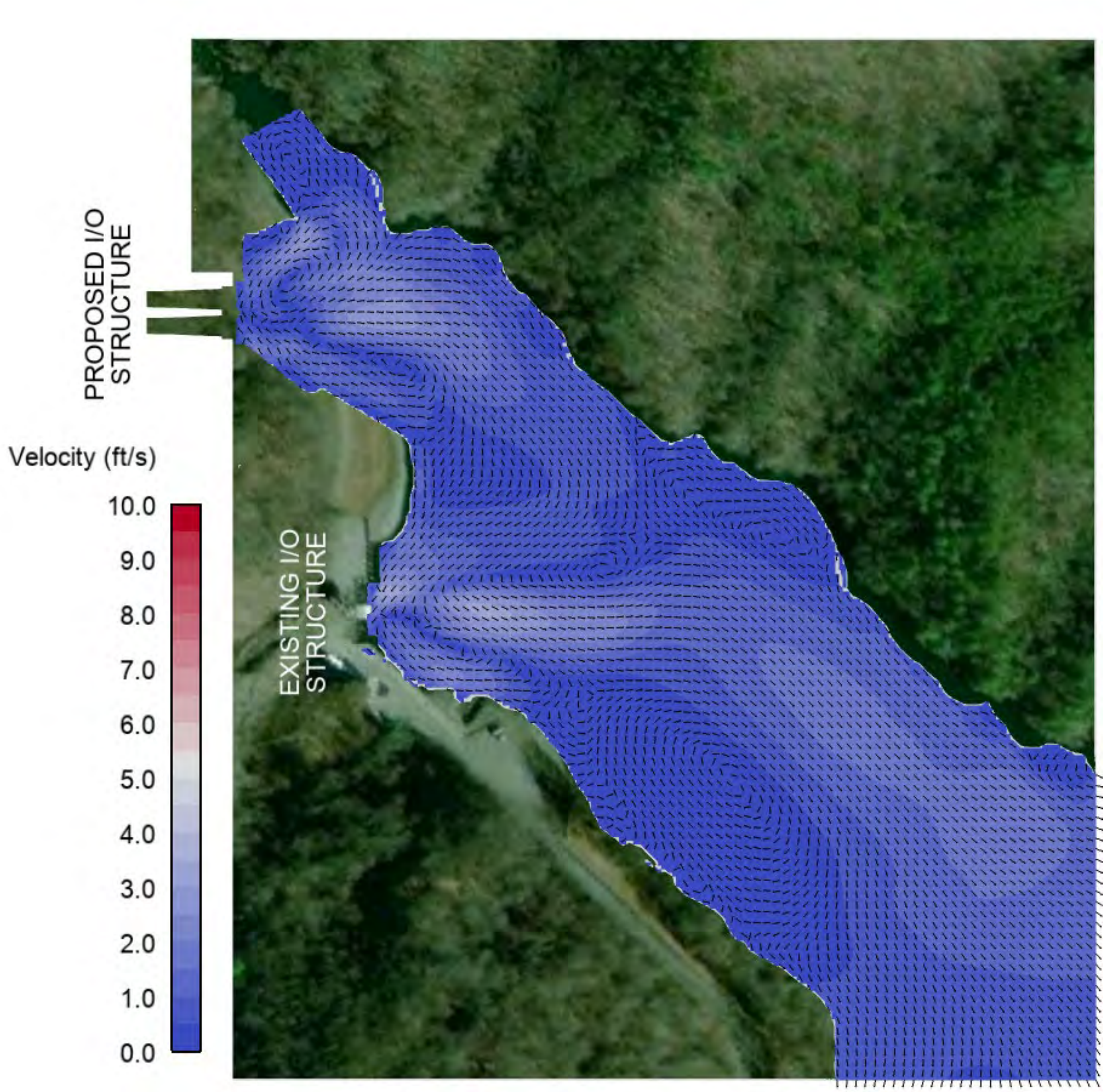

Figure 17. Case 3 (generation - maximum reservoir elevation) Velocity Vectors at Elevation 1,110 ft msl

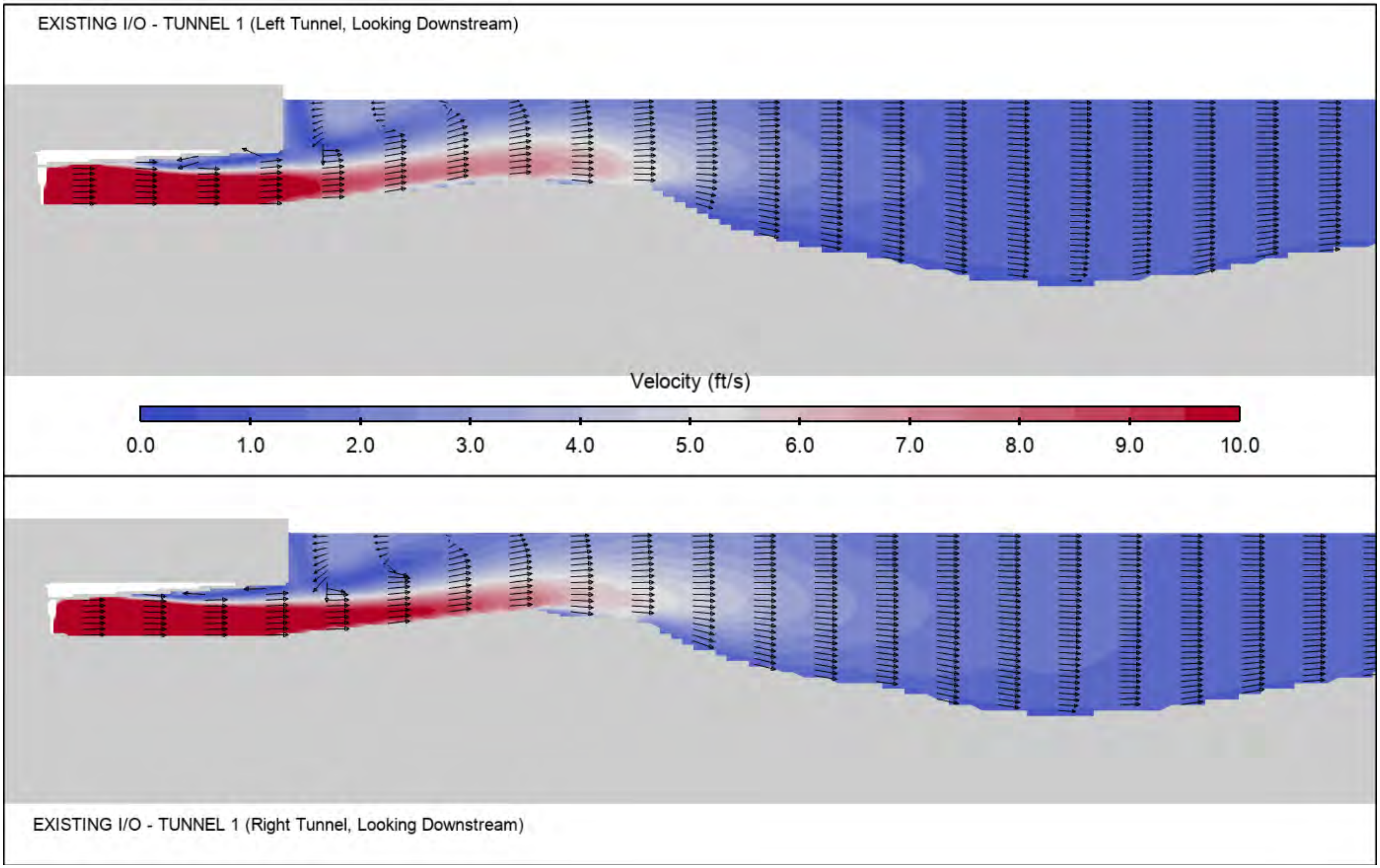

Figure 18. Case 3 (generation - maximum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

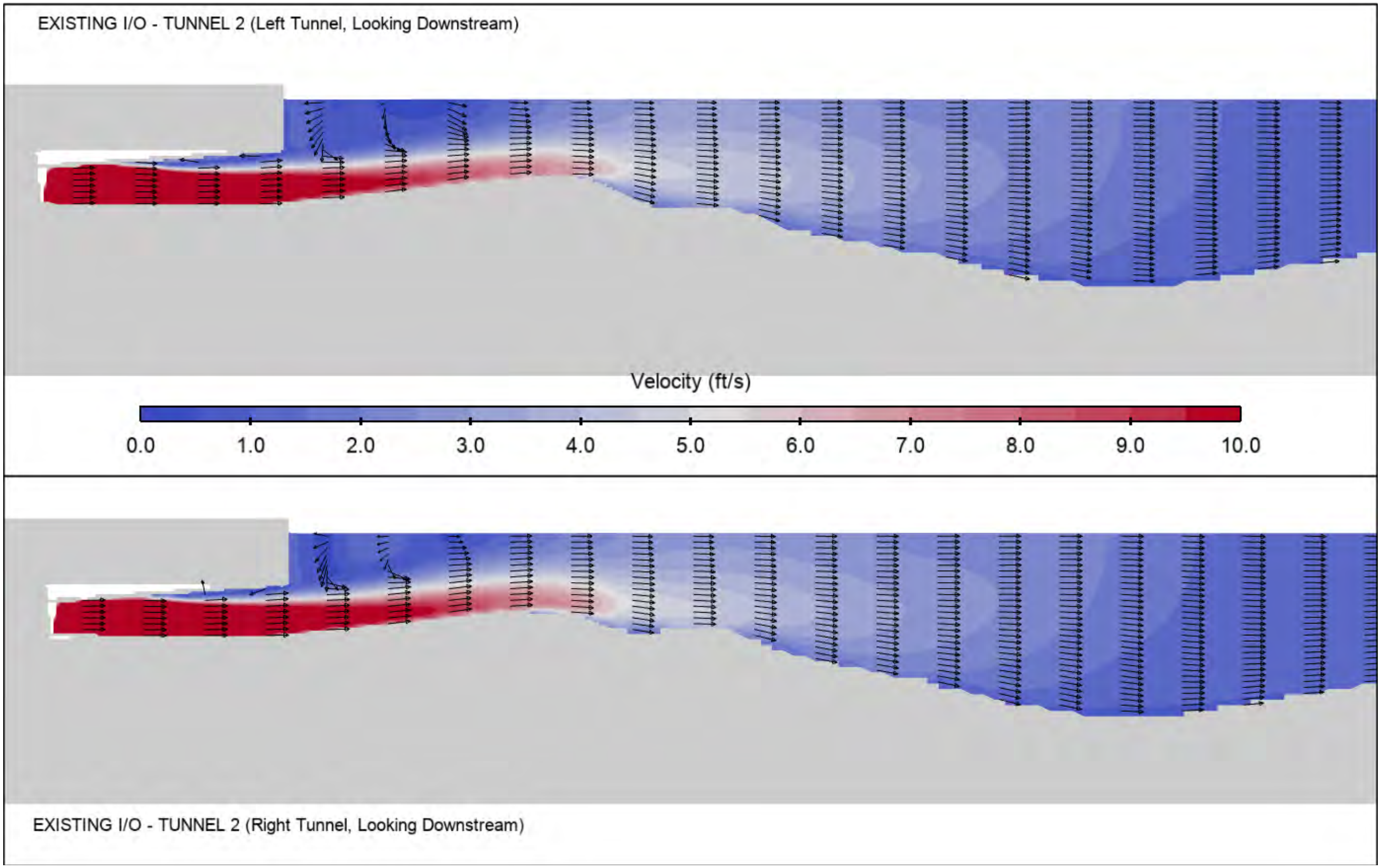

Figure 19. Case 3 (generation - maximum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

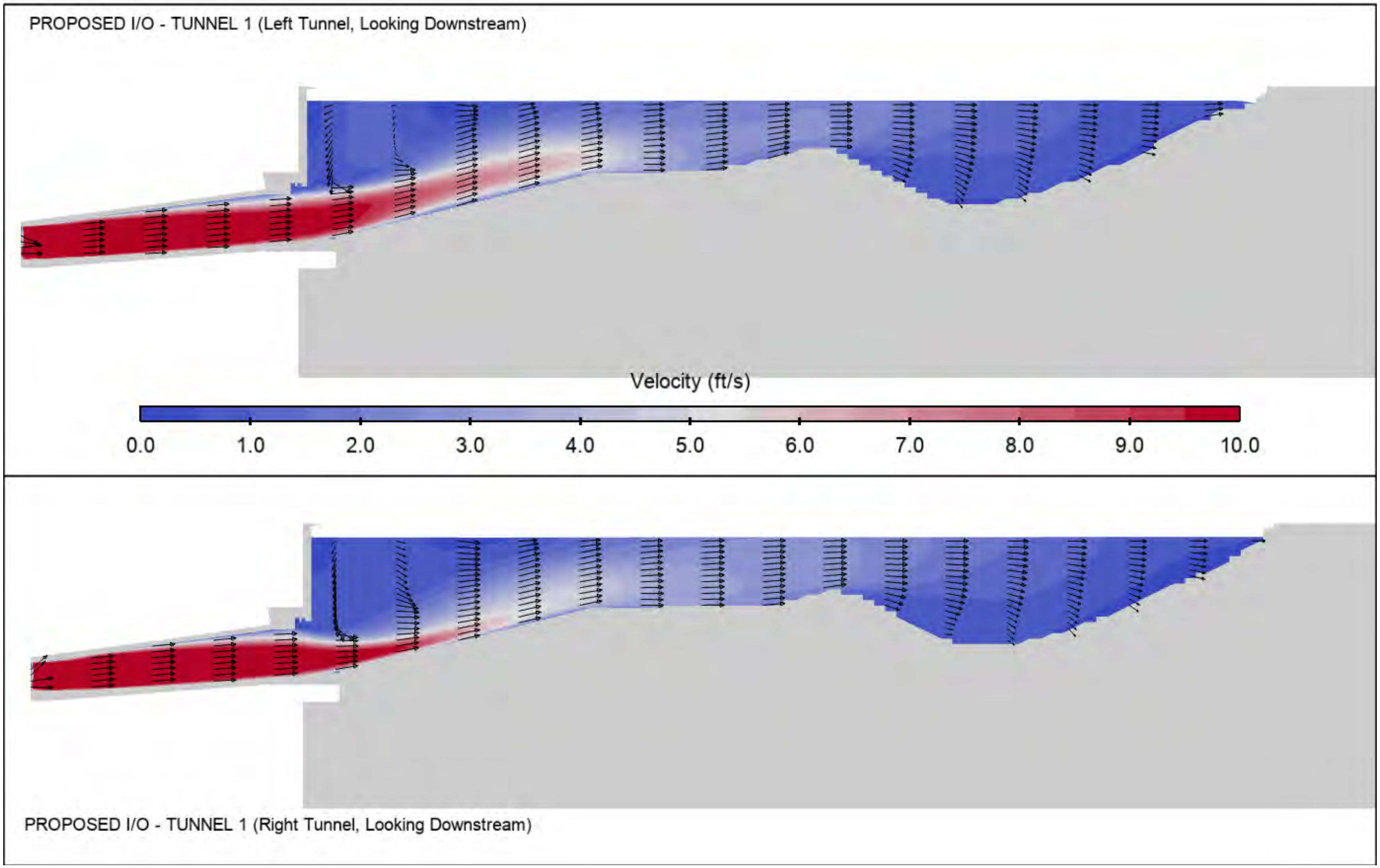

Figure 20. Case 3 (generation - maximum reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

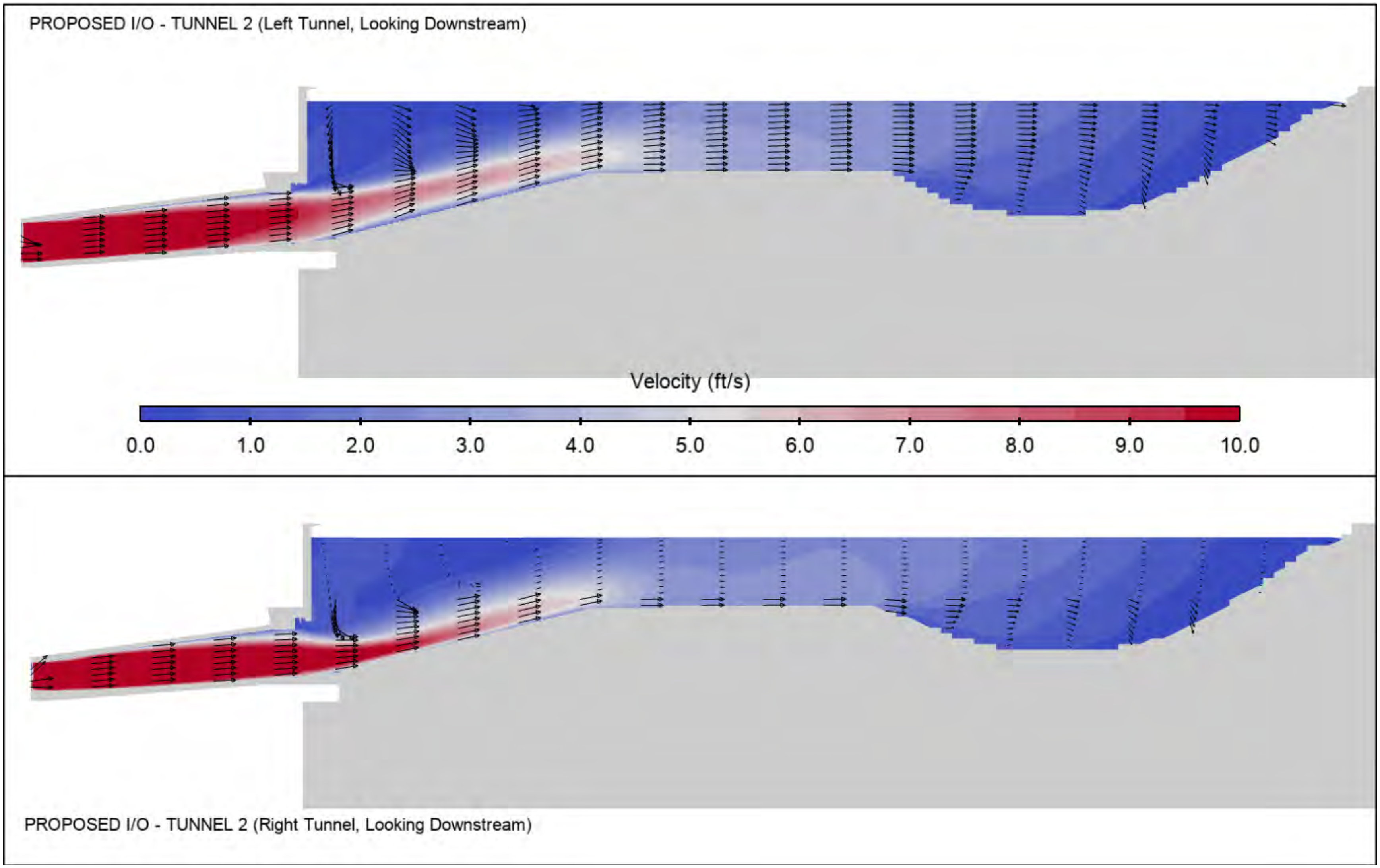

Figure 21. Case 3 (generation - maximum reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

4.2.2 Case 4: Lake Jocassee Normal Minimum Reservoir Elevation 1,080 ft msl

Figure 22 shows the plan view of streamlines from the normal minimum reservoir elevation scenario (Case 4). Flow patterns are similar to the full reservoir configuration, with increased velocities throughout, which would be expected.

Figure 23 through Figure 25 shows velocity vector slices at elevations 1,040 ft, 1,050 ft, and at the surface (1,080 ft), respectively. The lower Lake Jocassee level increases the effect of the concentrated flow from the I/O structures. Surface velocities exceed 5.0 fps, while flow along the east bank peaks at approximately 3.5 fps in the same location as Case 3 (existing I/O centerline). East bank velocities within the water column reach 5.0 fps approximately 500 ft upstream (i.e., north) of the existing I/O structure centerline. Surface velocities along the entire east bank peak at approximately 3.5 fps. The peak magnitude of the velocity along the east bank was approximately equal to the velocities measured in the ARL physical model. The change in location of the peak velocities should not affect bank conditions/erosion assuming the geology of the east bank is consistent upstream (i.e., north) of the existing structure (i.e., predominantly bedrock).

Figure 26 and Figure 29 show slices of velocity vectors and magnitudes through the two existing and two proposed I/O structure tunnels' centerlines, respectively. As in Case 3, these slices show velocities on the east bank below 2.5 fps along tunnel centerlines.

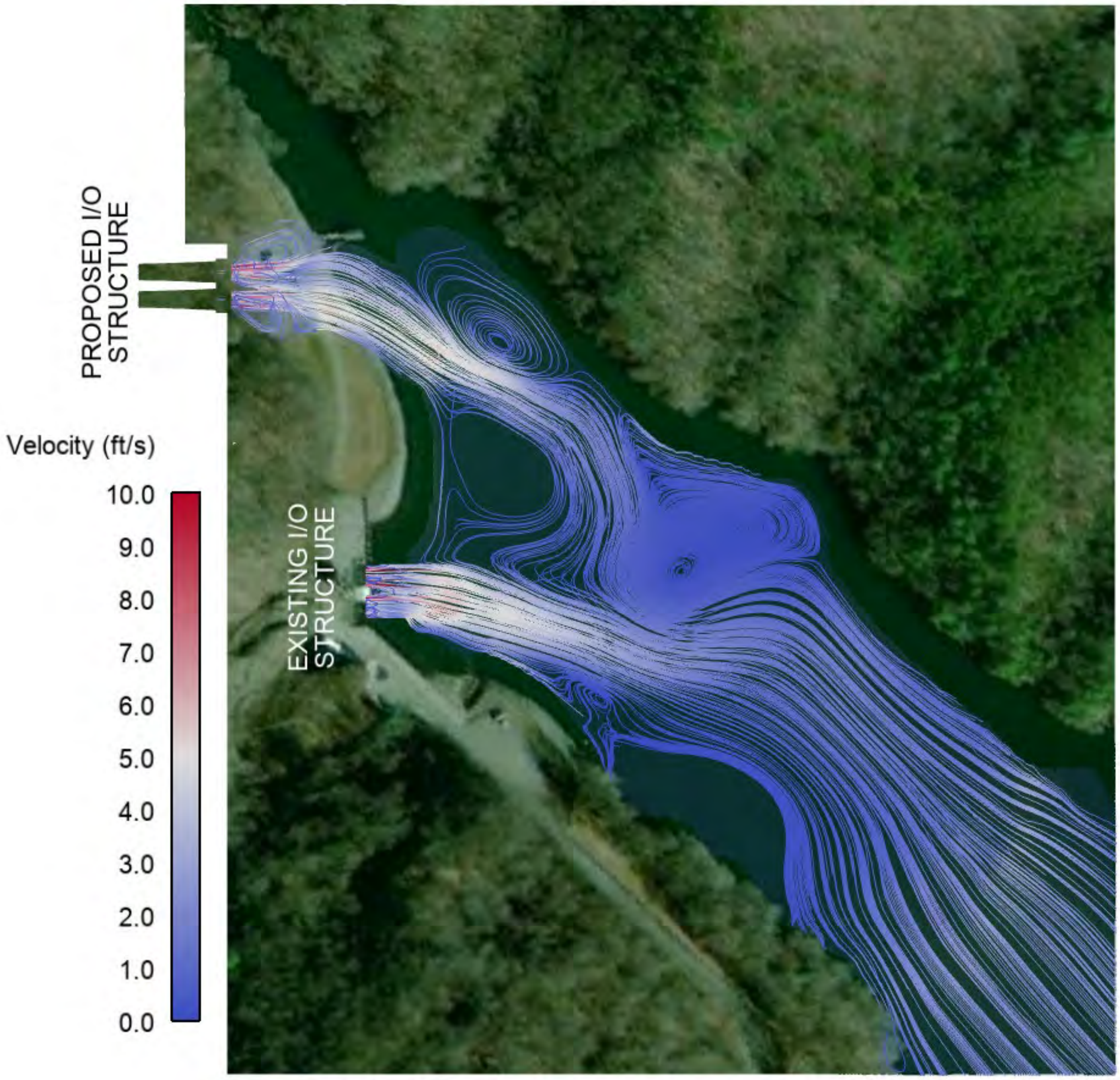

Figure 22. Case 4 (generation - minimum reservoir elevation) Velocity Streamlines under Normal Minimum Reservoir Elevation

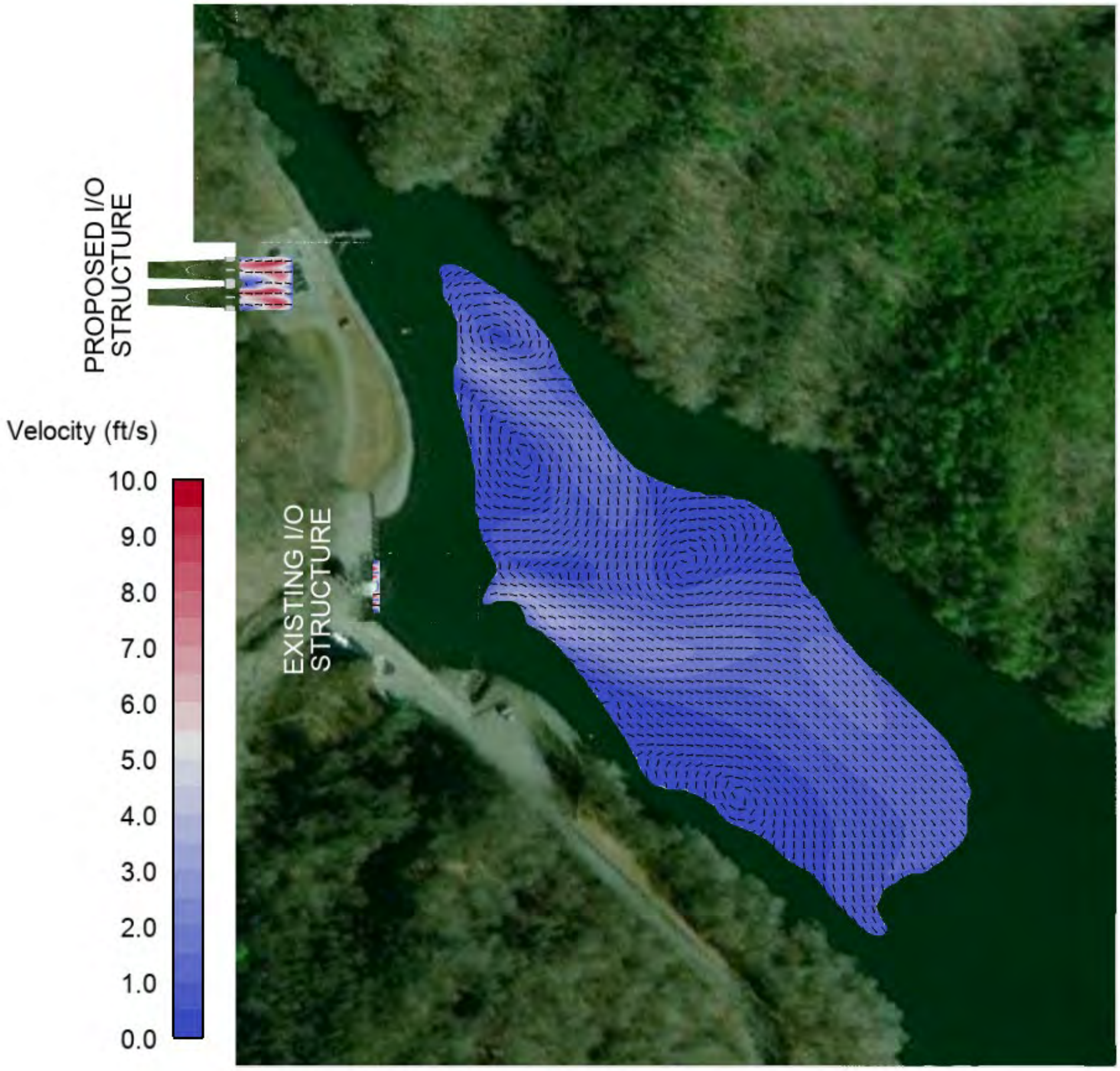

Figure 23. Case 4 (generation - minimum reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

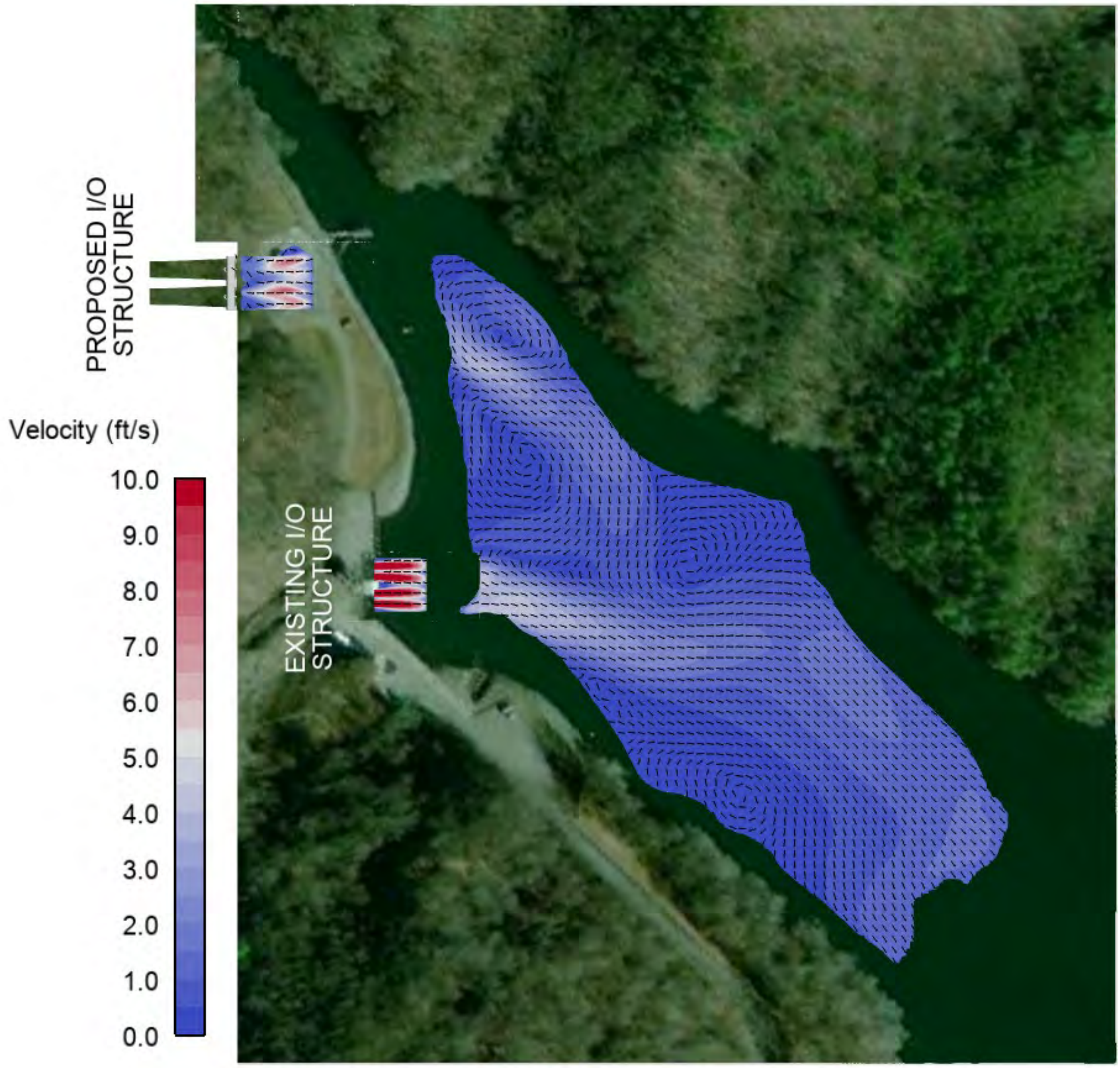

Figure 24. Case 4 (generation - minimum reservoir elevation) Velocity Vectors at Elevation 1,050 ft msl

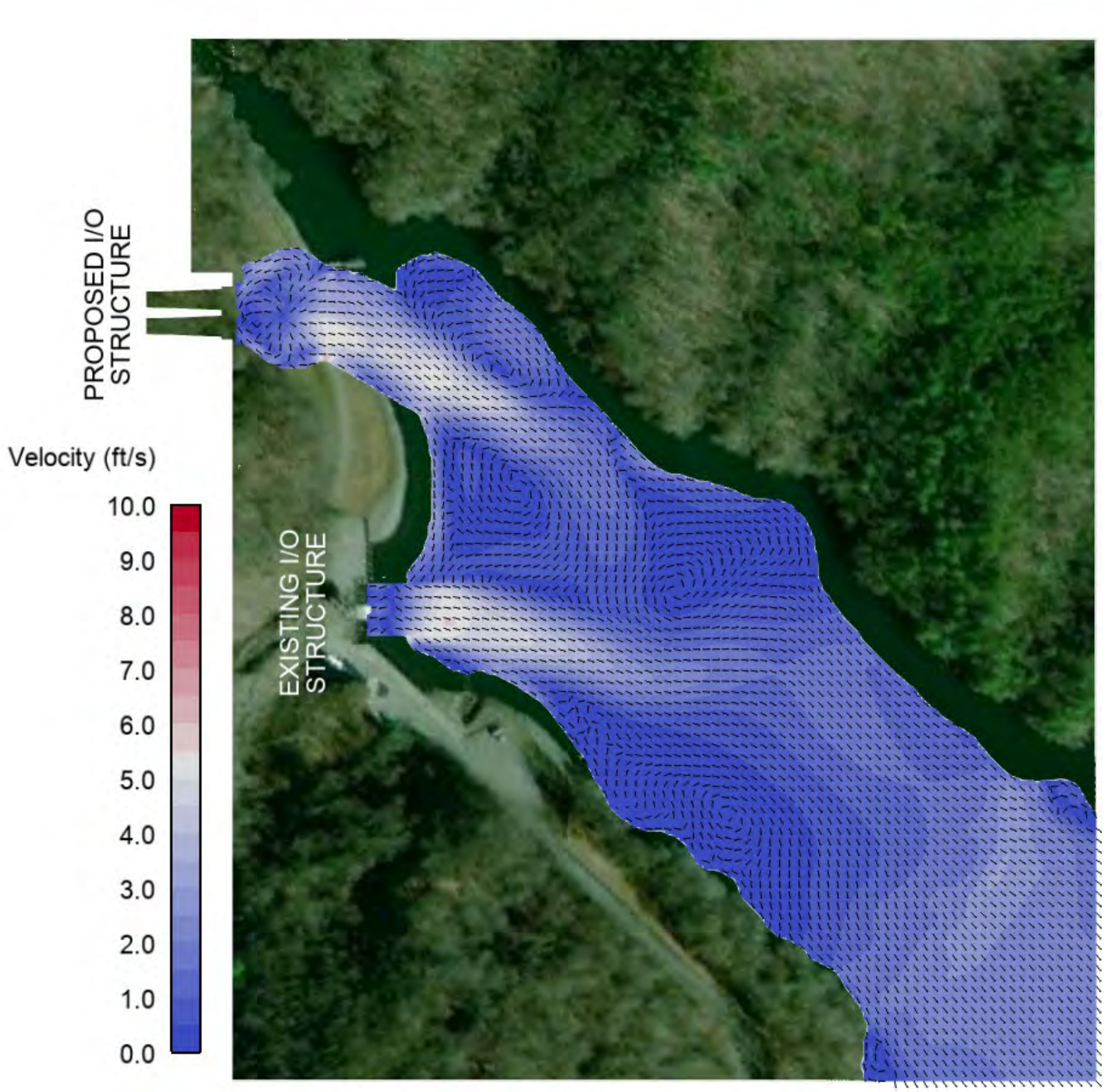

Figure 25. Case 4 (generation - minimum reservoir elevation) Velocity Vectors at Elevation 1,080 ft msl

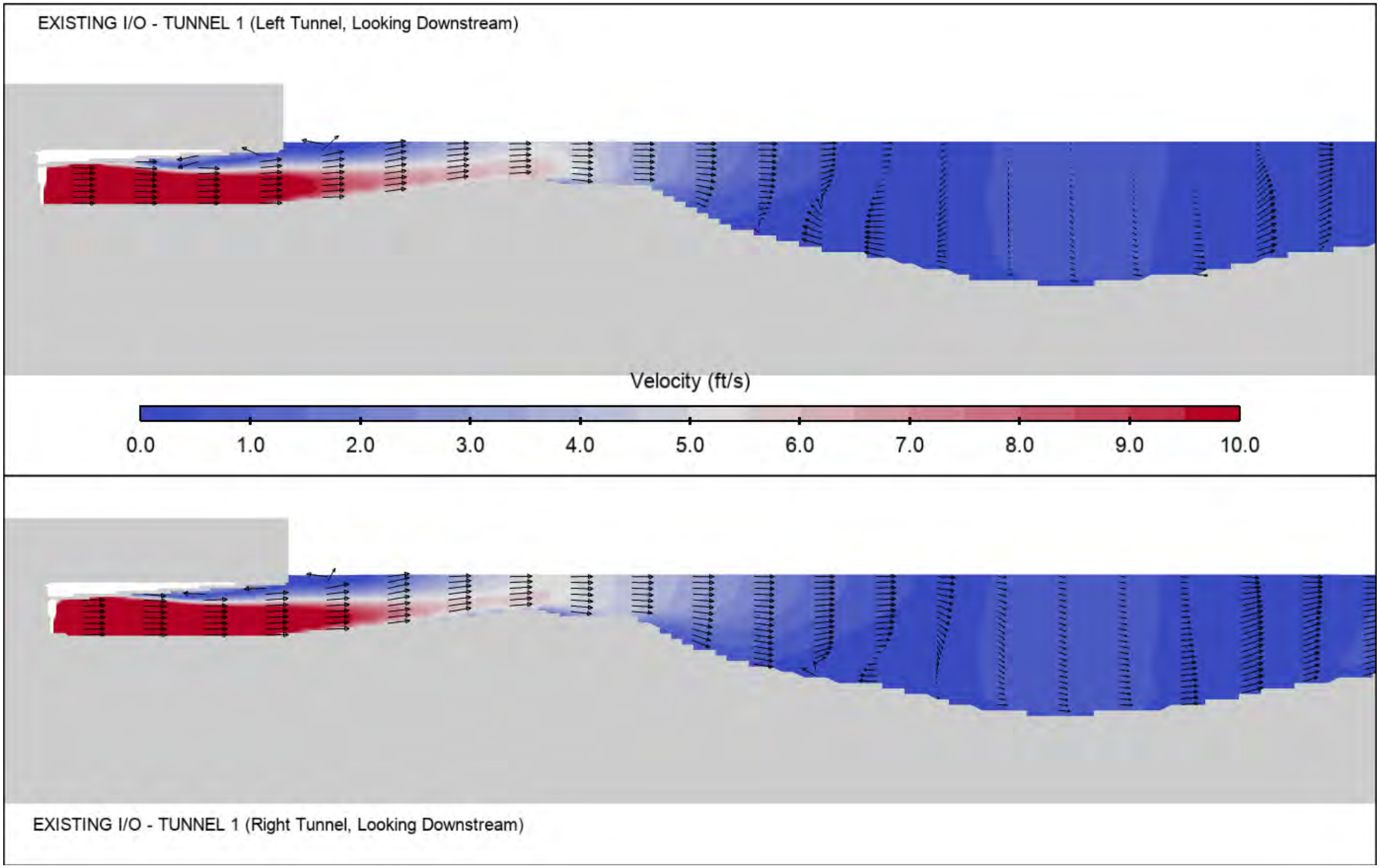

Figure 26. Case 4 (generation - minimum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

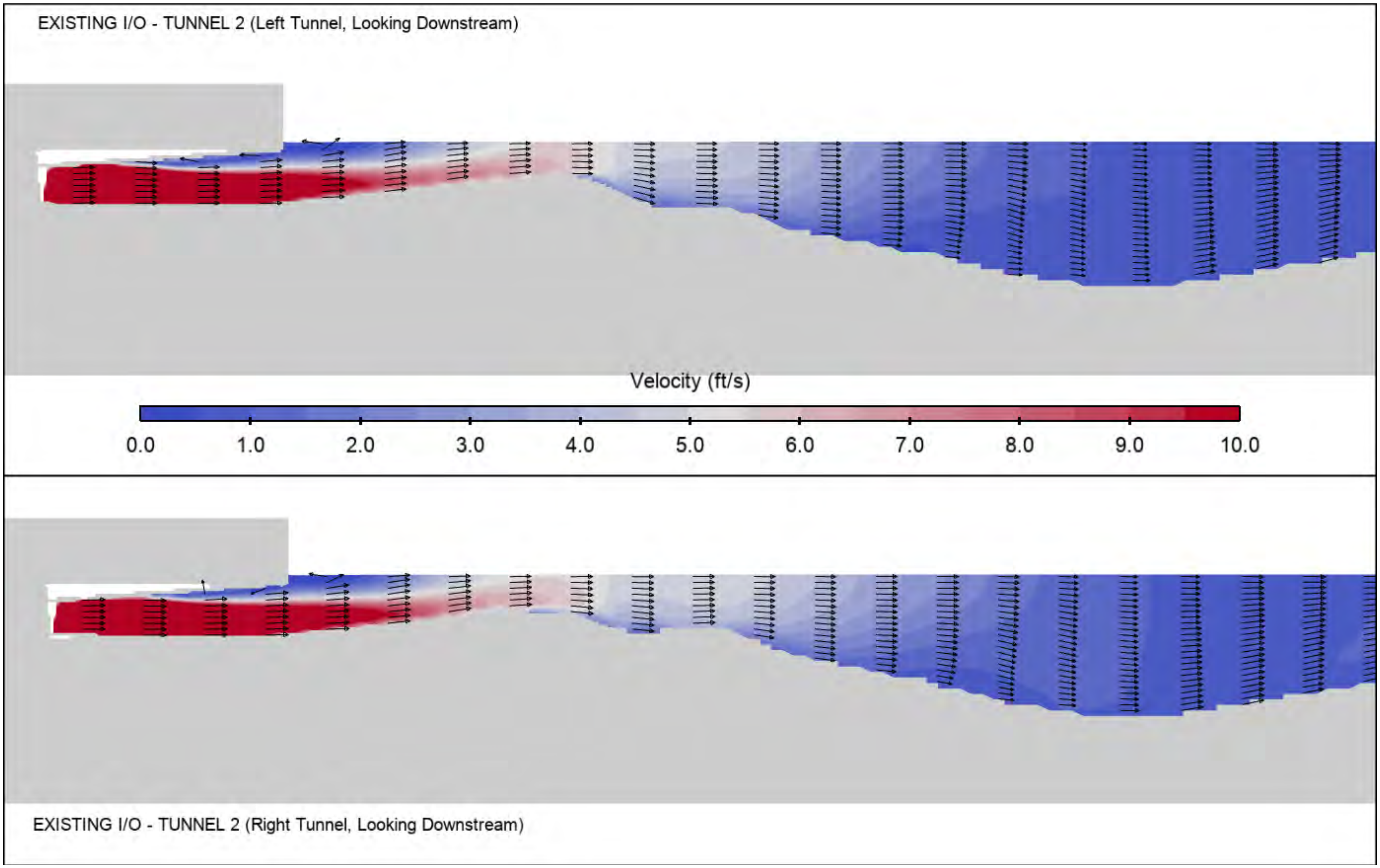

Figure 27. Case 4 (generation - minimum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

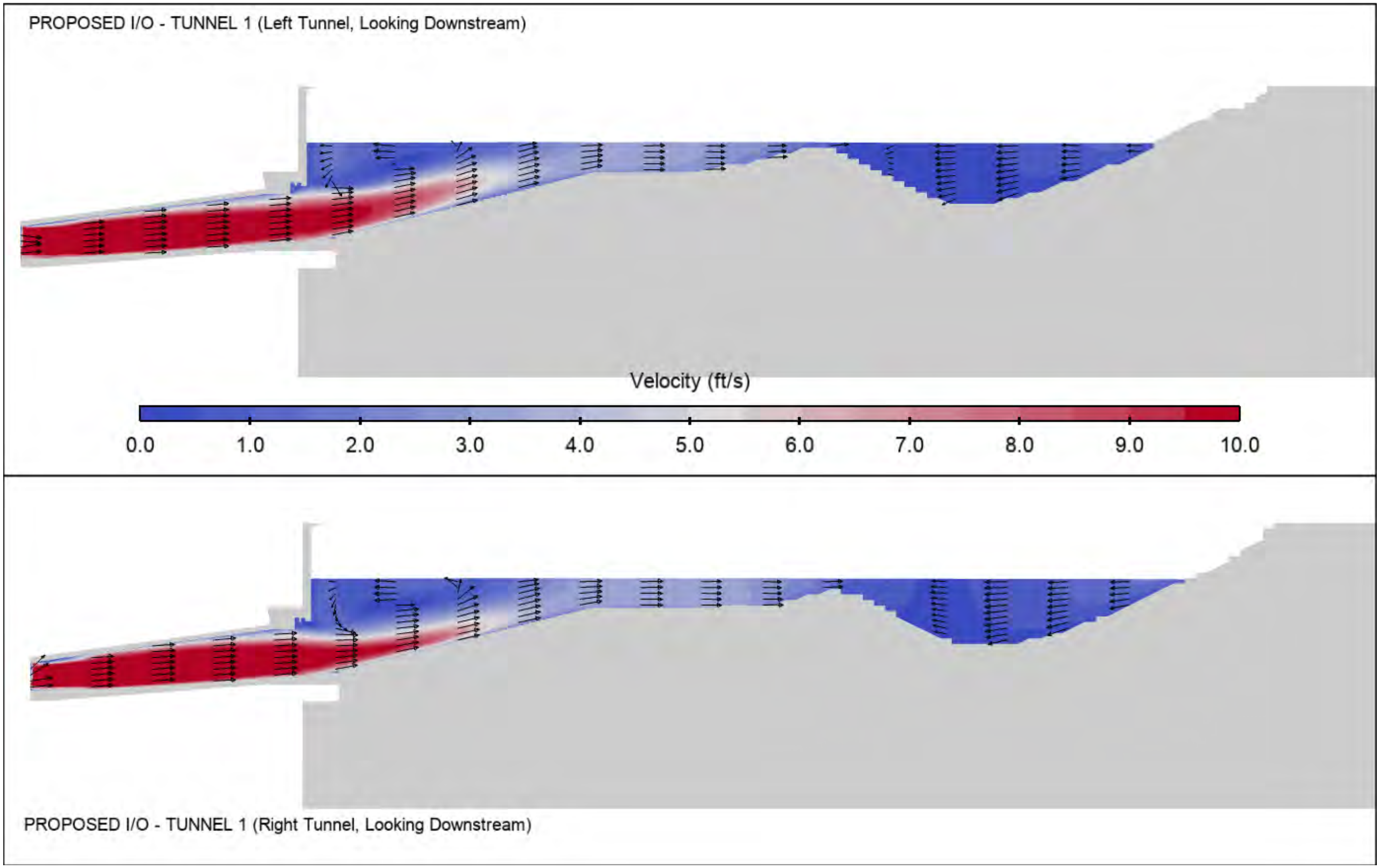

Figure 28. Case 4 (generation - minimum reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

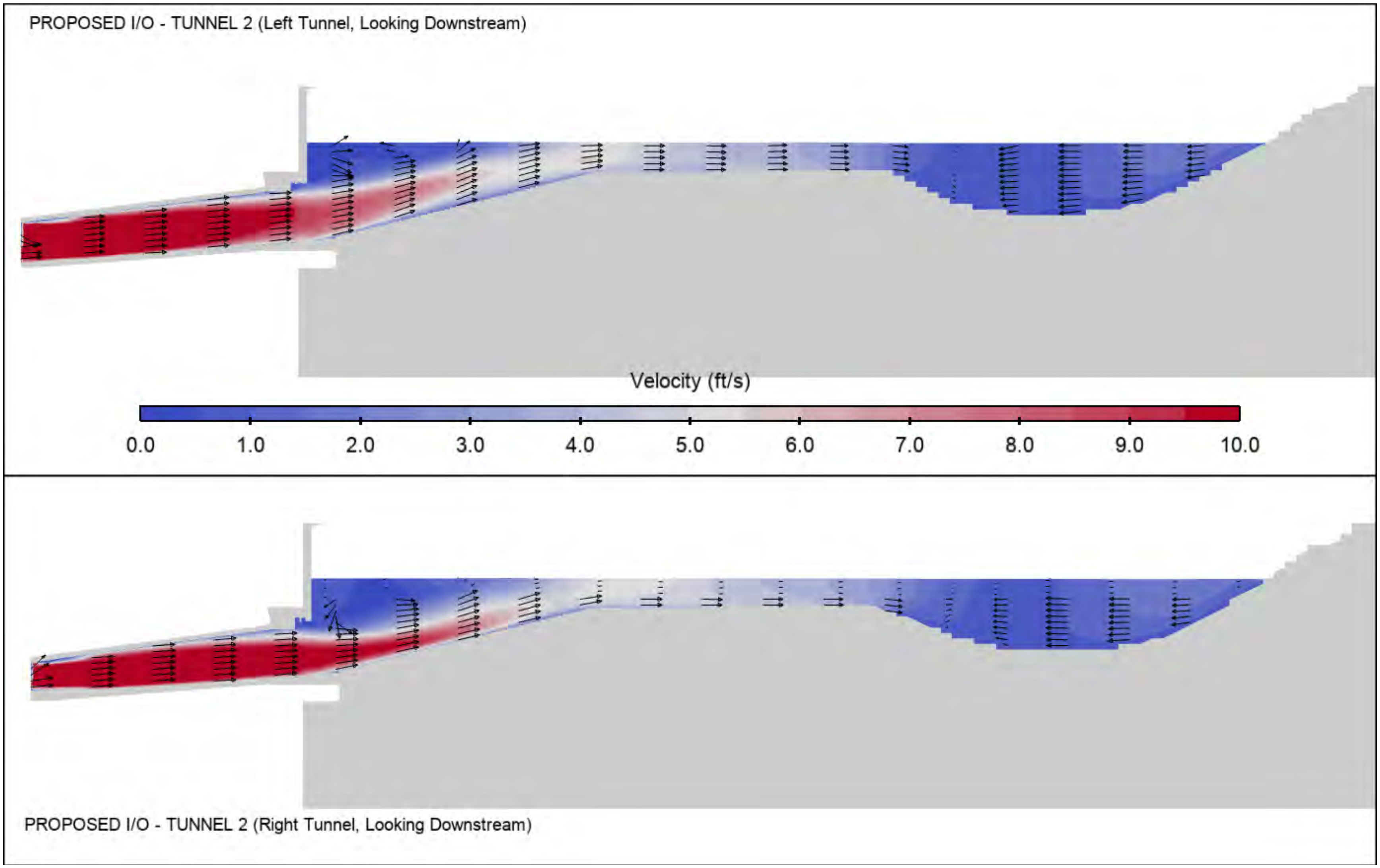

Figure 29. Case 4 (generation - minimum reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

4.2.3 Case 5: Lake Jocassee Assumed Intermediate Reservoir Elevation 1,096 ft msl

Figure 30 shows the plan view of streamlines from the intermediate reservoir elevation scenario (Case 5). Flow patterns are similar to the full reservoir configuration, with increased velocities throughout, which would be expected.

Figure 31 through Figure 34 shows velocity vector slices at elevations 1,040 ft, 1,050 ft, 1,080 ft, and at the surface (1,096 ft), respectively. The lower Lake Jocassee level increases the effect of the concentrated flow from the I/O structures. Surface velocities exceed 5.0 fps, while flow along the east bank peaks at approximately 3.5 fps in the same location as Case 3 (existing I/O centerline). East bank velocities within the water column reach 5.0 fps approximately 500 ft upstream (north) of the existing I/O structure centerline. Surface velocities along the entire east bank peak at approximately 3.5 fps. The peak magnitude of the velocity along the east bank was approximately equal to the velocities measured in the ARL physical model. The change in location of the peak velocities should not affect bank conditions/erosion assuming the geology of the east bank is consistent upstream (i.e., north) of the existing structure (i.e., predominantly bedrock).

Figure 35 and Figure 37 show slices of velocity vectors and magnitudes through the two existing and two proposed I/O structure tunnels' centerlines, respectively. As in Case 3, these slices show velocities on the east bank below 2.5 fps along tunnel centerlines.

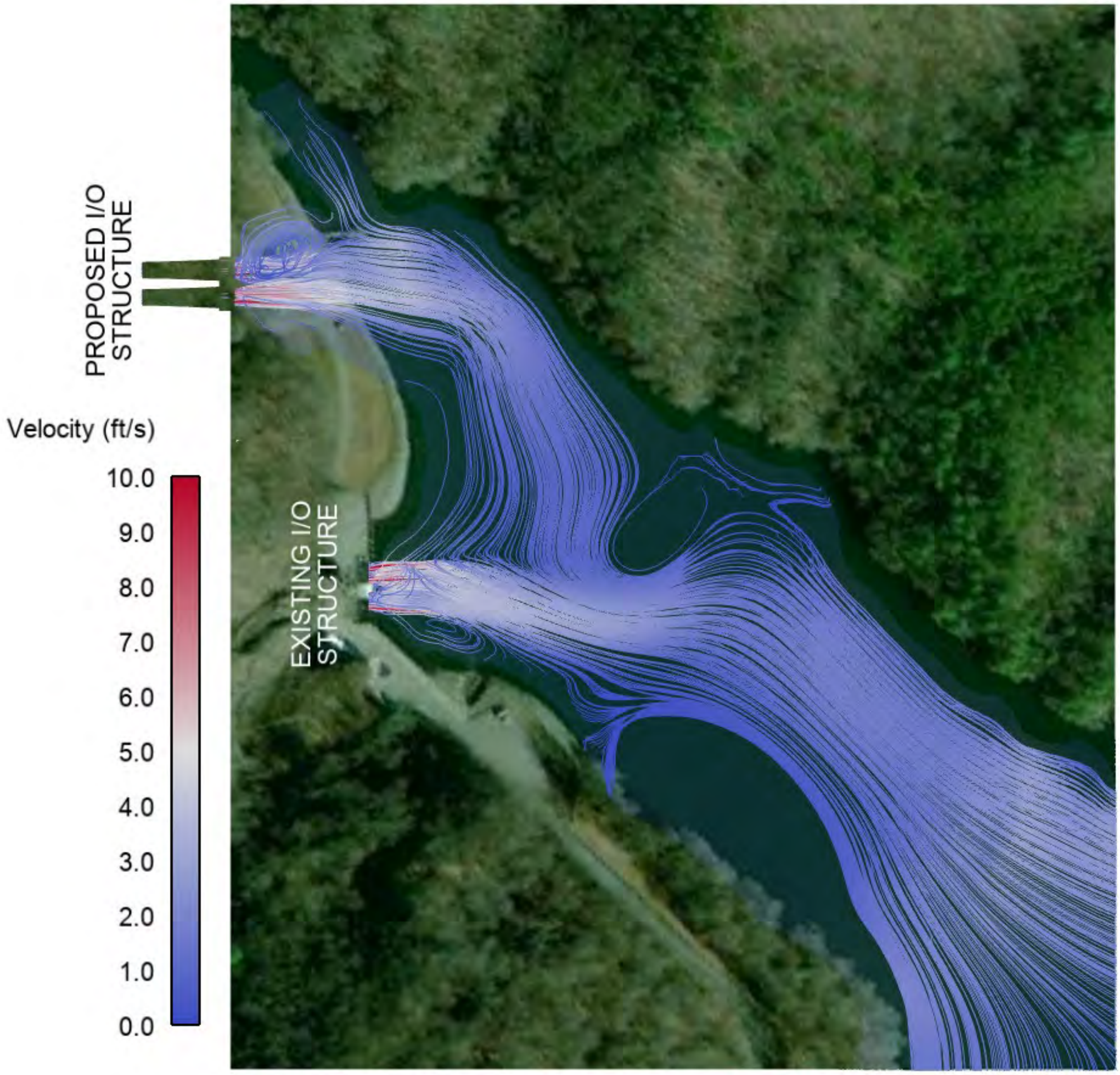

Figure 30. Case 5 (generation - intermediate reservoir elevation) Velocity Streamlines under Normal Minimum Reservoir Elevation

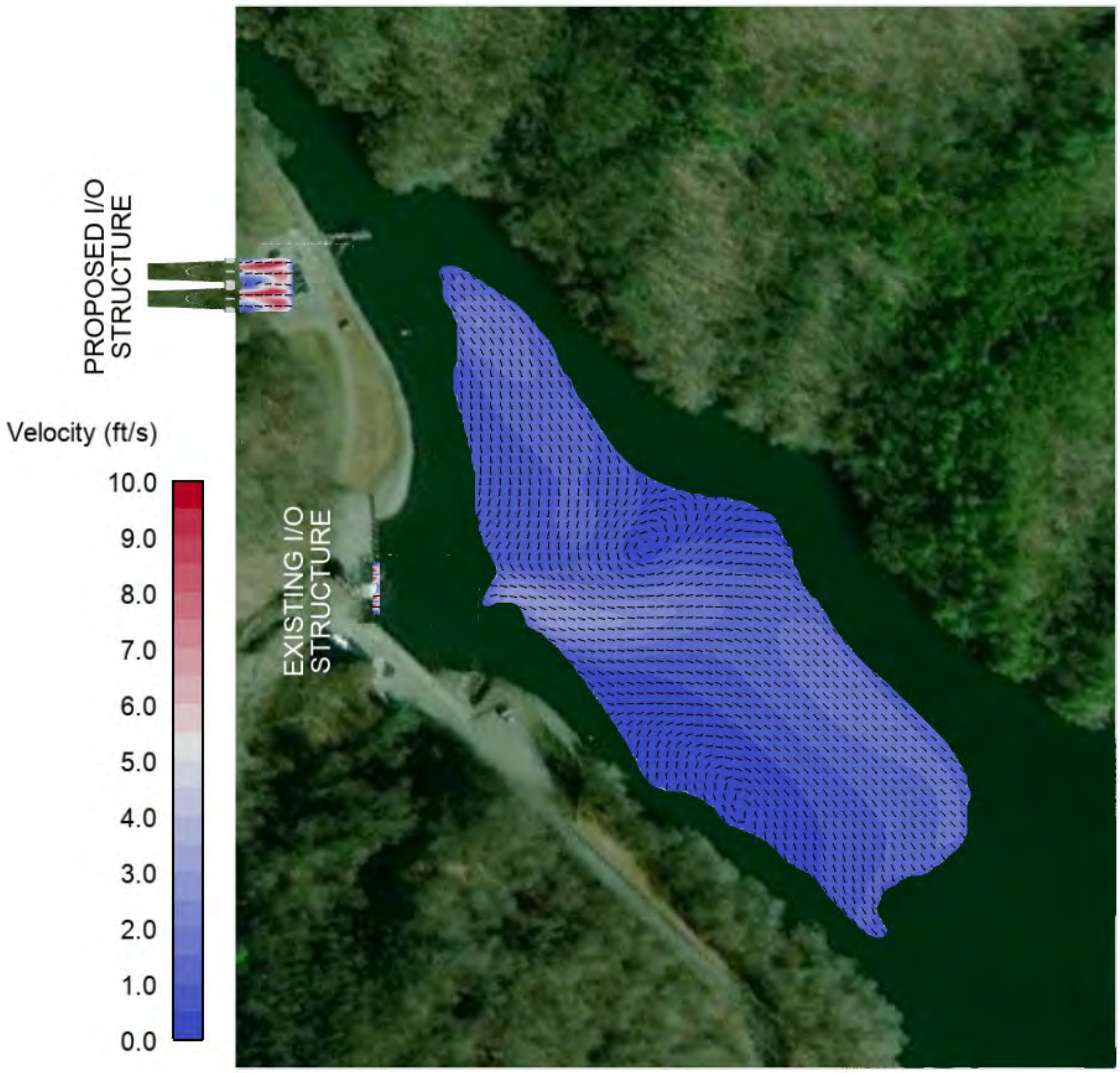

Figure 31. Case 5 (generation - intermediate reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

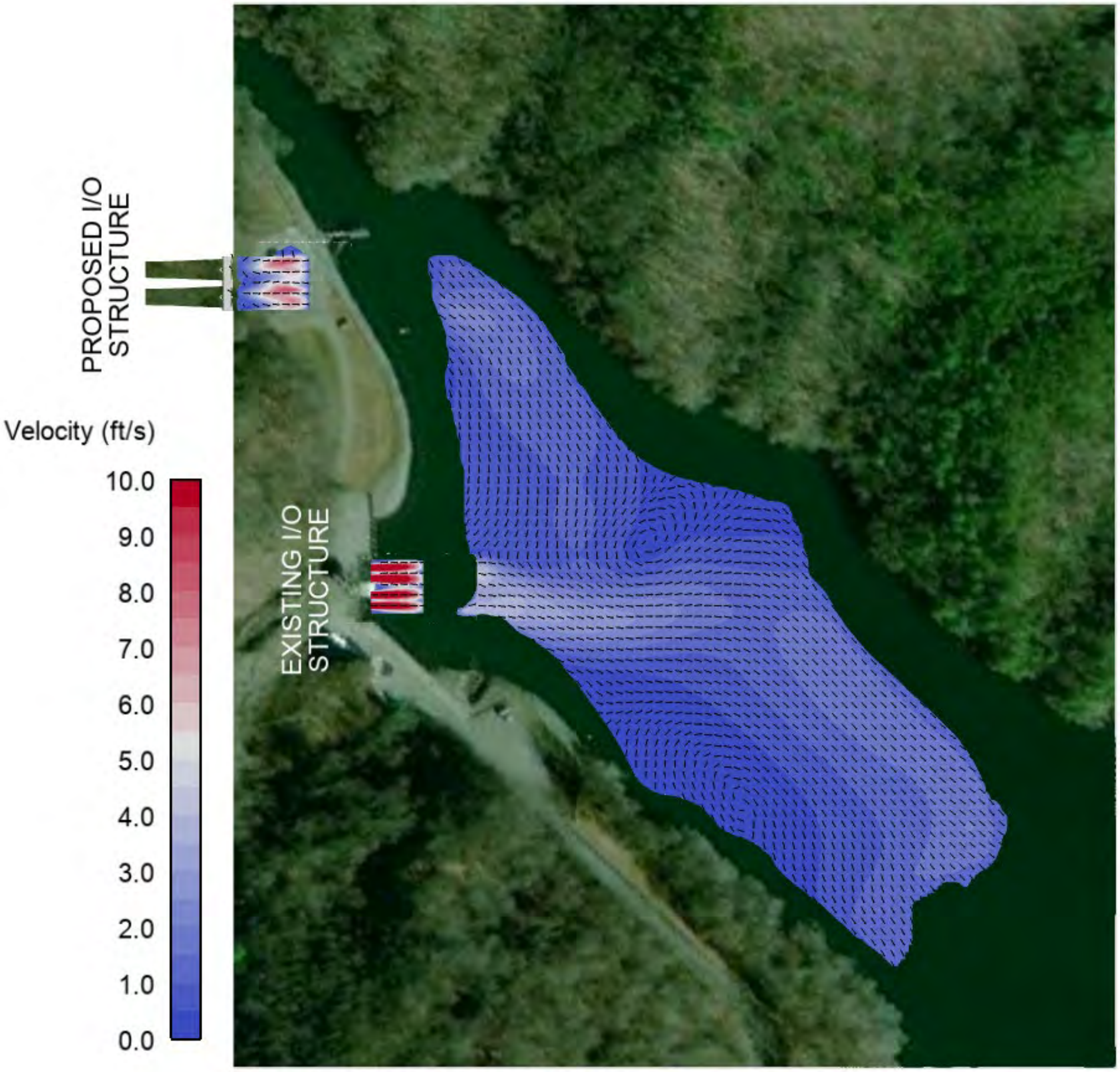

Figure 32. Case 5 (generation - intermediate reservoir elevation) Velocity Vectors at Elevation 1,050 ft msl

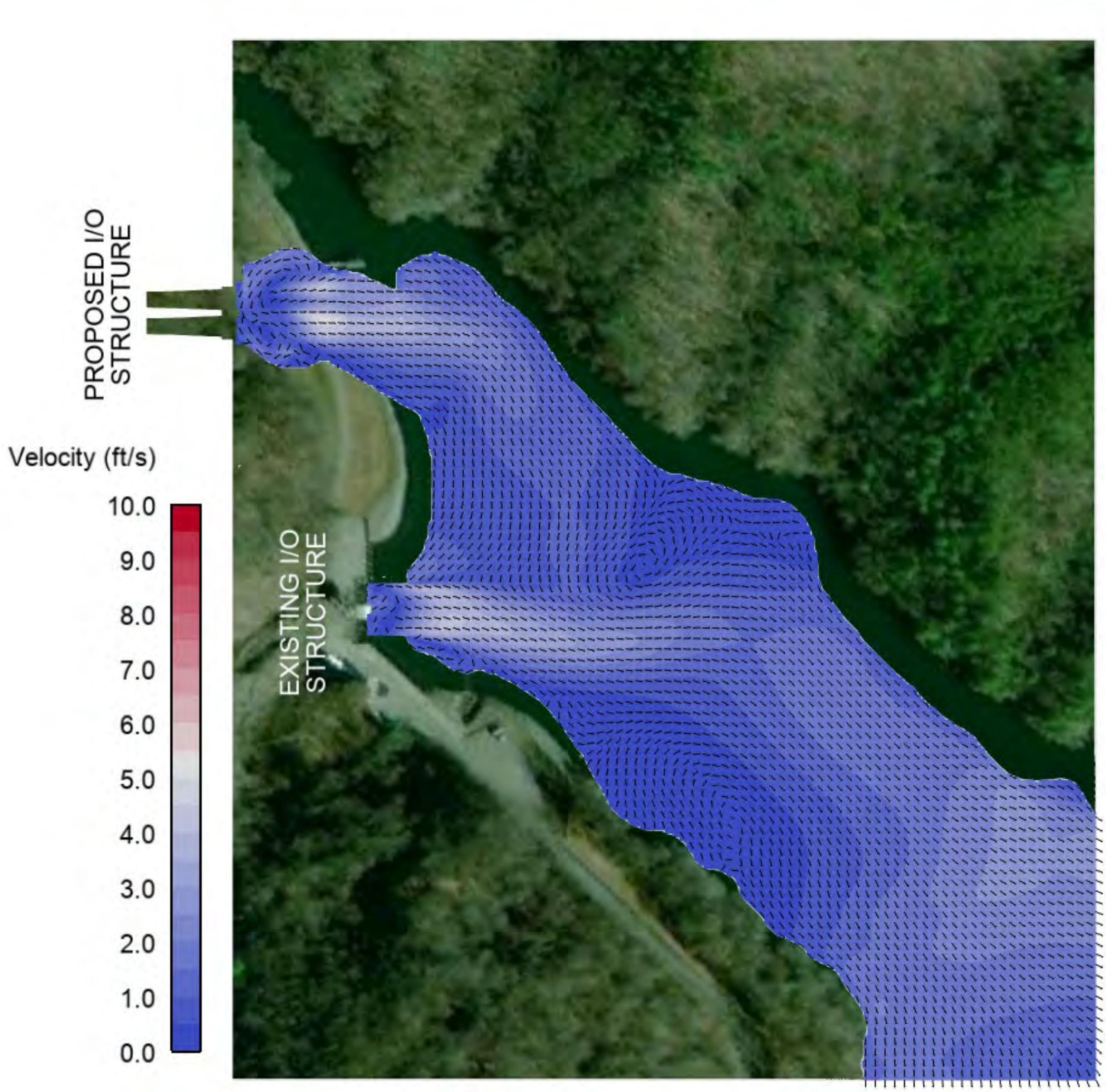

Figure 33. Case 5 (generation - intermediate reservoir elevation) Velocity Vectors at Elevation 1,080 ft msl

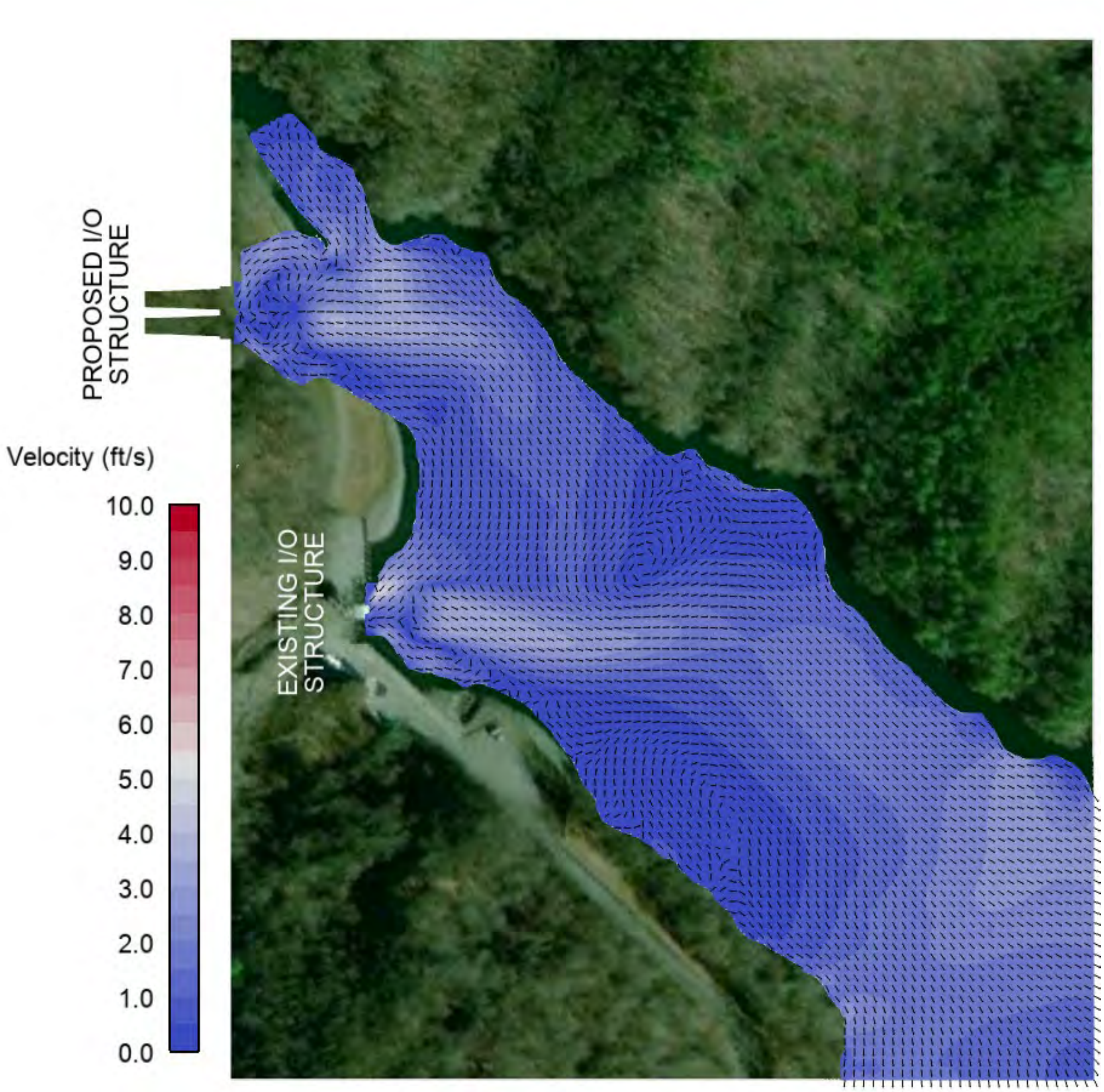

Figure 34. Case 5 (generation – intermediate reservoir elevation) Velocity Vectors at Elevation 1,096 ft msl

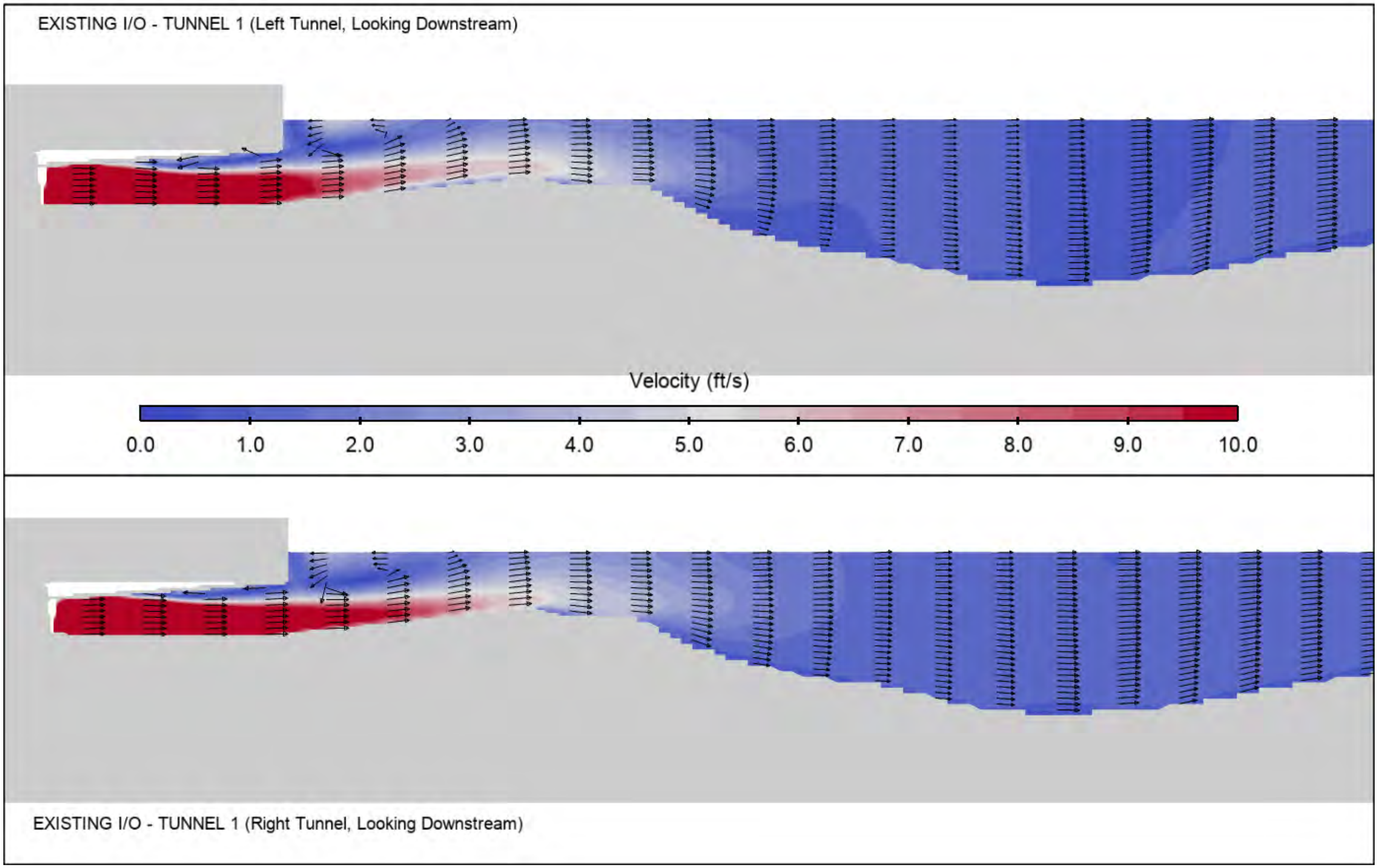

Figure 35. Case 5 (generation - intermediate reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

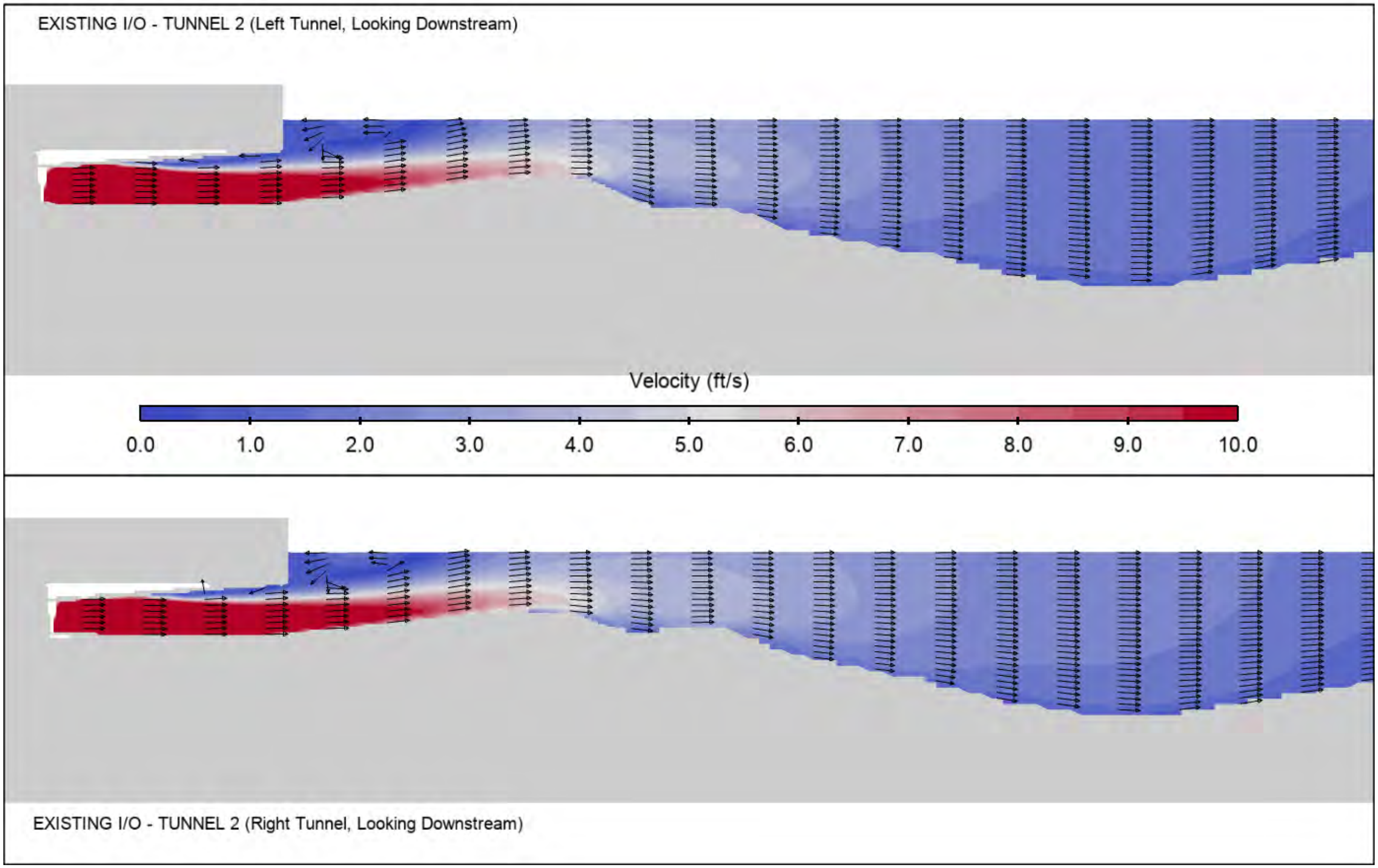

Figure 36. Case 5 (generation - intermediate reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

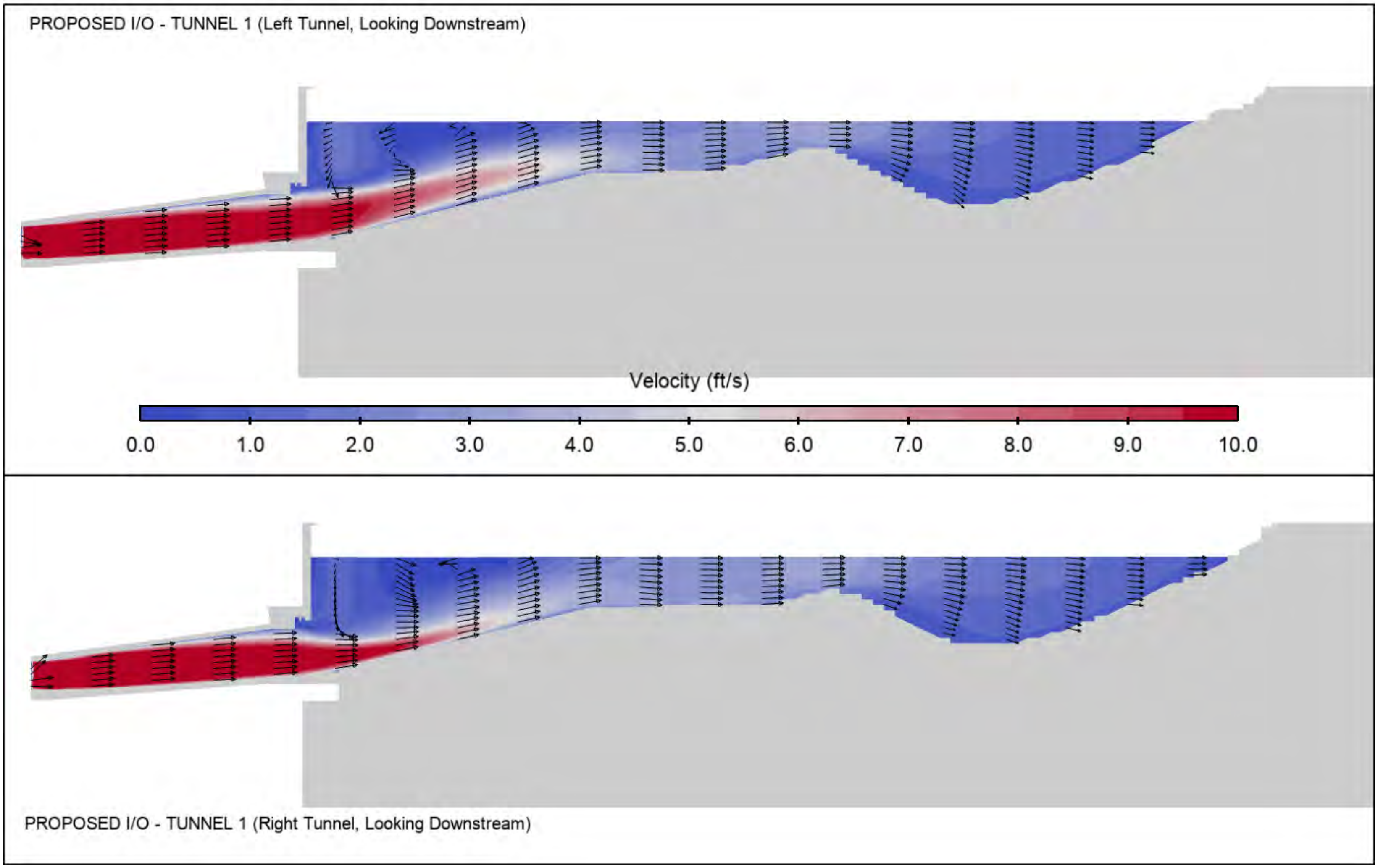

Figure 37. Case 5 (generation - intermediate reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

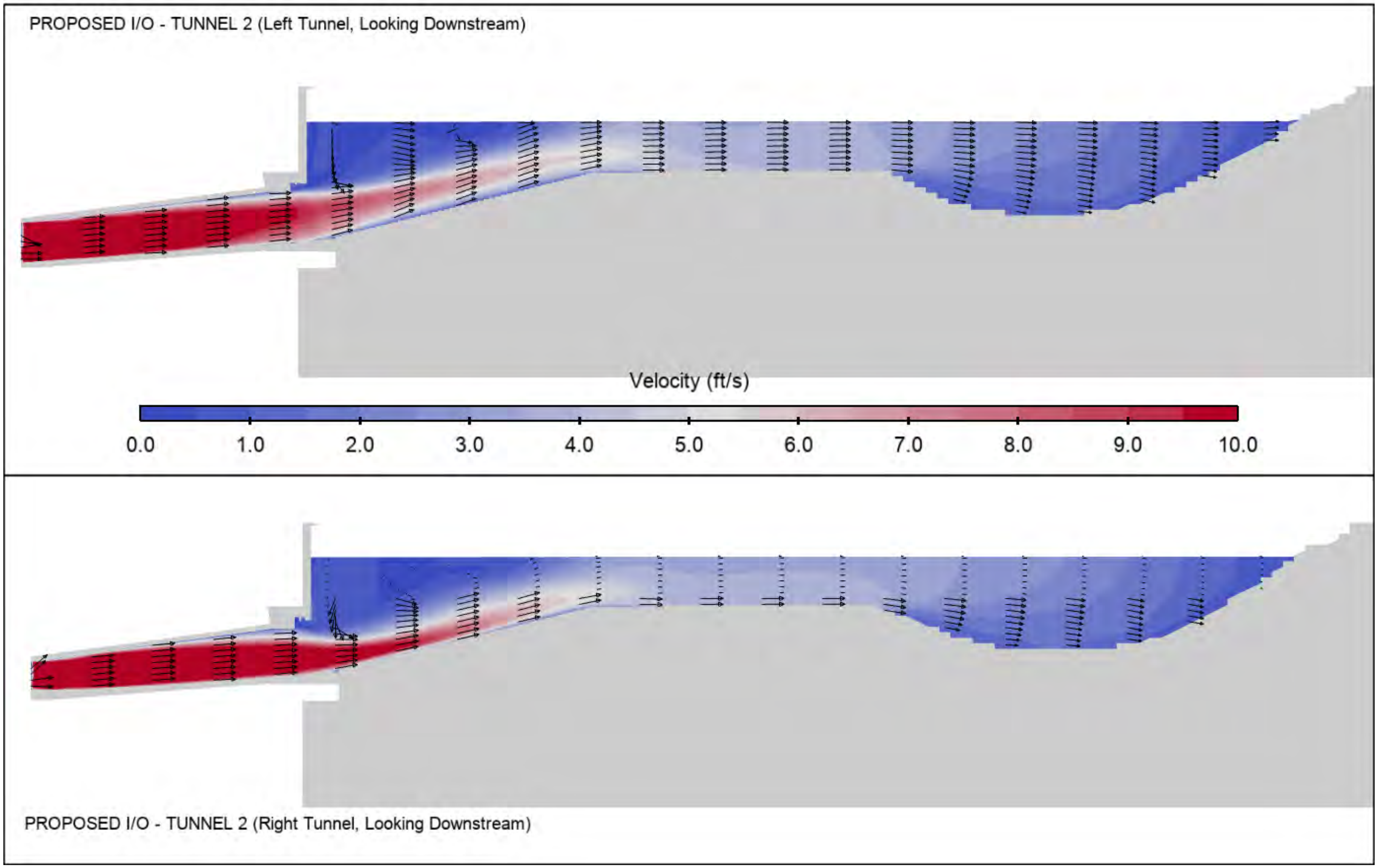

Figure 38. Case 5 (generation - intermediate reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

4.3 Proposed Configuration - Cases 6 through 8 (Pump Mode)

The proposed Bad Creek II I/O structure configuration was modeled for both reservoir elevations and assuming full pumping at both I/O structures (combined 32,720 cfs) to determine impacts to the channel and east bank of the Lake Jocassee Whitewater River cove and hydraulic approach to the proposed I/O structure.

4.3.1 Case 6: Lake Jocassee Normal Full Reservoir Elevation 1,110 ft msl

Results of the proposed configuration at normal full reservoir elevation are presented on Figure 39 through Figure 47. Figure 39 shows the plan view of the streamlines. Flow from the proposed I/O structure approaches from the east bank, while flow entering the existing I/O structure approaches from the west bank. Velocities increase upstream of the I/O structures but were lower than velocities in the generation simulations.

Figure 40 through Figure 43 show slices of the velocity vectors at four elevations within the water column: 1,040 ft msl, 1,050 ft msl, 1,080 ft msl, and at the surface (i.e., 1,110 ft msl). The flow patterns at each depth are relatively similar throughout the water column. The water velocities near the submerged weir were less than 2.0 fps.

Figure 44 through Figure 47 show model slices of velocity vectors and magnitudes through the two existing and two proposed I/O structure tunnels centerlines, respectively. These slices show velocities on the east bank below 2.5 fps along tunnel centerlines.

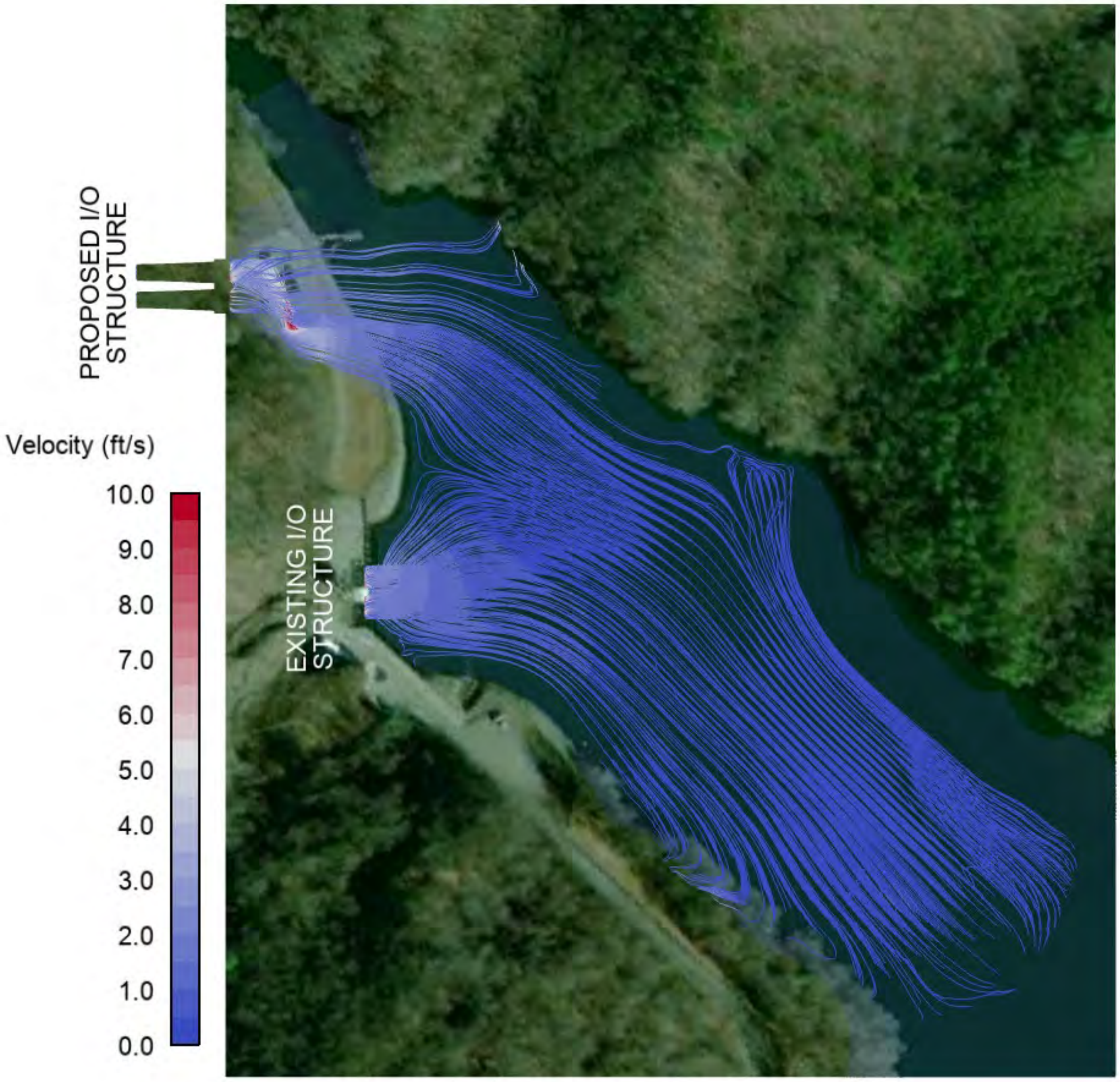

Figure 39. Case 6 (pumping - maximum reservoir elevation) Velocity Streamlines at Normal Full Pool Elevation

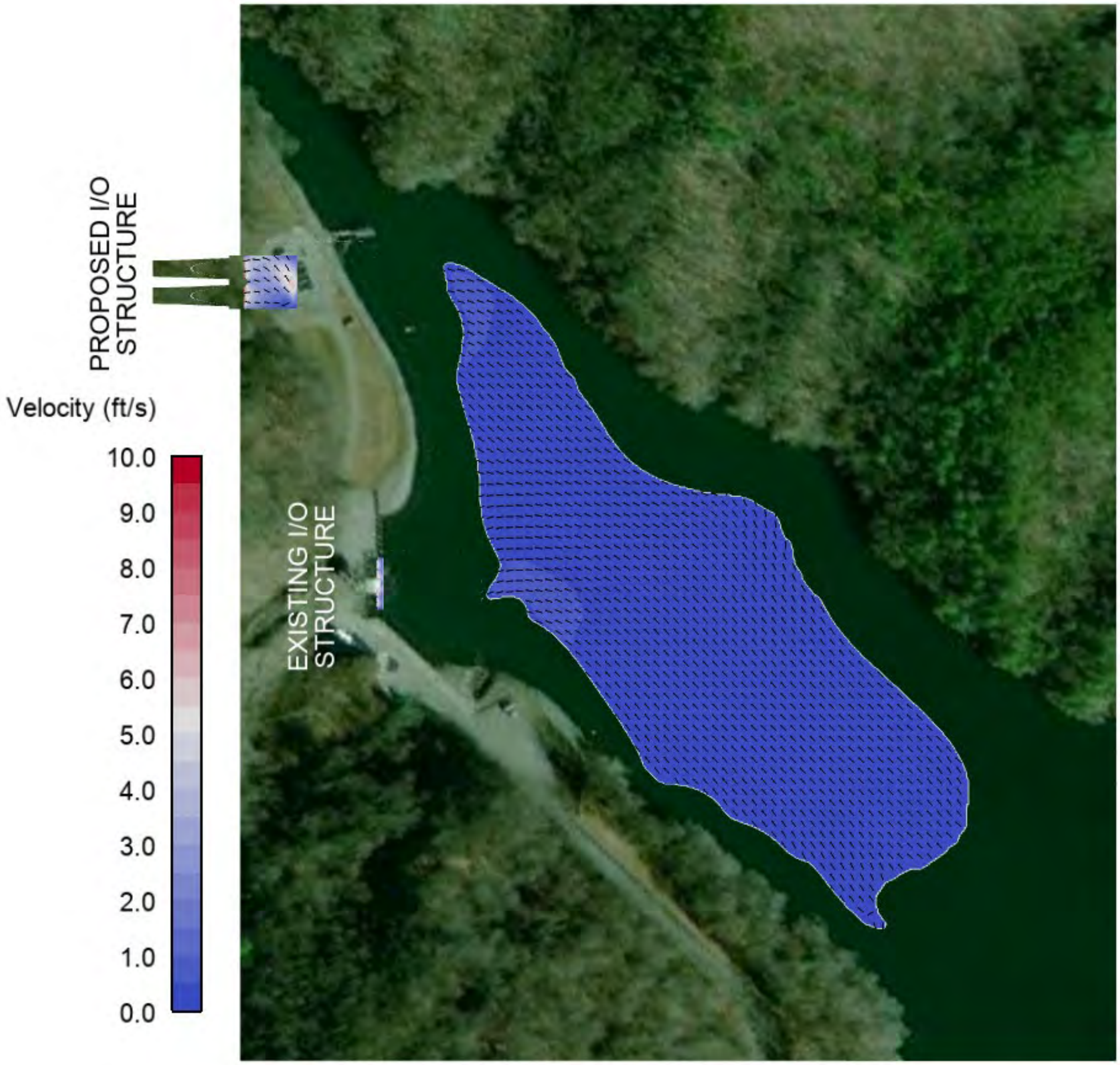

Figure 40. Case 6 (pumping - maximum reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

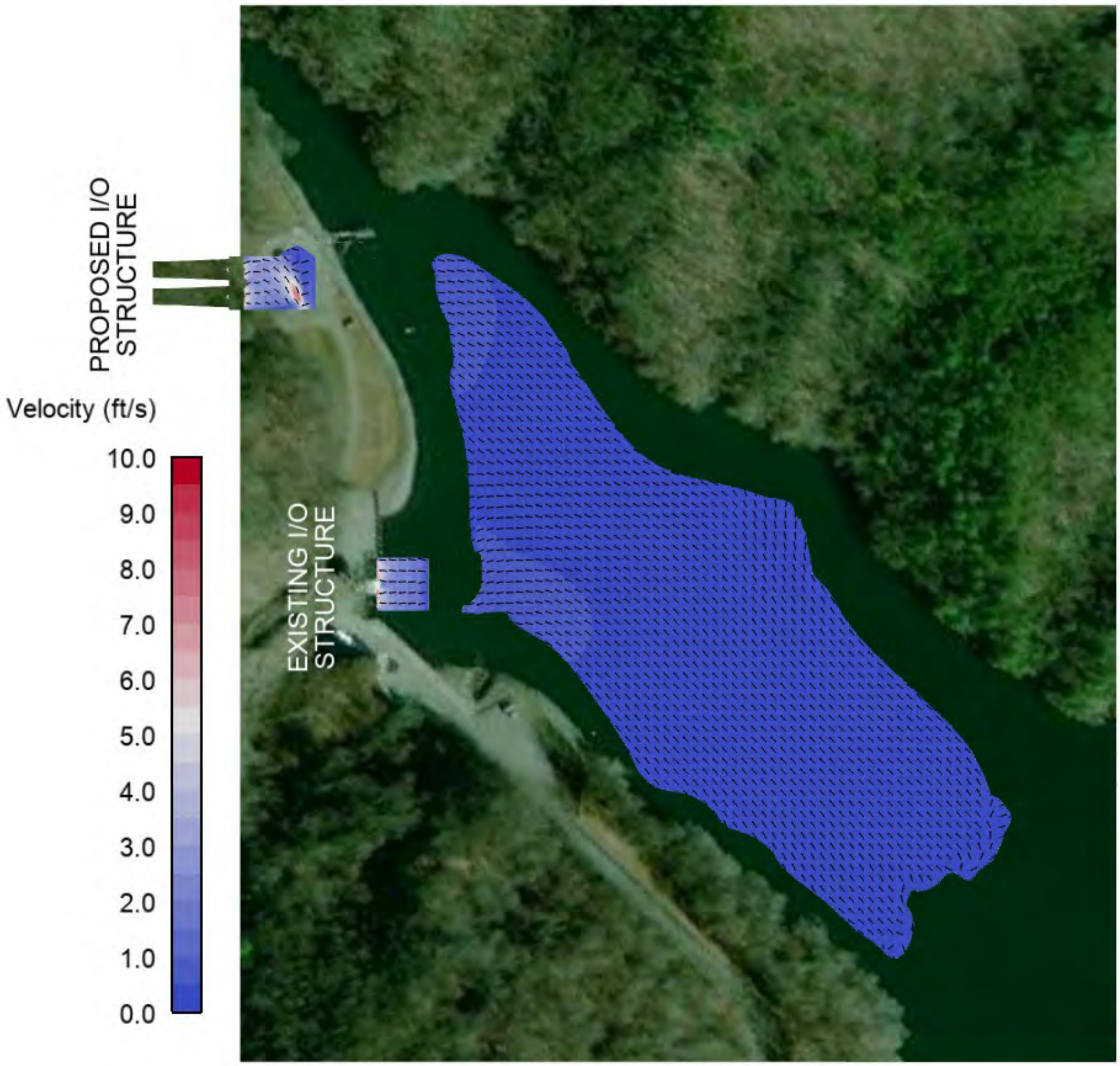

Figure 41. Case 6 (pumping - maximum reservoir elevation) Velocity Vectors at Elevation 1,050 ft

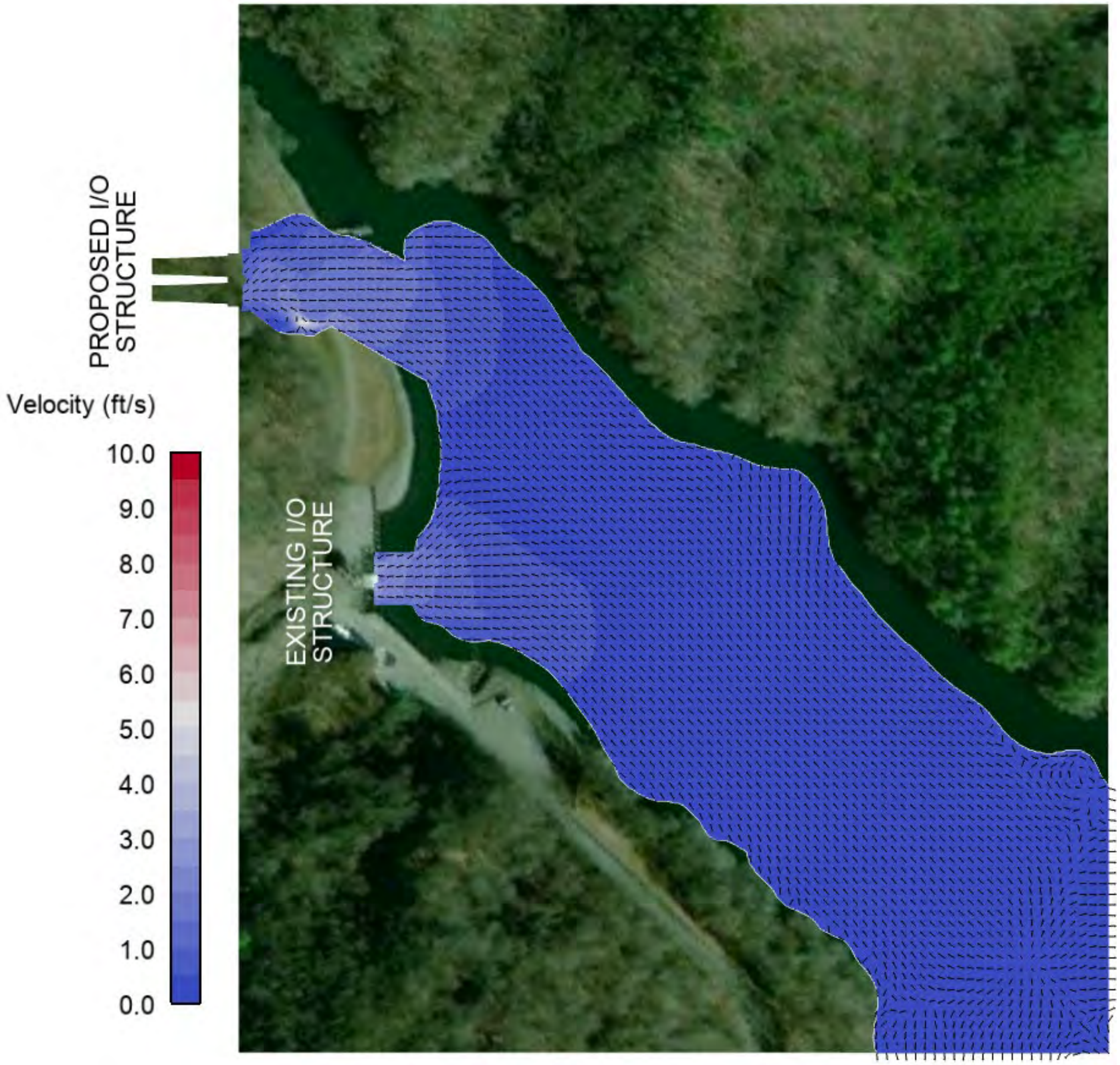

Figure 42. Case 6 (pumping - maximum reservoir elevation) Velocity Vectors at Elevation 1,080 ft

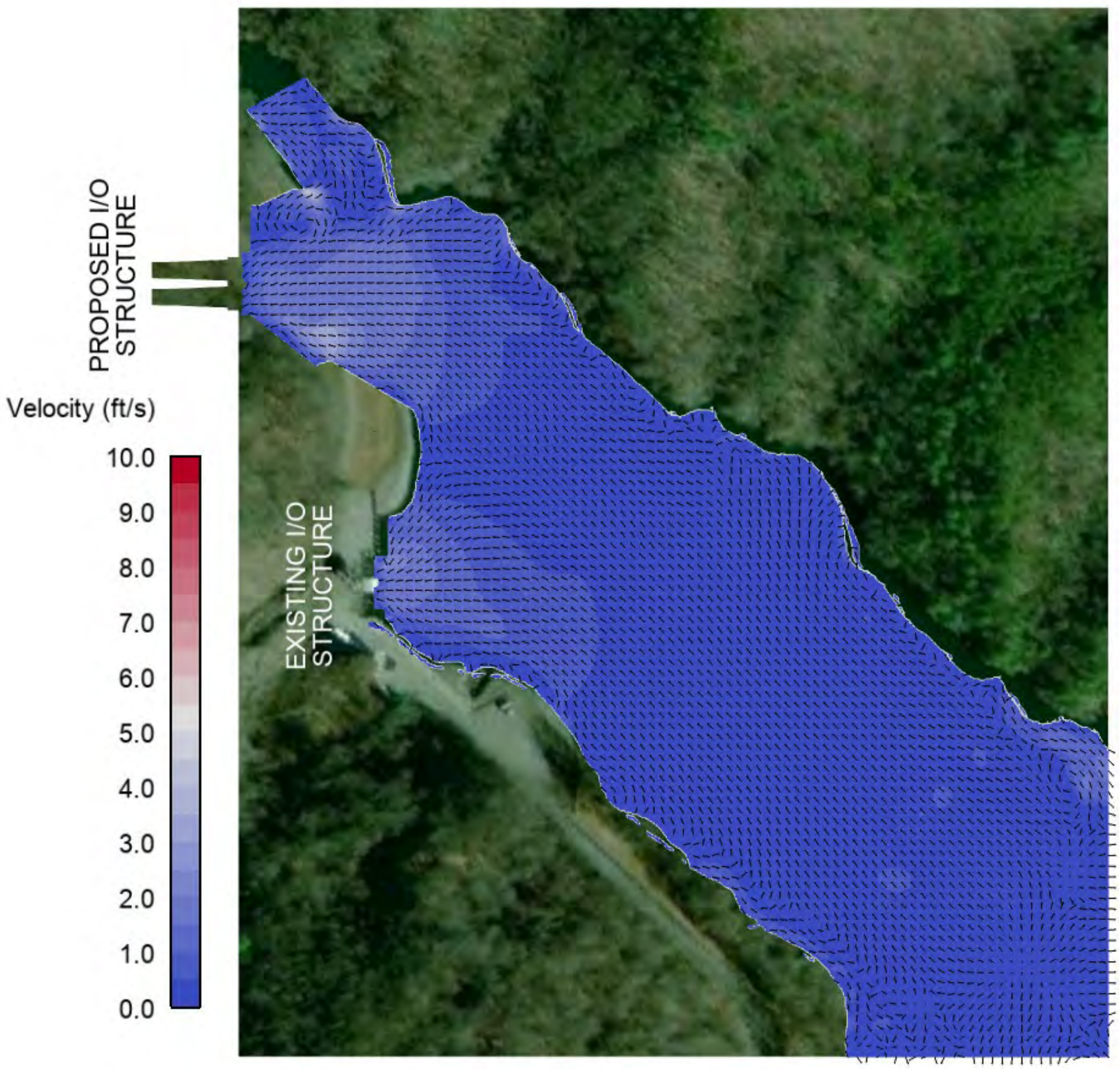

Figure 43. Case 6 (pumping - maximum reservoir elevation) Velocity Vectors at Elevation 1,110 ft msl

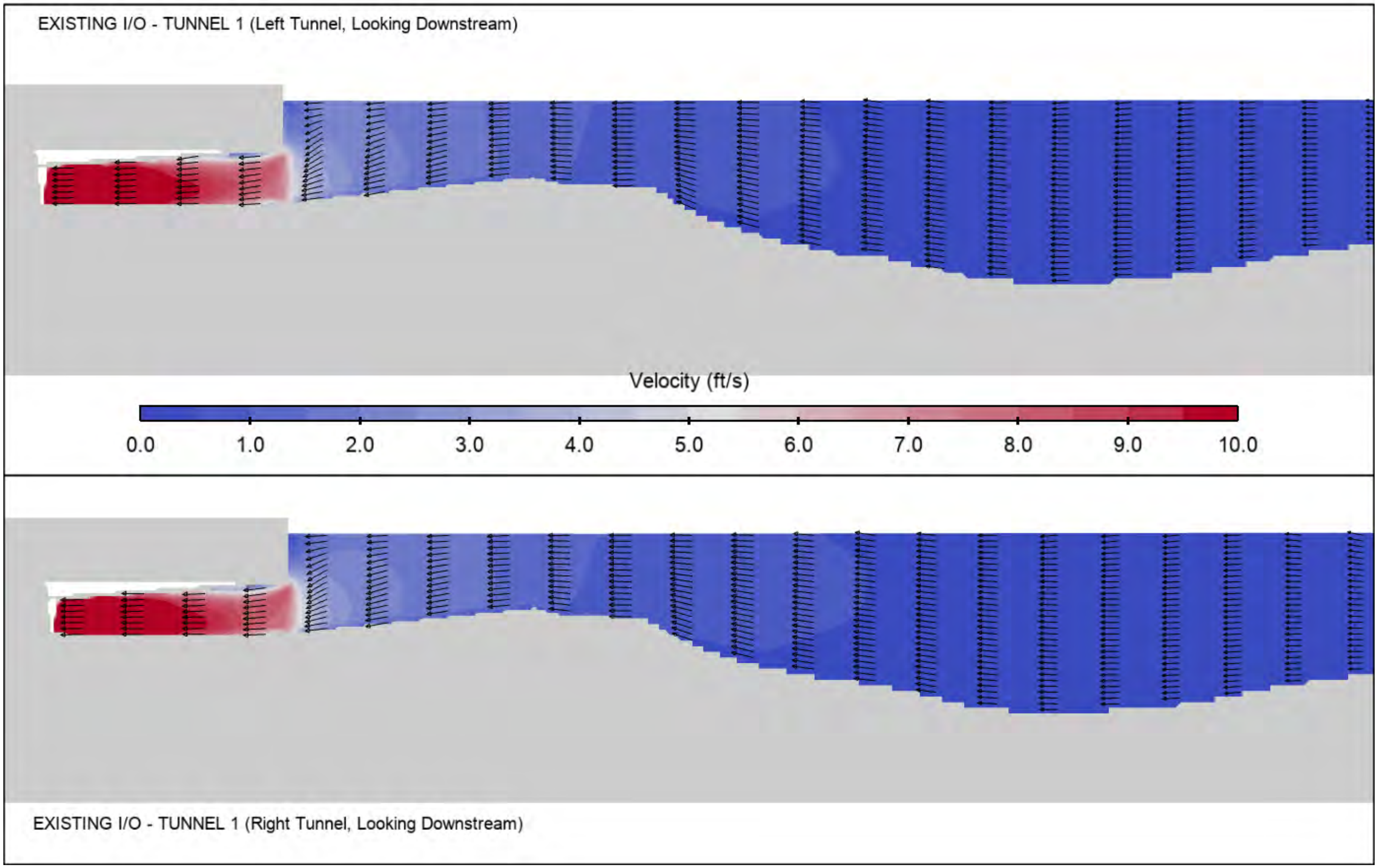

Figure 44. Case 6 (pumping - maximum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

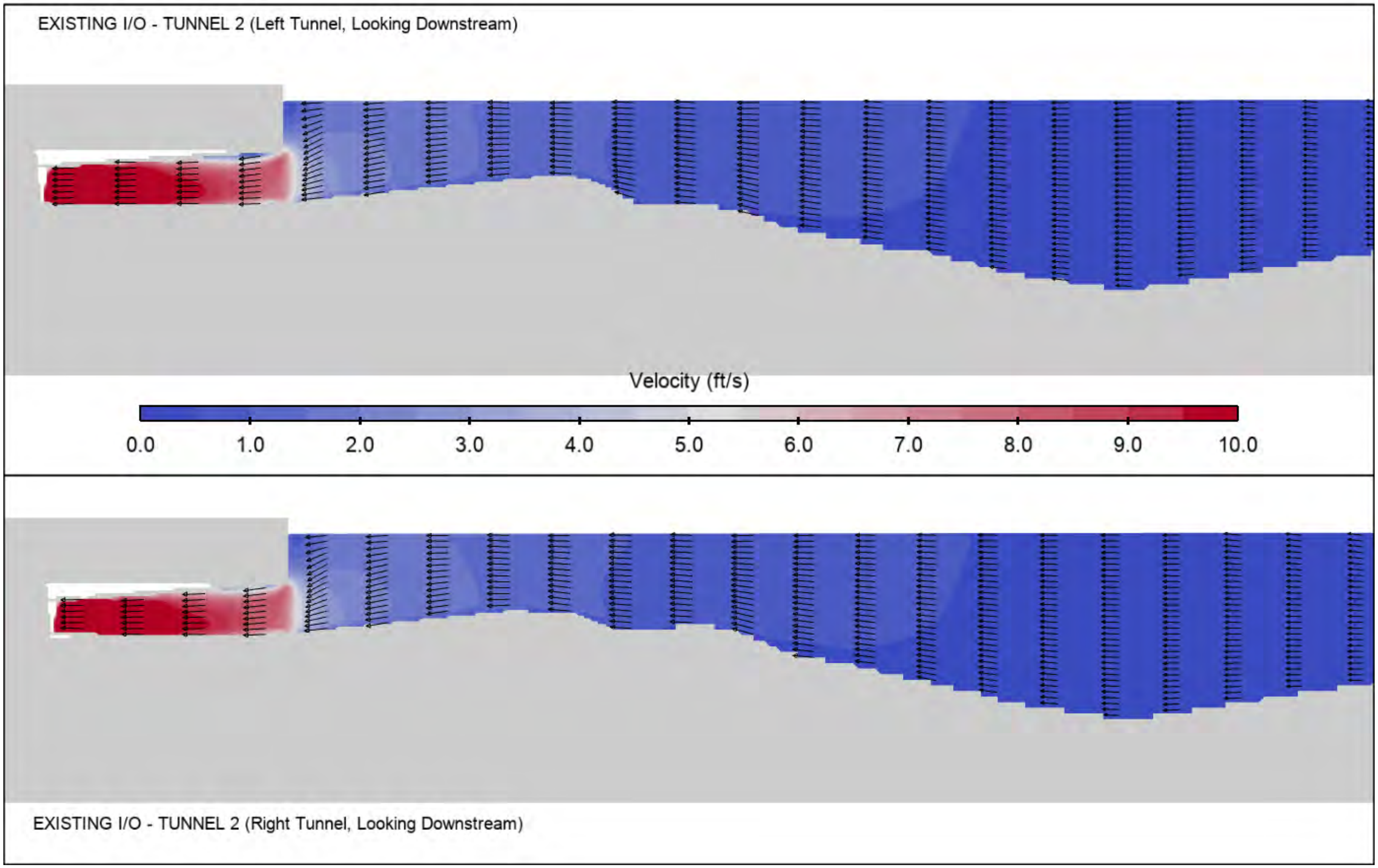

Figure 45. Case 6 (pumping - maximum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

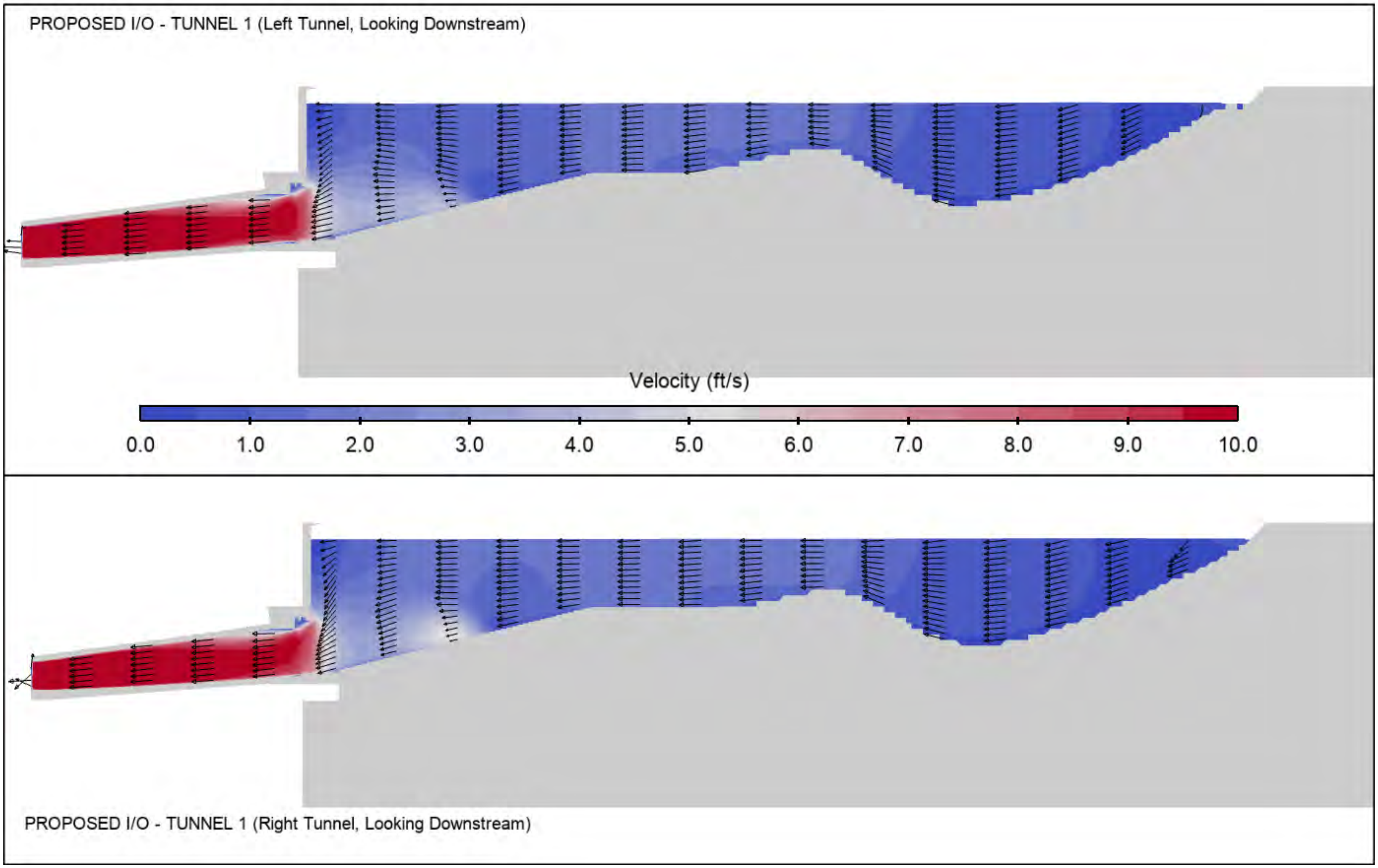

Figure 46. Case 6 (pumping - maximum reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

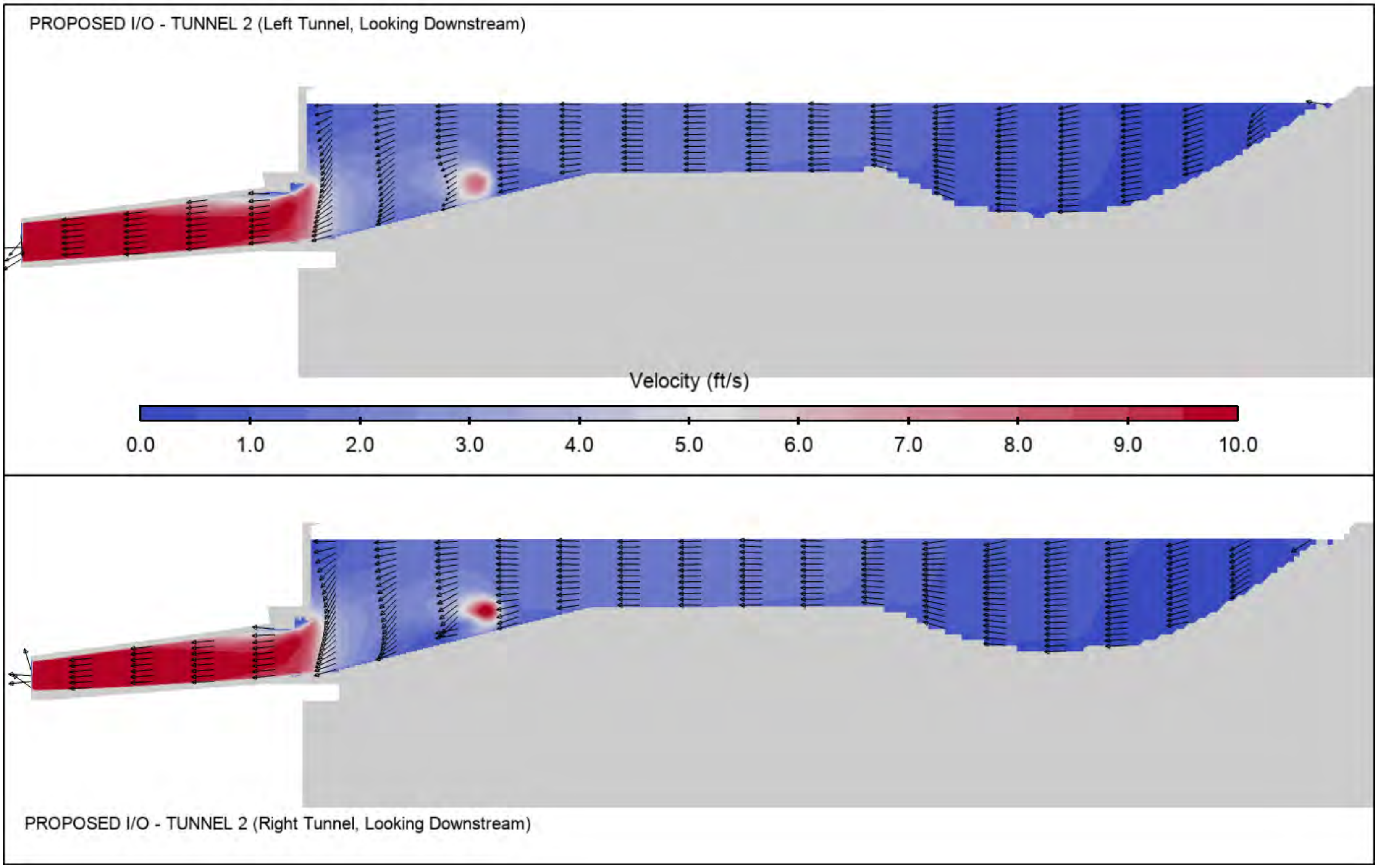

Figure 47. Case 6 (pumping - maximum reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

4.3.2 Case 7: Lake Jocassee Normal Minimum Reservoir Elevation 1,080 ft msl

Figure 48 shows the plan view of streamlines from the normal minimum reservoir elevation scenario (Case 7). Flow patterns are similar to the full reservoir configuration, with increased velocities throughout, which would be expected.

Figure 49 through Figure 51 show velocity vector slices at elevations 1,040 ft, 1,050 ft, and at the surface, respectively. The lower Lake Jocassee level increases the effect of the concentrated flow from the I/O structures. Surface velocities approach 5.0 fps near the submerged weir while flow along the east bank was less than 2.0 fps.

Figure 52 and Figure 55 show slices of velocity vectors and magnitudes through the two existing and two proposed I/O structure tunnels' centerlines, respectively. As in Case 6, these slices show velocities on the east bank below 2.5 fps along tunnel centerlines.

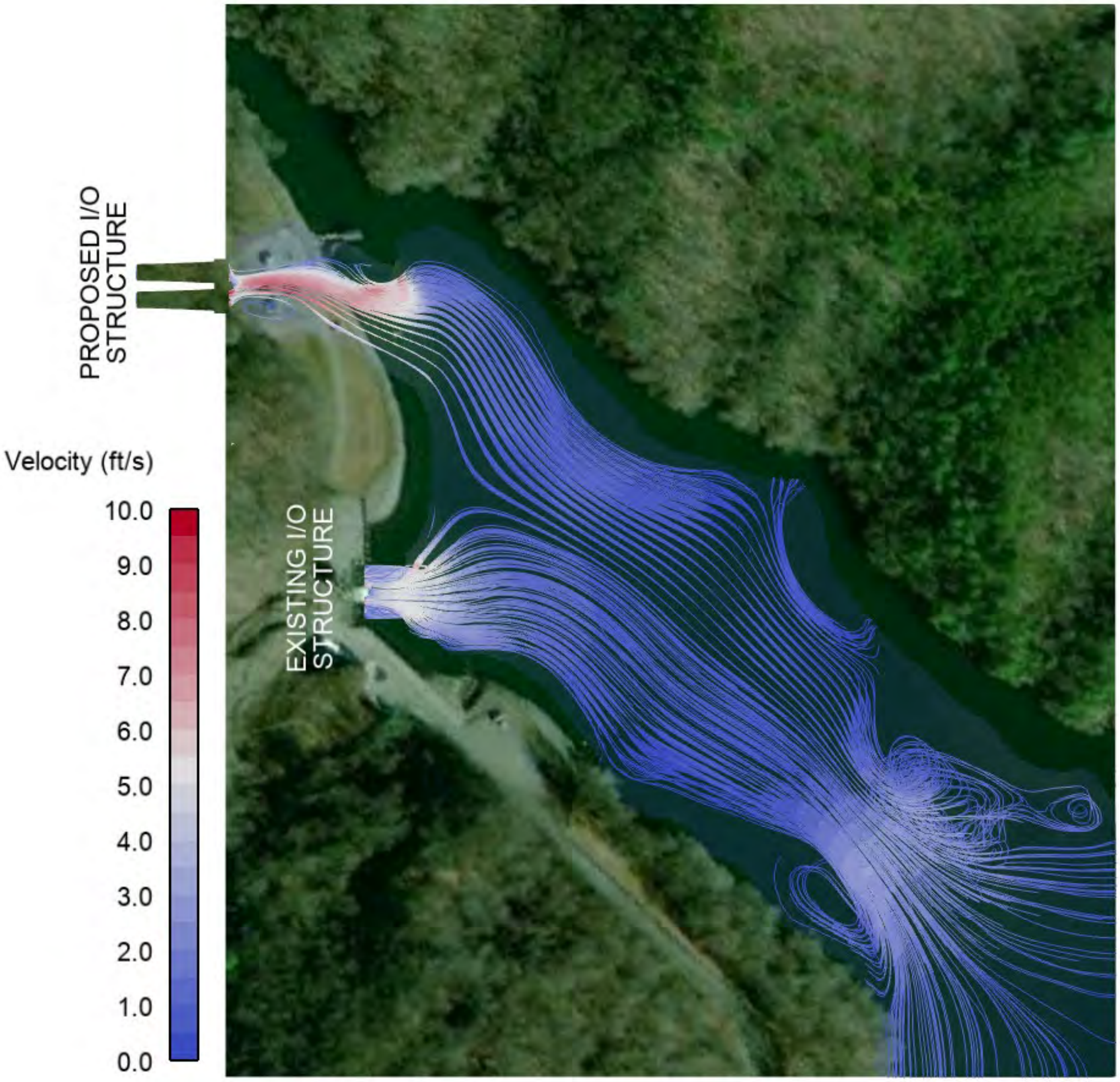

Figure 48. Case 7 (pumping - minimum reservoir elevation) Velocity Streamlines under Normal Minimum Reservoir Elevation

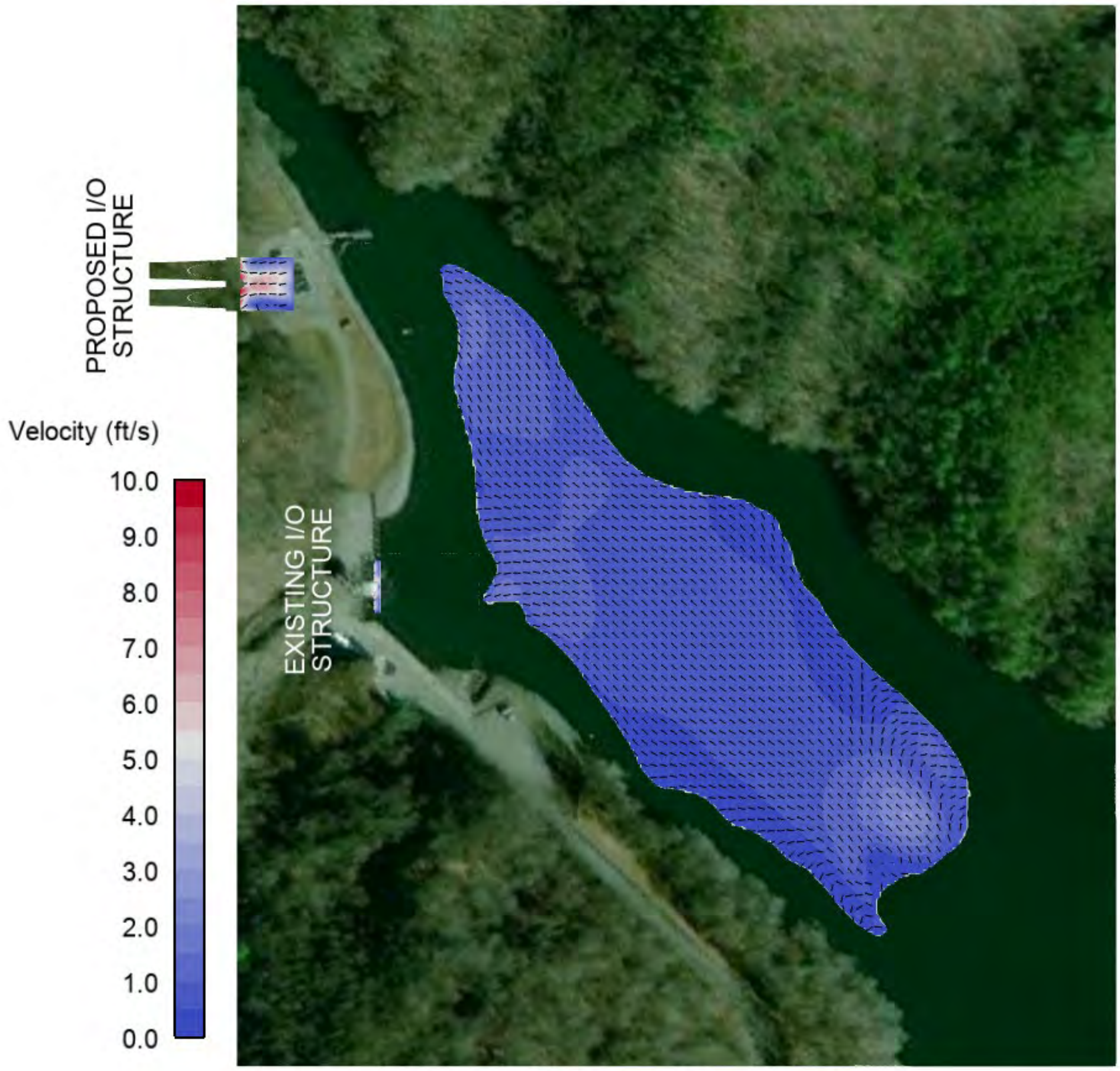

Figure 49. Case 7 (pumping - minimum reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

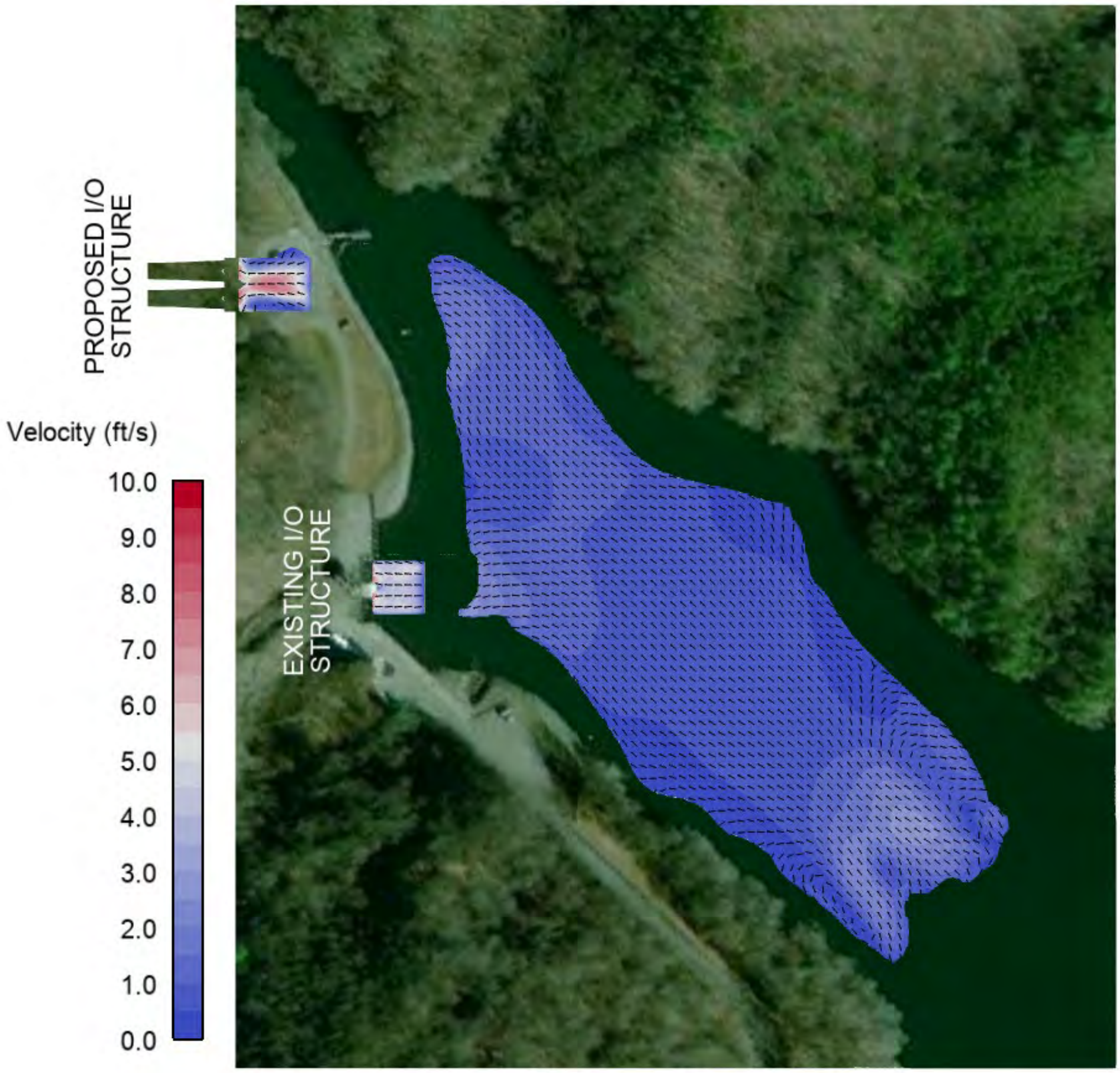

Figure 50. Case 7 (pumping - minimum reservoir elevation) Velocity Vectors at Elevation 1,050 ft msl

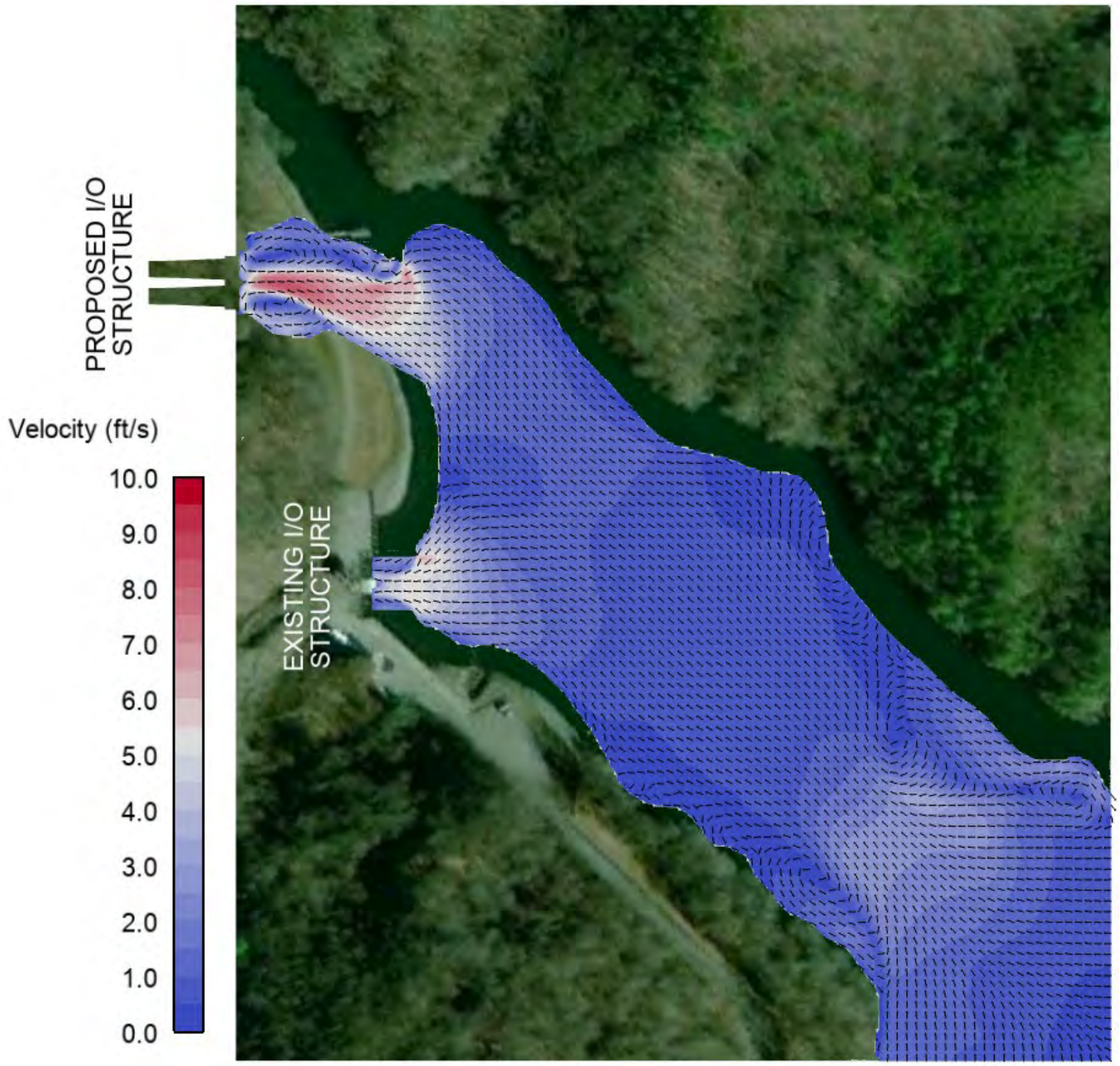

Figure 51. Case 7 (pumping - minimum reservoir elevation) Velocity Vectors at Elevation 1,080 ft msl

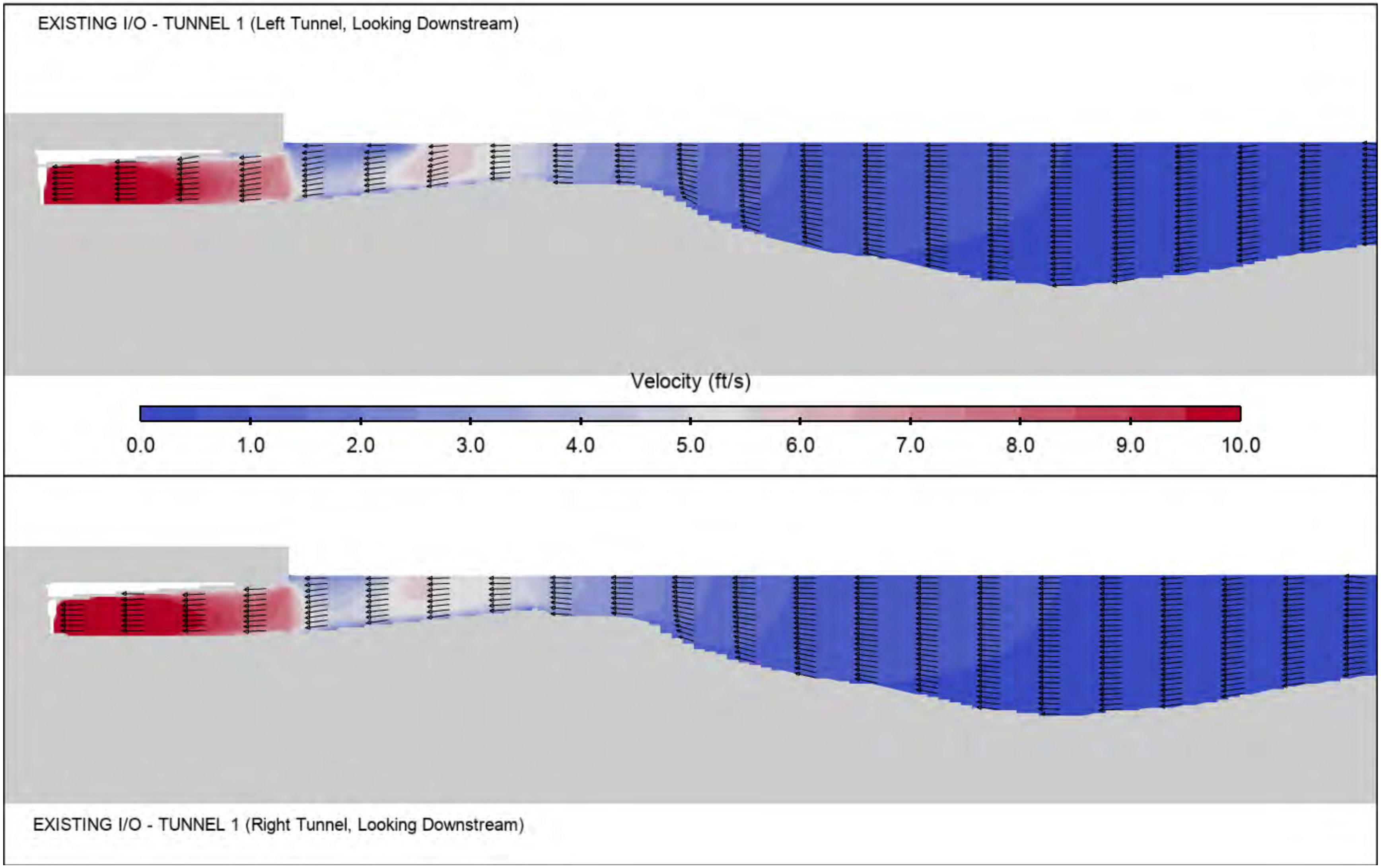

Figure 52. Case 7 (pumping - minimum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

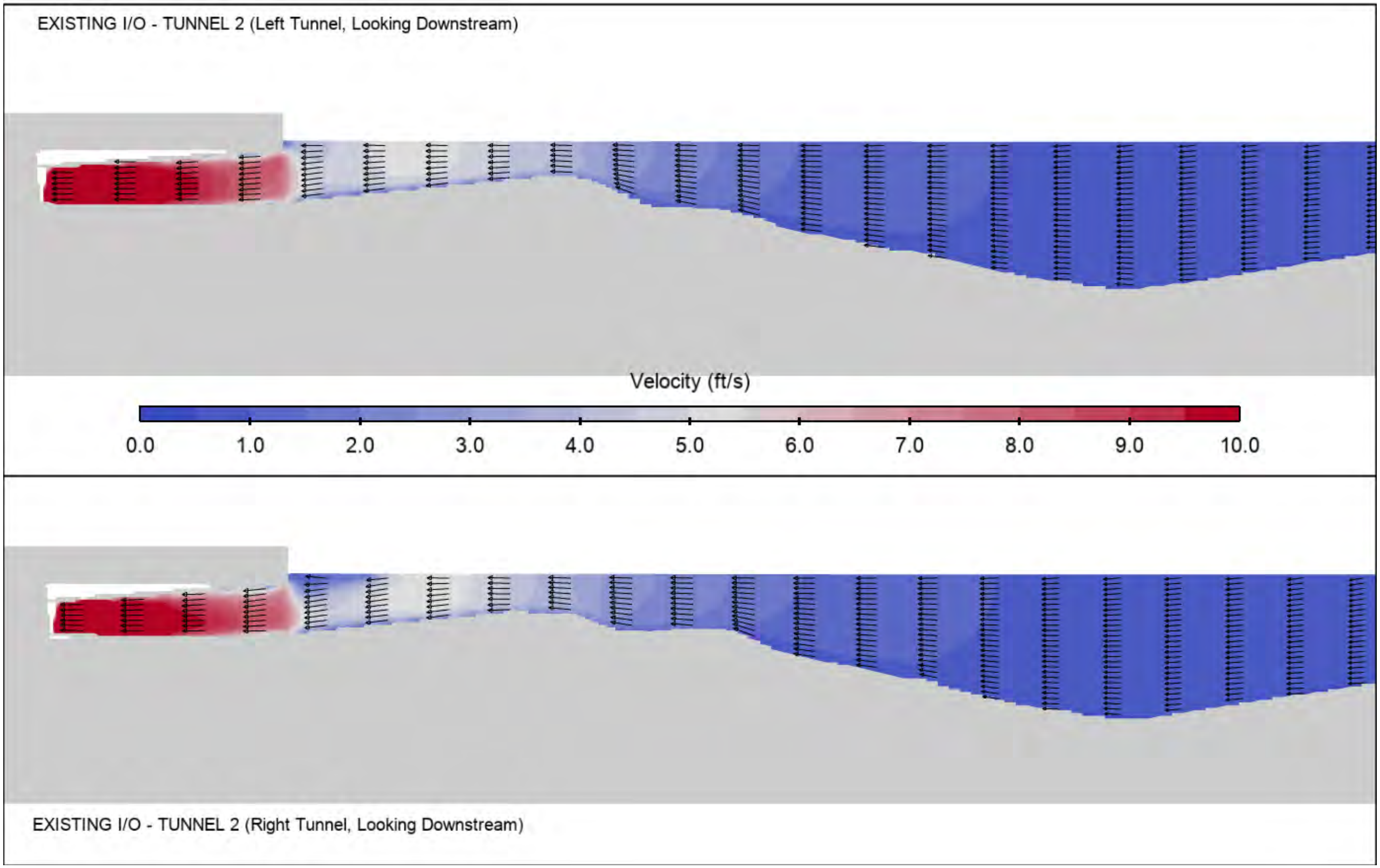

Figure 53. Case 7 (pumping - minimum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

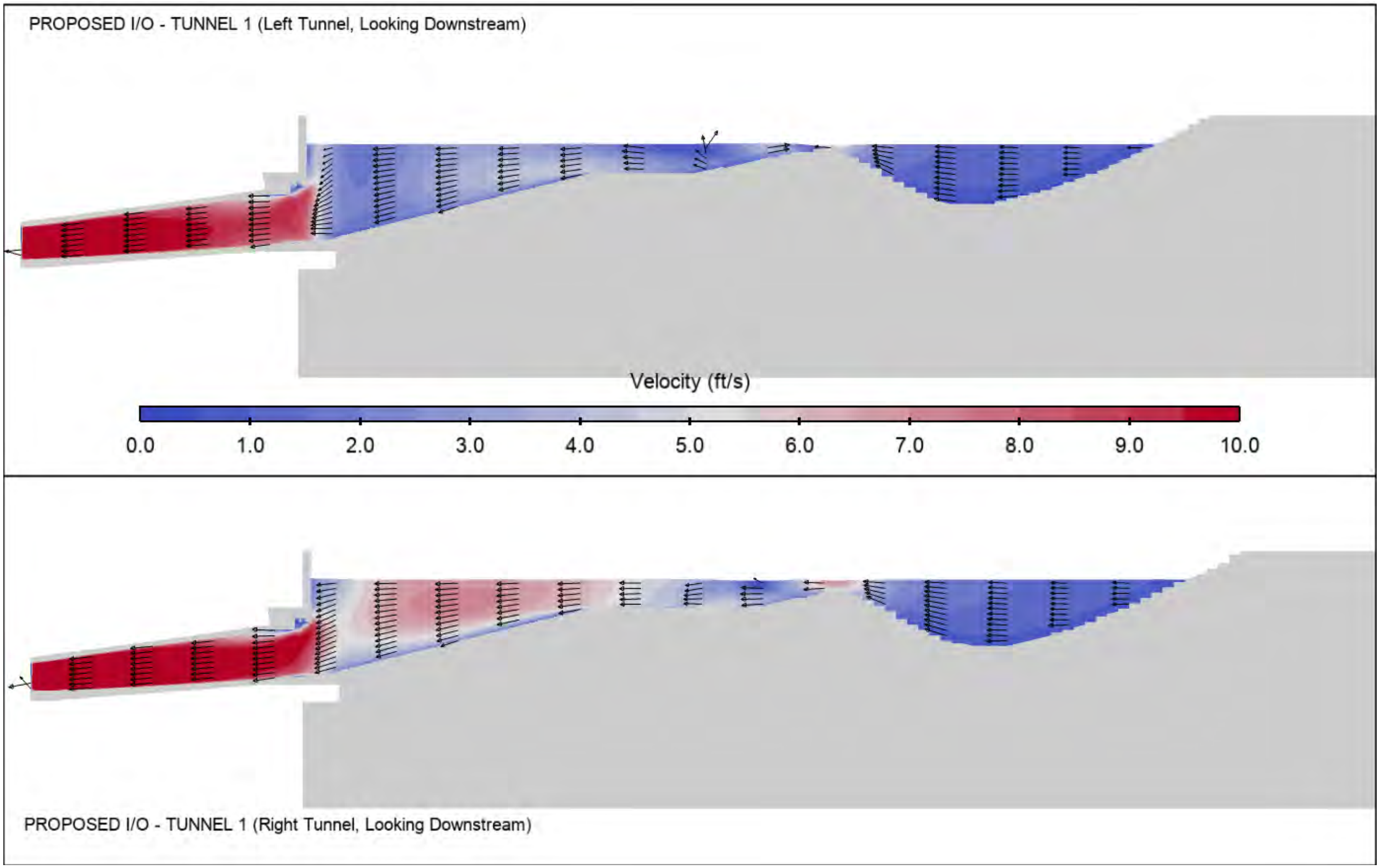

Figure 54. Case 7 (pumping - minimum reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

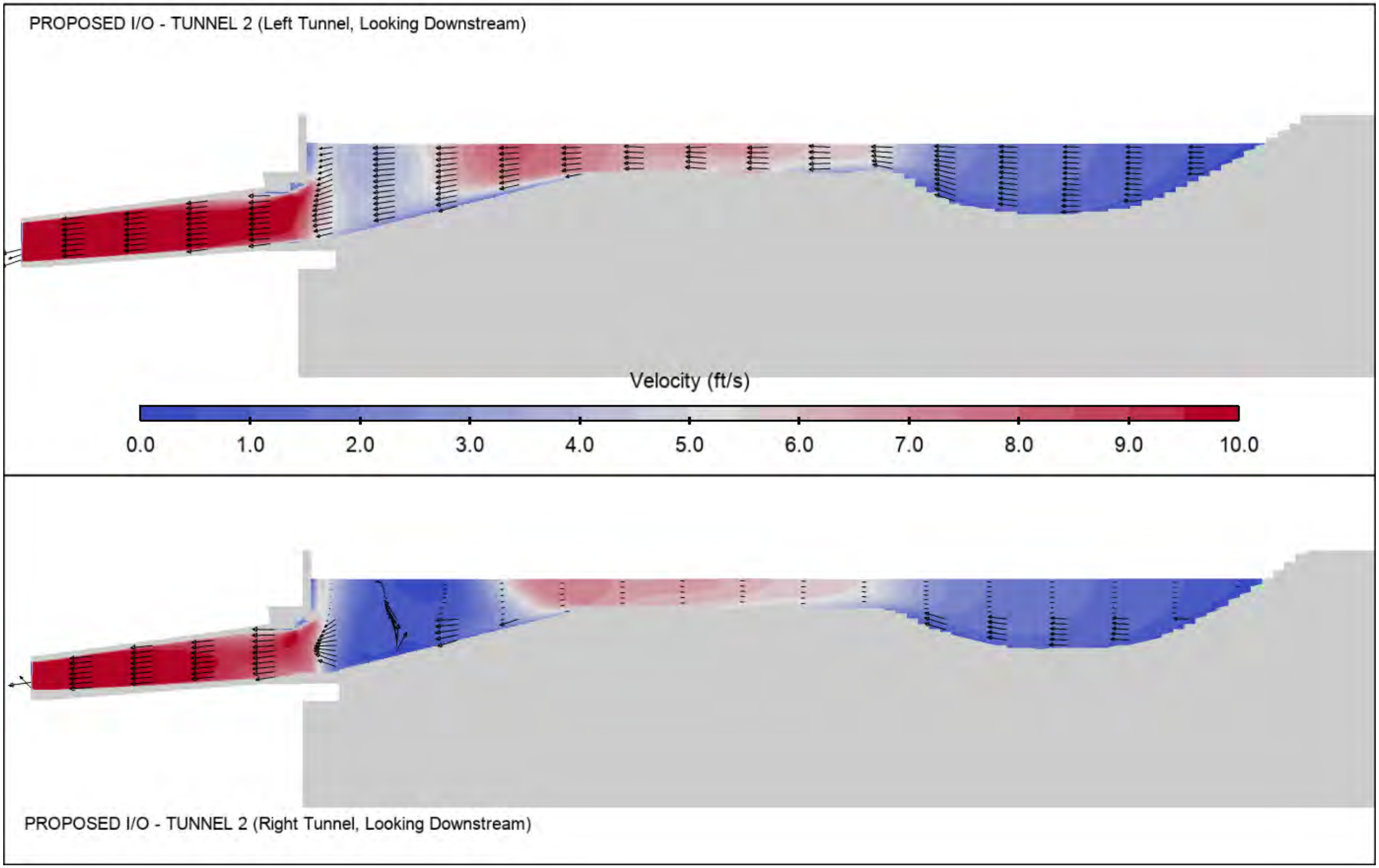

Figure 55. Case 7 (pumping - minimum reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

4.3.3 Case 8: Lake Jocassee Intermediate Reservoir Elevation 1,096 ft msl

Results of the proposed configuration at normal full reservoir elevation are presented on Figure 56 through Figure 64. Figure 56 shows the plan view of the streamlines. Flow from the proposed I/O structure approaches from the east bank, while flow entering the existing I/O structure approaches from the west bank. Velocities increase upstream of the I/O structures but are lower than velocities in the generation simulations.

Figure 57 through Figure 60 show slices of the velocity vectors at four elevations within the water column: 1,040 ft msl, 1,050 ft msl, 1,080 ft msl, and at the surface (i.e., 1,110 ft msl). The flow patterns at each depth are relatively similar throughout the water column. The water velocities near the submerged weir are less than 2.0 fps.

Figure 61 through Figure 63 show model slices of velocity vectors and magnitudes through the two existing and two proposed I/O structure tunnels centerlines, respectively. These slices show velocities on the east bank below 2.5 fps along tunnel centerlines.

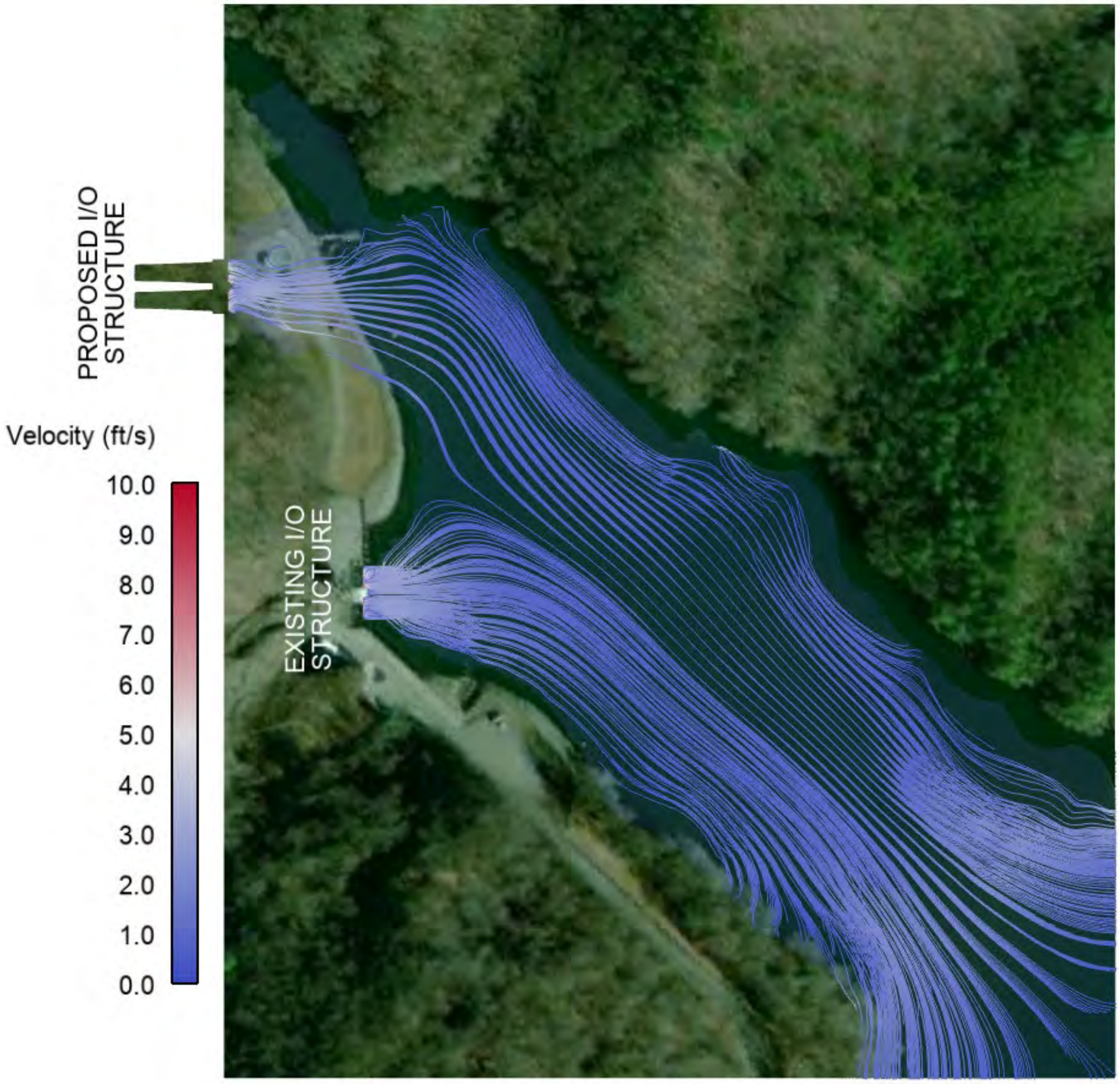

Figure 56. Case 8 (pumping - intermediate reservoir elevation) Velocity Streamlines at Normal Full Pool Elevation

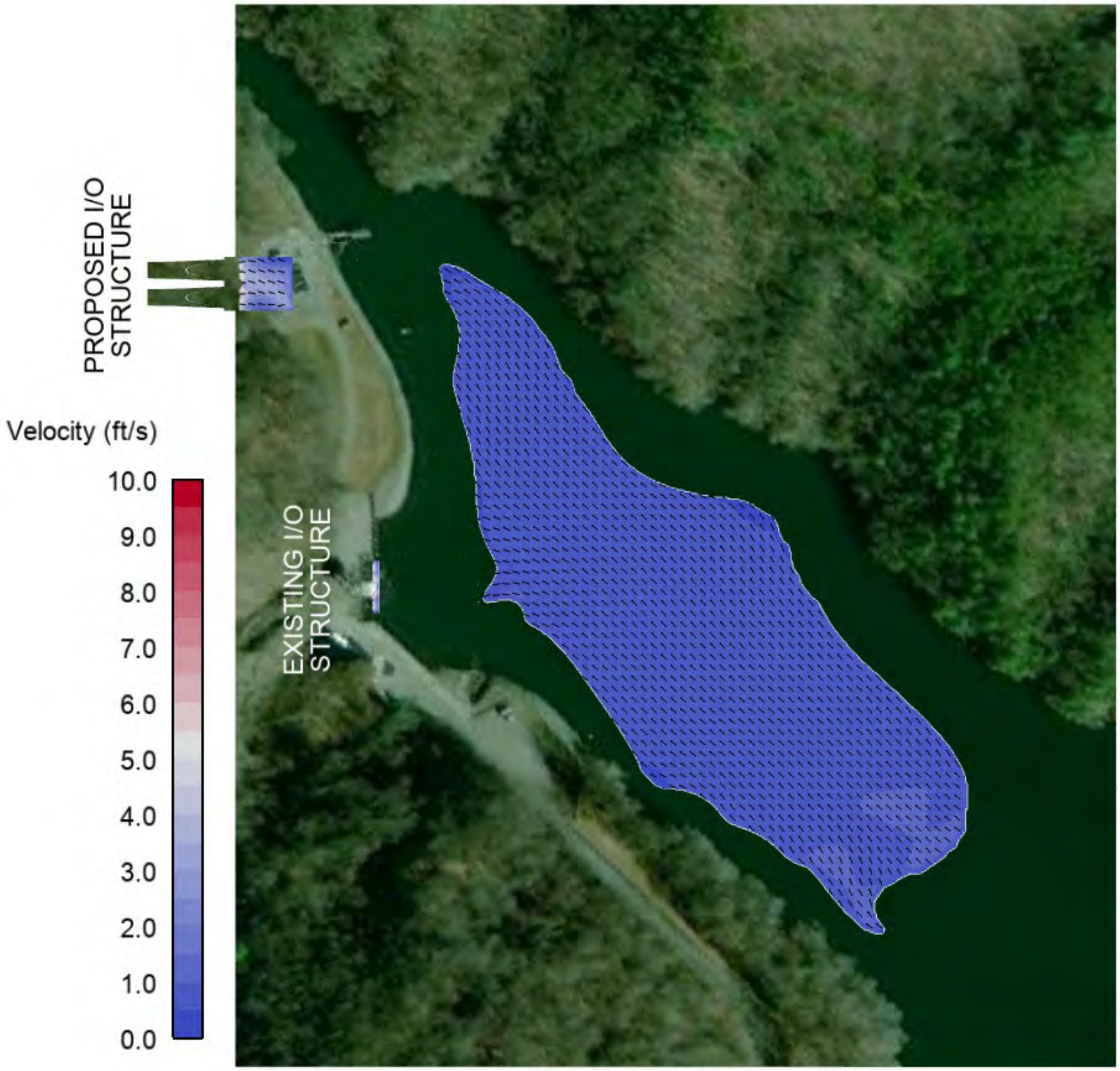

Figure 57. Case 8 (pumping - intermediate reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

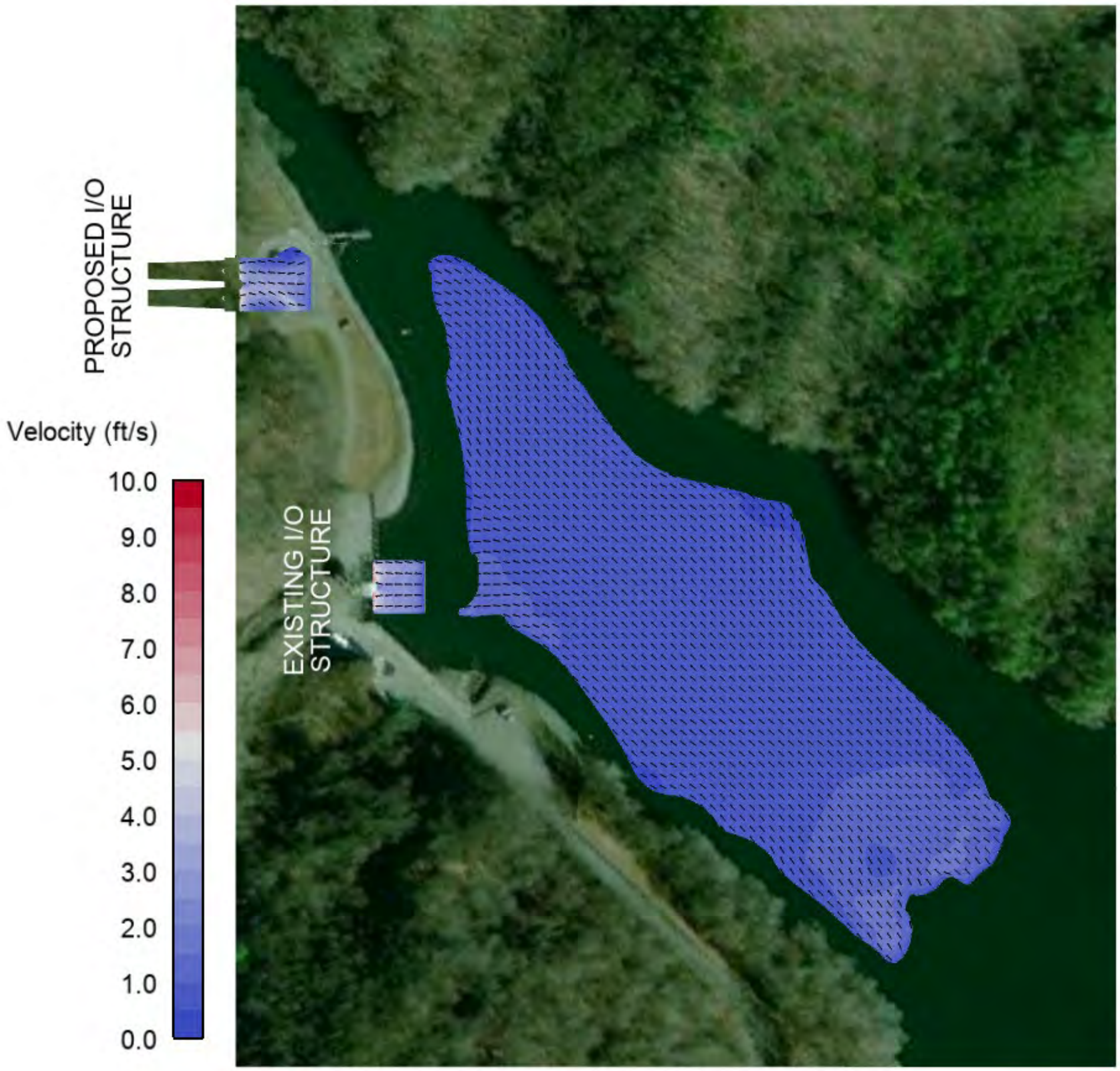

Figure 58. Case 8 (pumping - intermediate reservoir elevation) Velocity Vectors at Elevation 1,050 ft

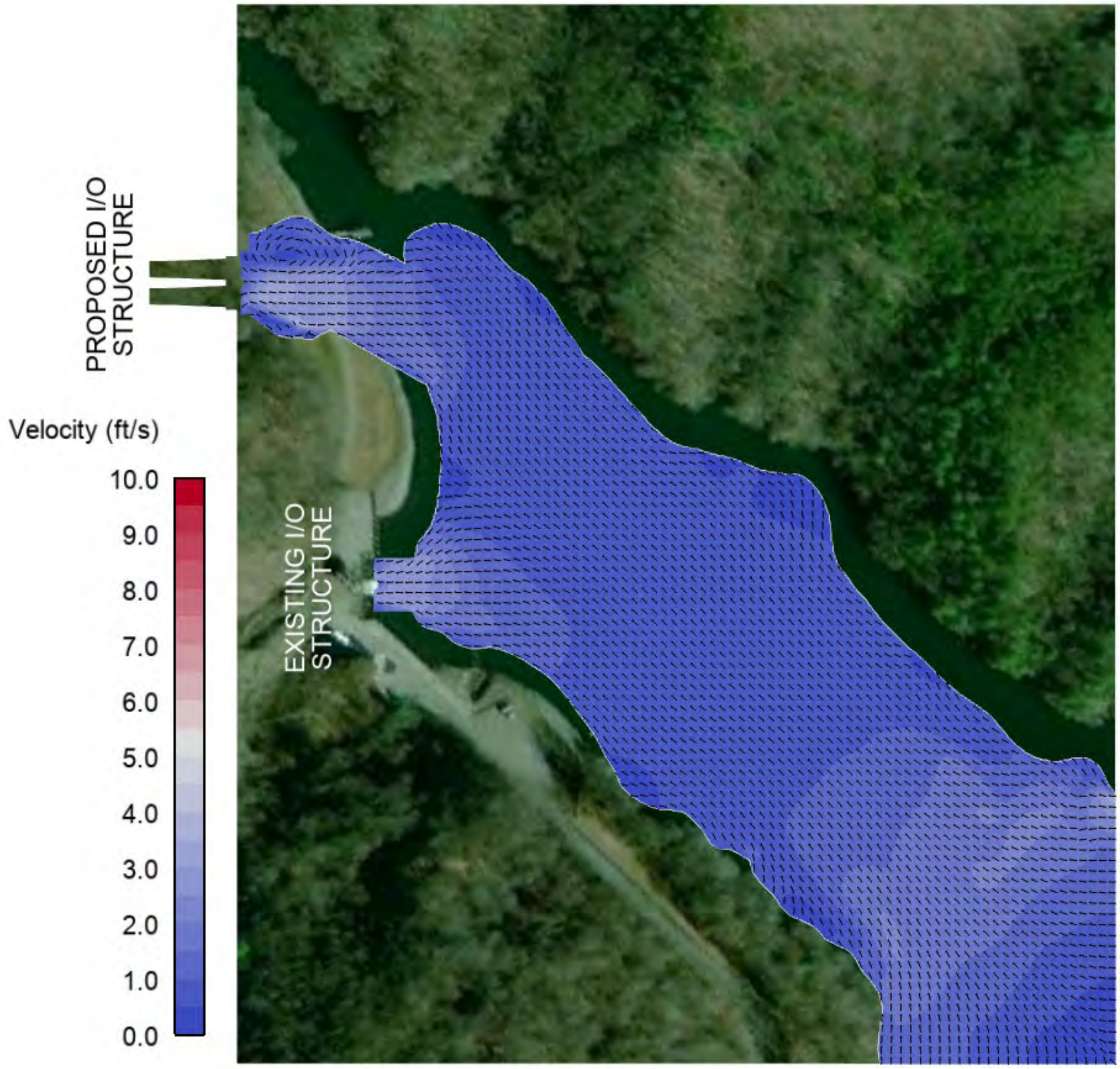

Figure 59. Case 8 (pumping - intermediate reservoir elevation) Velocity Vectors at Elevation 1,080 ft

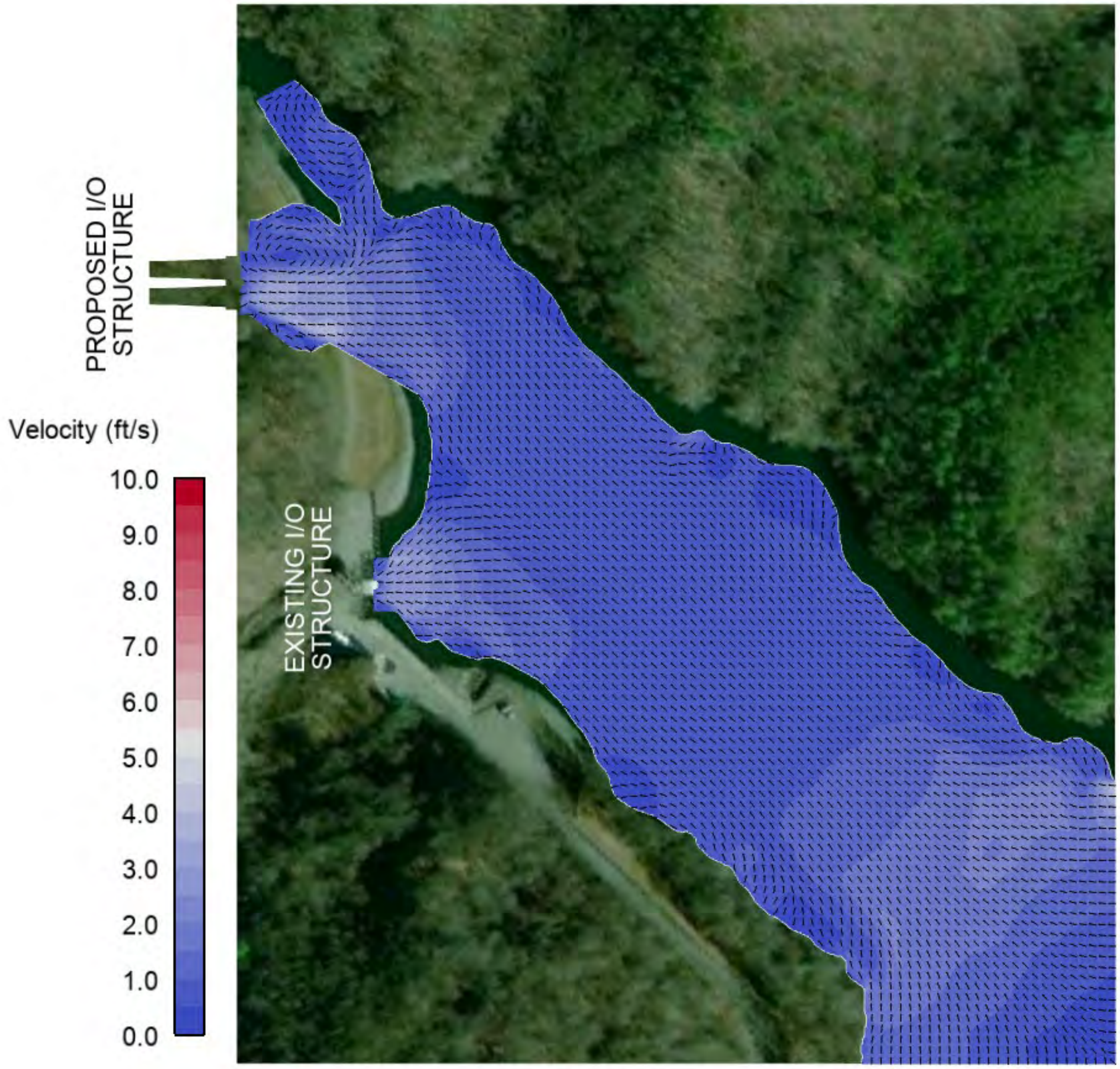

Figure 60. Case 8 (pumping - intermediate reservoir elevation) Velocity Vectors at Elevation 1,096 ft msl

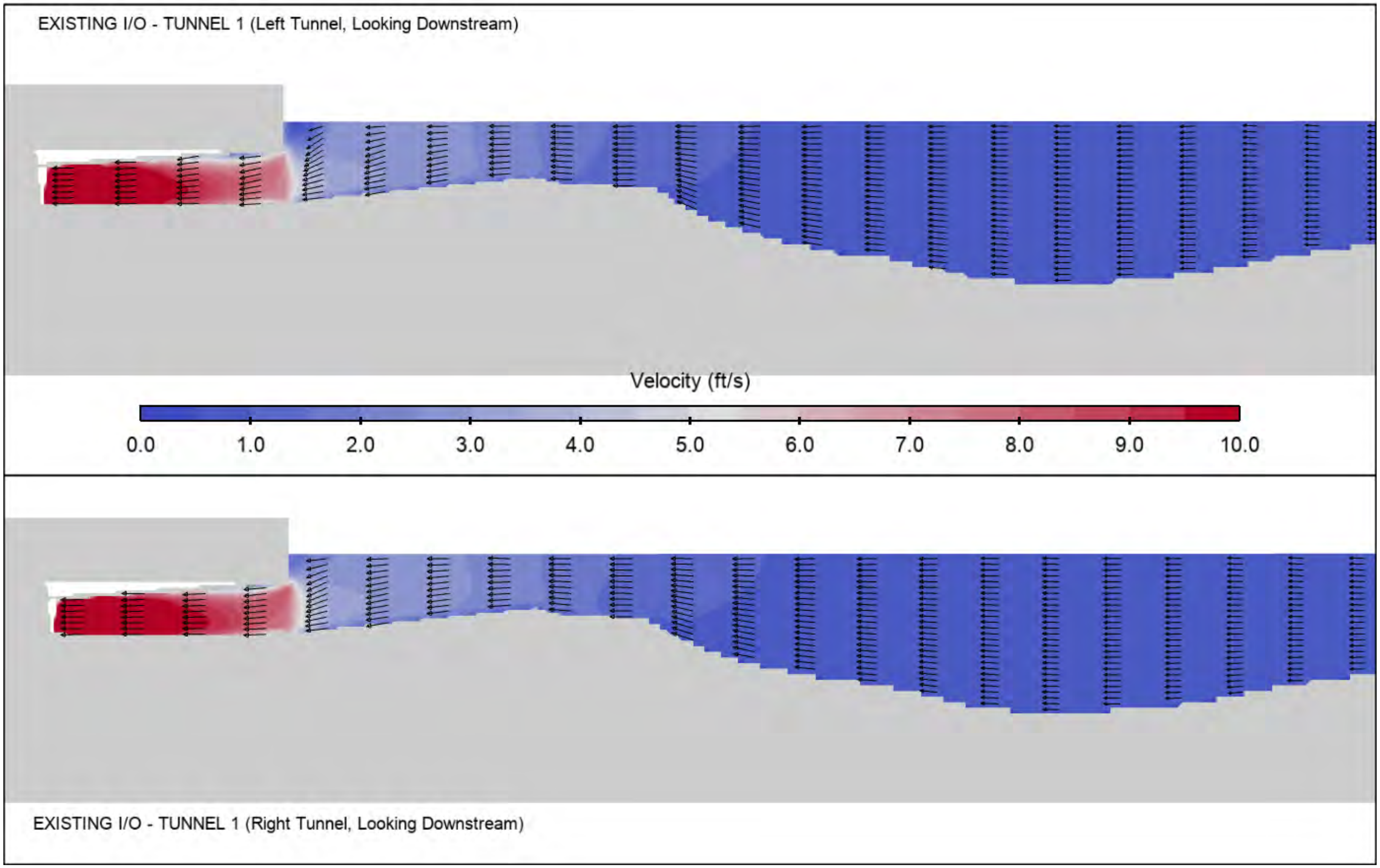

Figure 61. Case 8 (pumping - intermediate reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

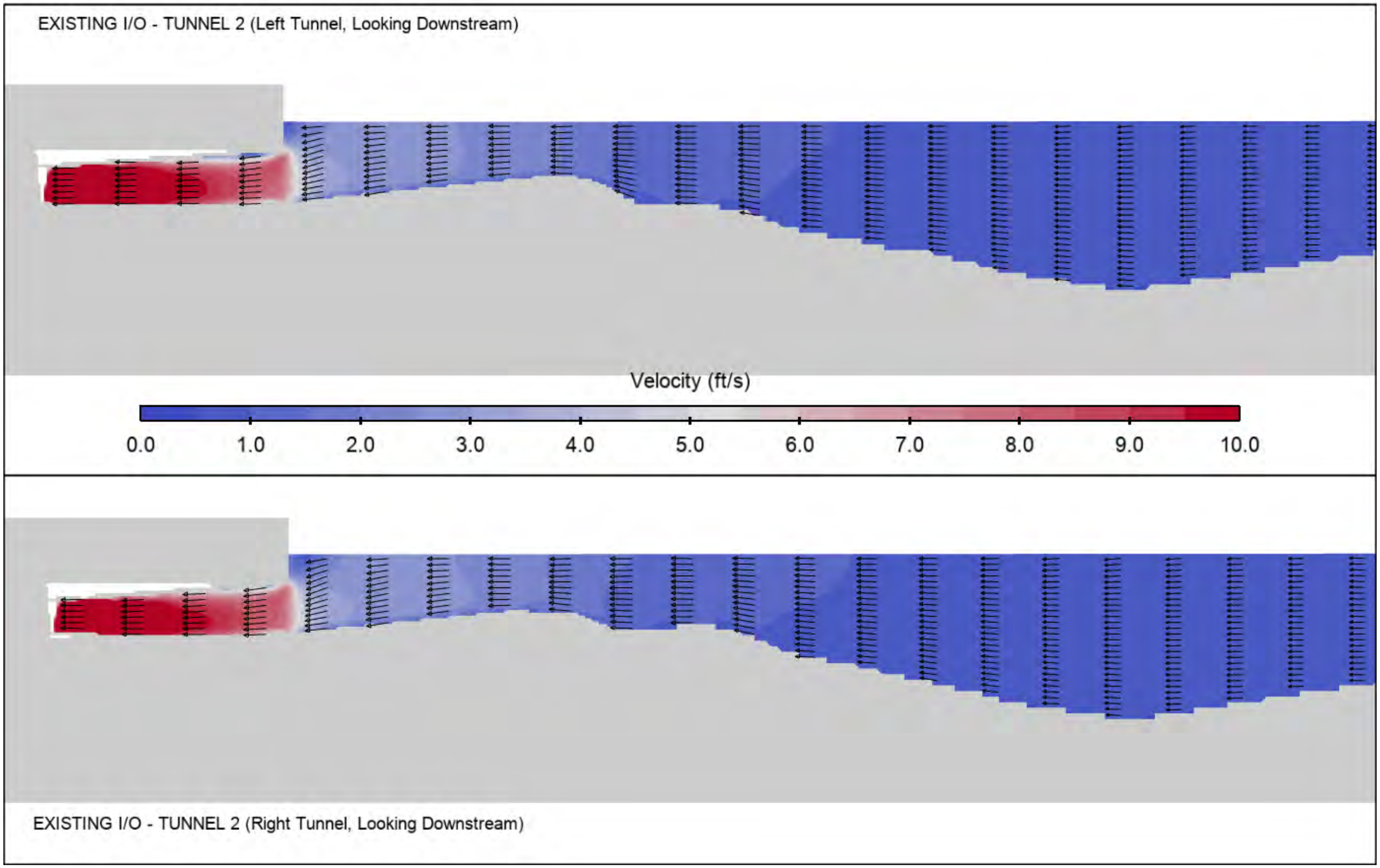

Figure 62. Case 8 (pumping - intermediate reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

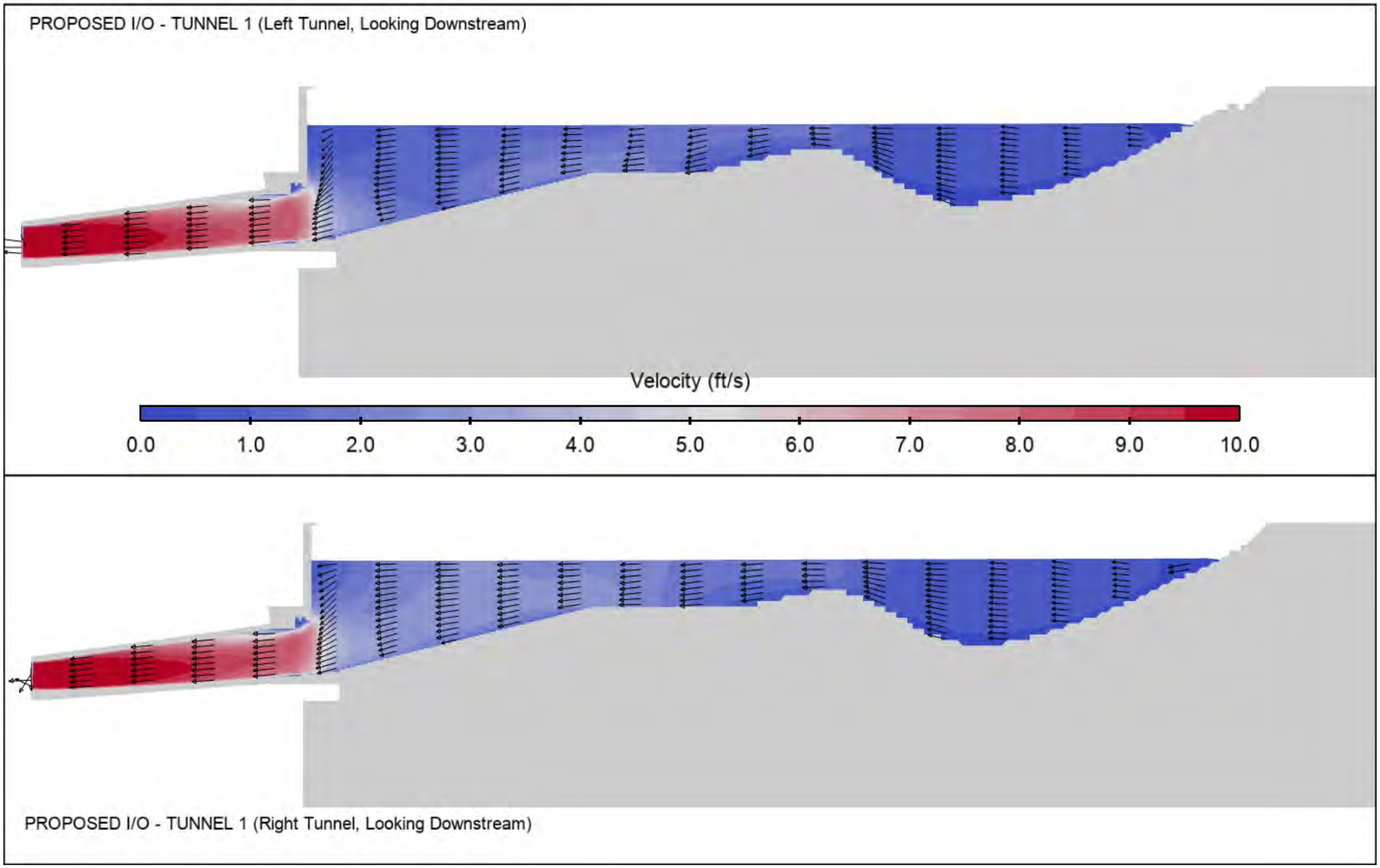

Figure 63. Case 8 (pumping - intermediate reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

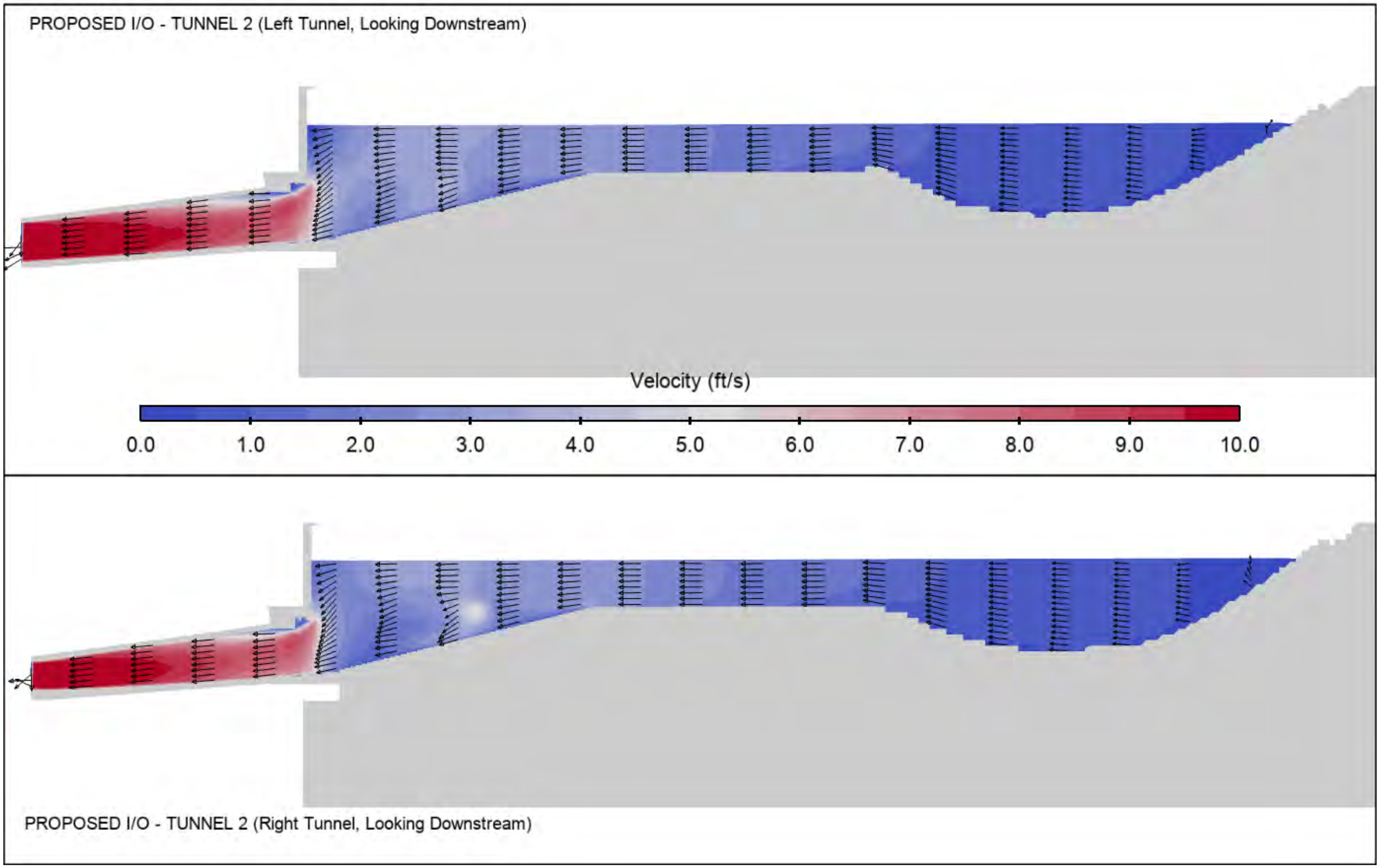

Figure 64. Case 8 (pumping - intermediate reservoir elevation) Slices through Proposed I/O Structure Tunnel Centerlines - Velocity Vectors

4.4 Construction Configuration - Cases 9 through 12 Generation and Pump Modes

Additional simulations were performed to evaluate the hydraulic conditions after the placement of the rock spoil (i.e., construction configuration) near the existing submerged weir. The construction configuration was modeled for both reservoir elevations and assuming full generation and pumping at the existing structure I/O structures (19,760 cfs [generation] or 16,240 cfs [pumping]). The analysis was carried out to determine impacts near the submerged weir and the hydraulic approach to the existing I/O structure.

4.4.1 Case 9: Lake Jocassee Normal Full Reservoir Elevation 1,110 ft msl - Generation

Results of the construction configuration at normal full reservoir elevation are presented on Figure 65 through Figure 71. Figure 65 shows the plan view of the streamlines. Flow from the existing I/O structure creates multiple large, low velocity areas of recirculation as flows extend into the reservoir. Velocities increase upstream of submerged weir but were less than 2.0 fps.

Figure 66 through Figure 69 show slices of the velocity vectors at four elevations within the water column: 1,040 ft msl, 1,050 ft msl, 1,080 ft msl, and at the surface (i.e., 1,110 ft msl). The flow patterns at each depth are relatively similar throughout the water column. The water velocities near the submerged weir were less than 2.0 fps.

Figure 70 and Figure 71 show model slices of velocity vectors and magnitudes through the two existing I/O structure tunnels centerlines. These slices show velocities on the east bank below 1.5 fps along tunnel centerlines.

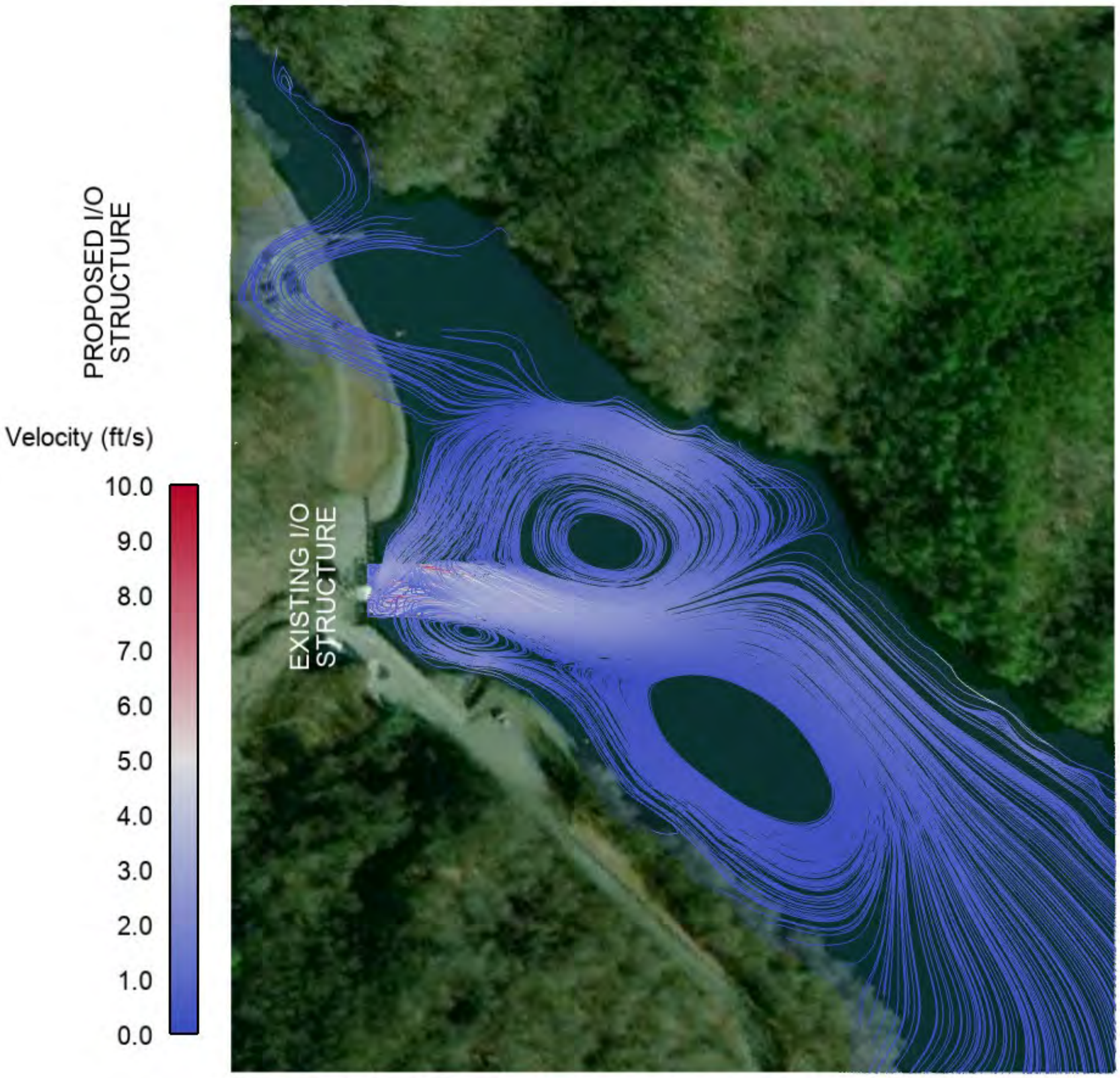

Figure 65. Case 9 (generating - maximum reservoir elevation) Velocity Streamlines at Normal Full Pool Elevation

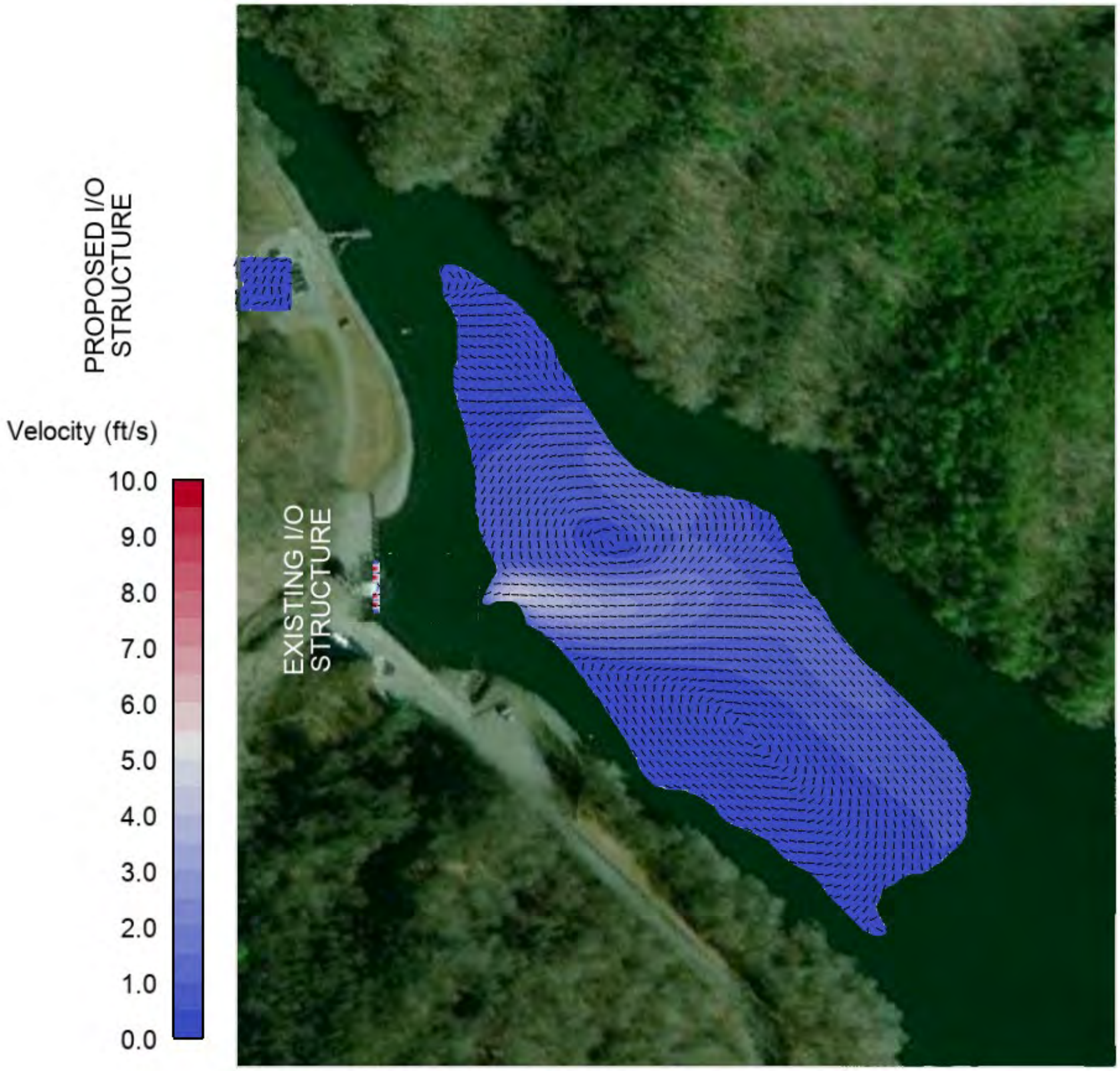

Figure 66. Case 9 (generating - maximum reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

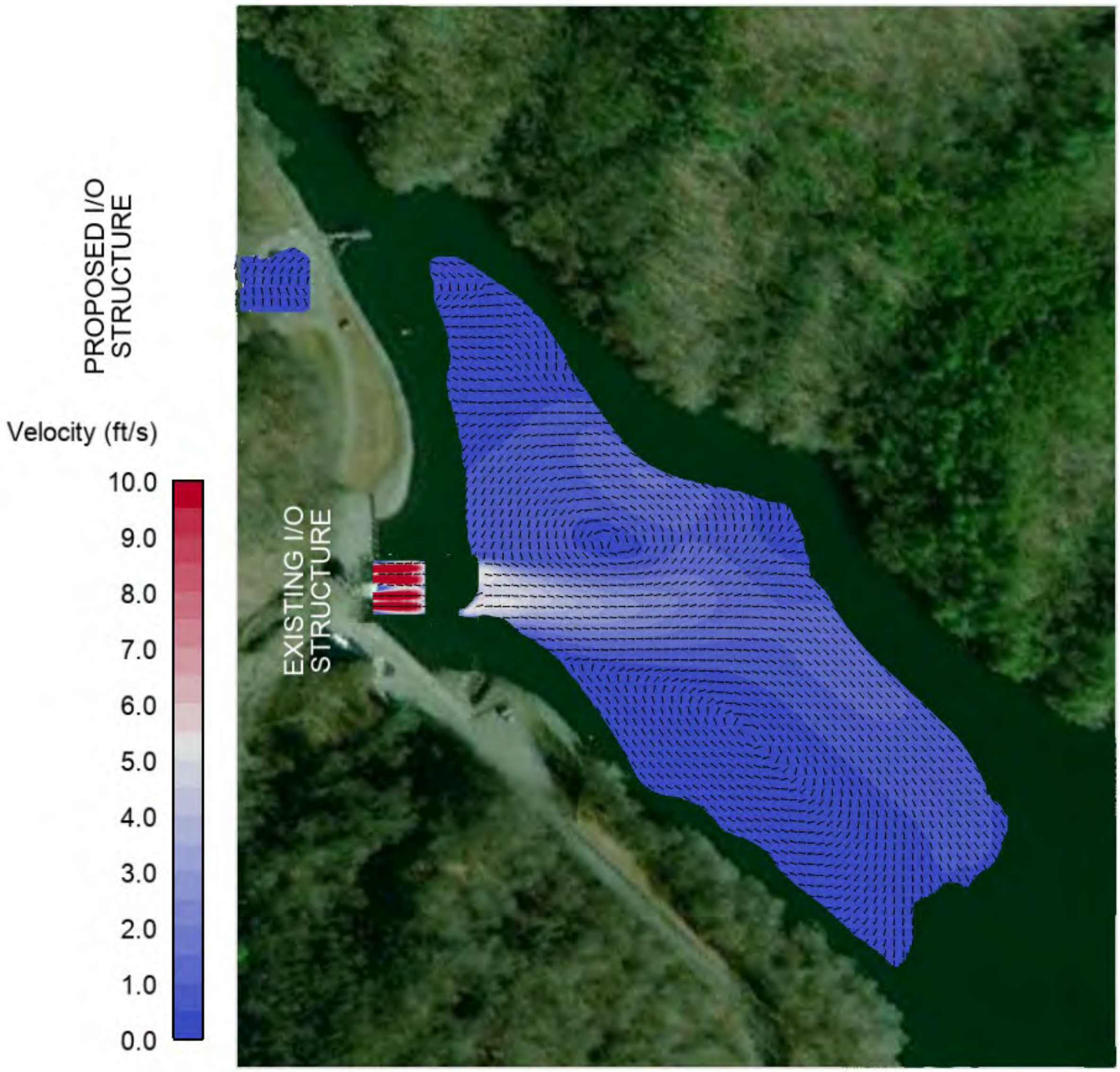

Figure 67. Case 9 (generating - maximum reservoir elevation) Velocity Vectors at Elevation 1,050 ft

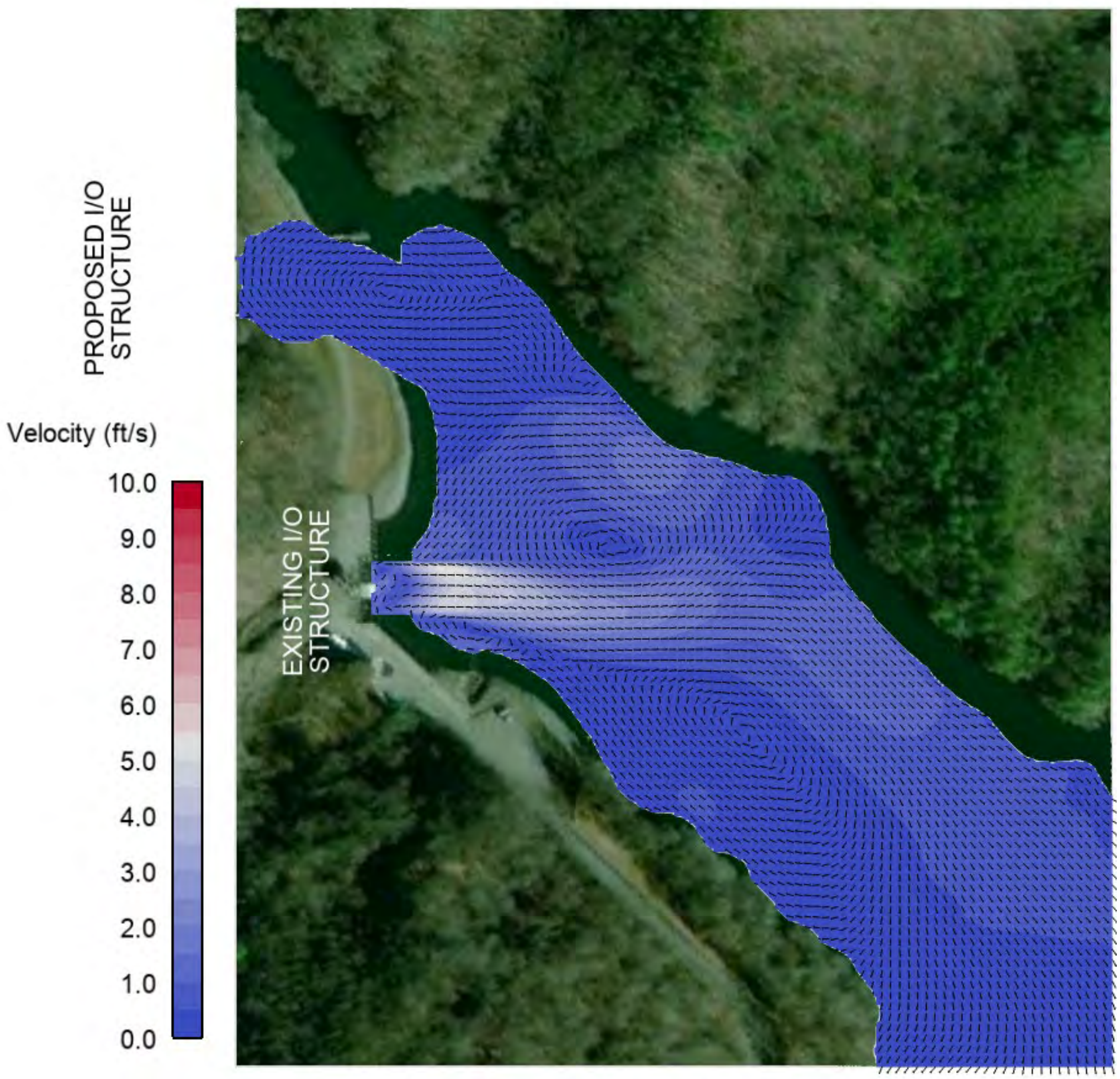

Figure 68. Case 9 (generating - maximum reservoir elevation) Velocity Vectors at Elevation 1,080 ft

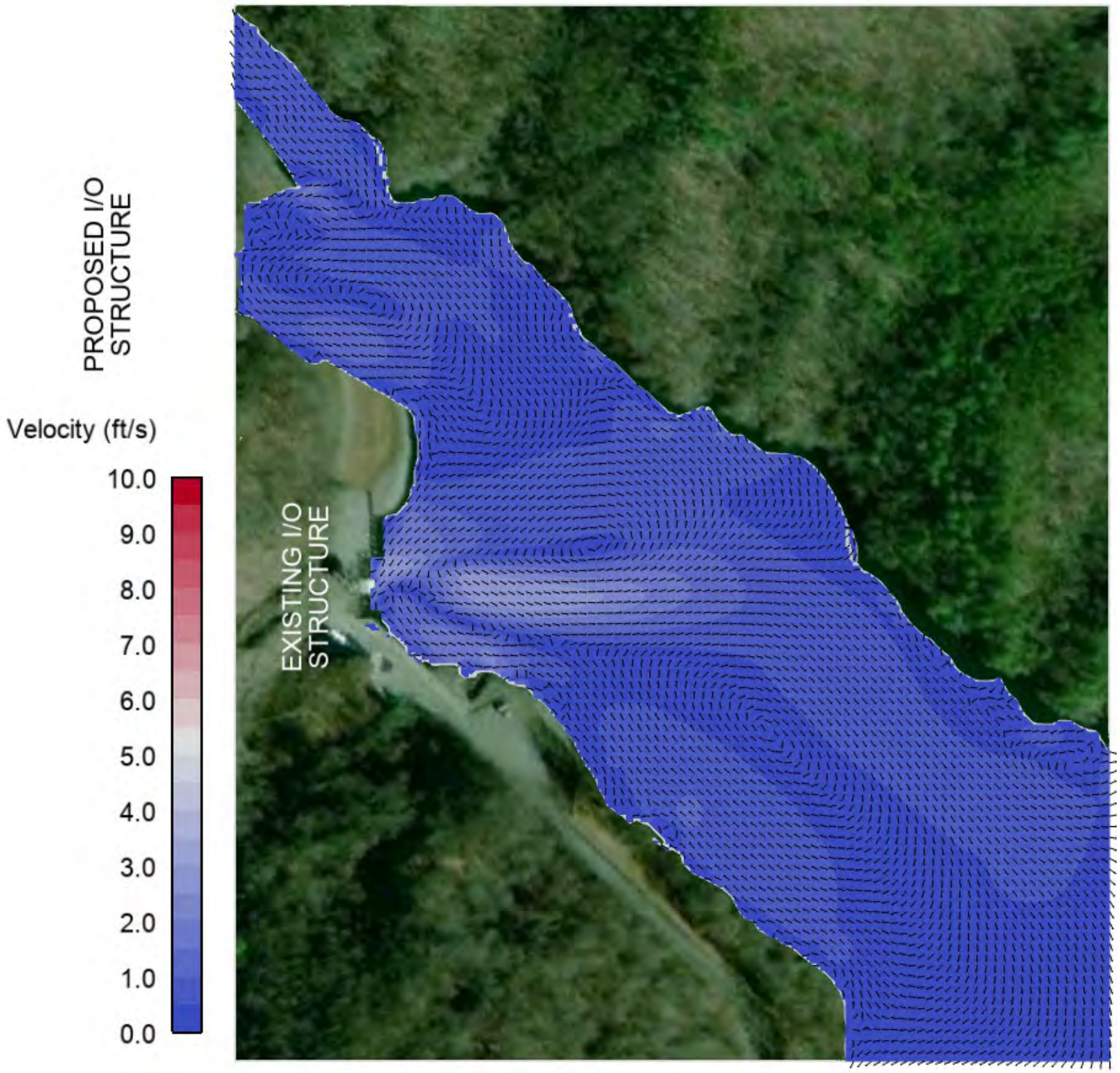

Figure 69. Case 9 (generating - maximum reservoir elevation) Velocity Vectors at Elevation 1,110 ft msl

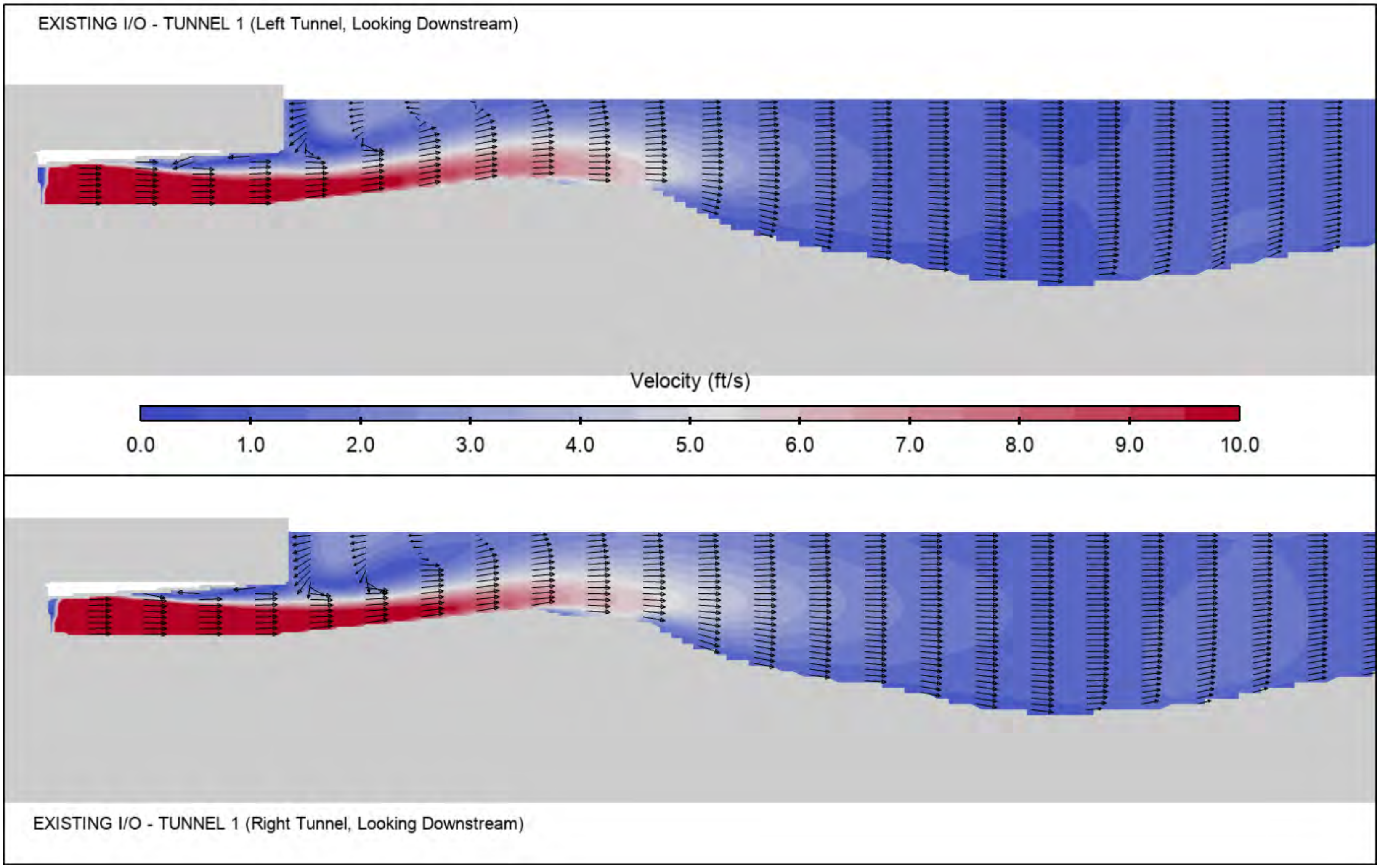

Figure 70. Case 9 (generating - maximum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

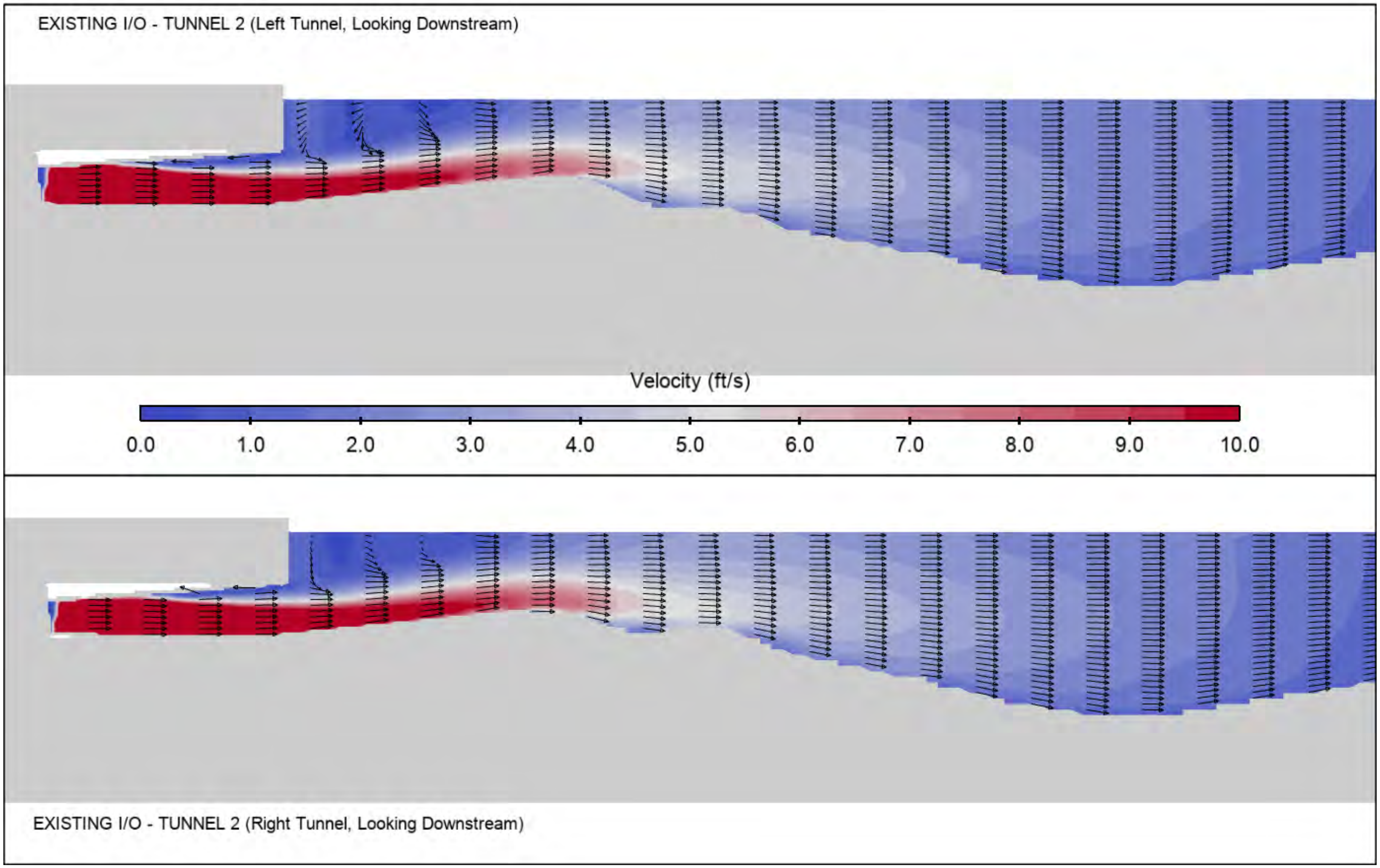

Figure 71. Case 9 (generating - maximum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

4.4.2 Case 10: Lake Jocassee Normal Minimum Reservoir Elevation 1080 ft msl - Generation

Results of the construction configuration at normal minimum reservoir elevation are presented on Figure 72 through Figure 77. Figure 72 shows the plan view of the streamlines. Velocities are higher near the submerged weir due to the decreased depth.

Figure 73 through Figure 75 show slices of the velocity vectors at four elevations within the water column: 1,040 ft msl, 1,050 ft msl, and at the surface (i.e., 1,080 ft msl). The flow patterns at each depth are relatively similar throughout the water column. The water velocities near the submerged weir were less than 2.5 fps.

Figure 76 and Figure 77 show model slices of velocity vectors and magnitudes through the two existing I/O structure tunnels centerlines. These slices show velocities on the east bank below 2.5 fps along tunnel centerlines.

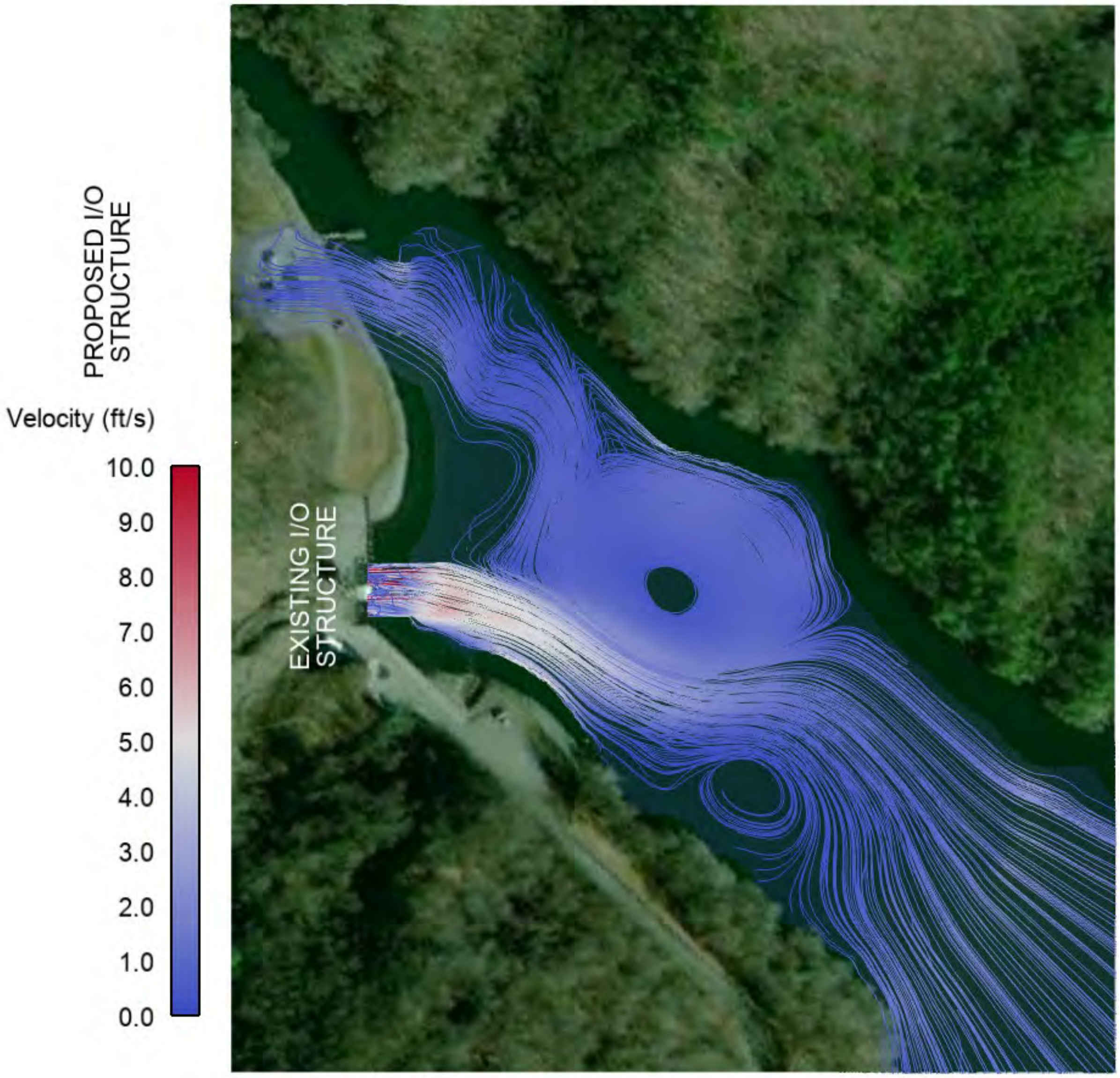

Figure 72. Case 10 (generating - minimum reservoir elevation) Velocity Streamlines at Normal Full Pool Elevation

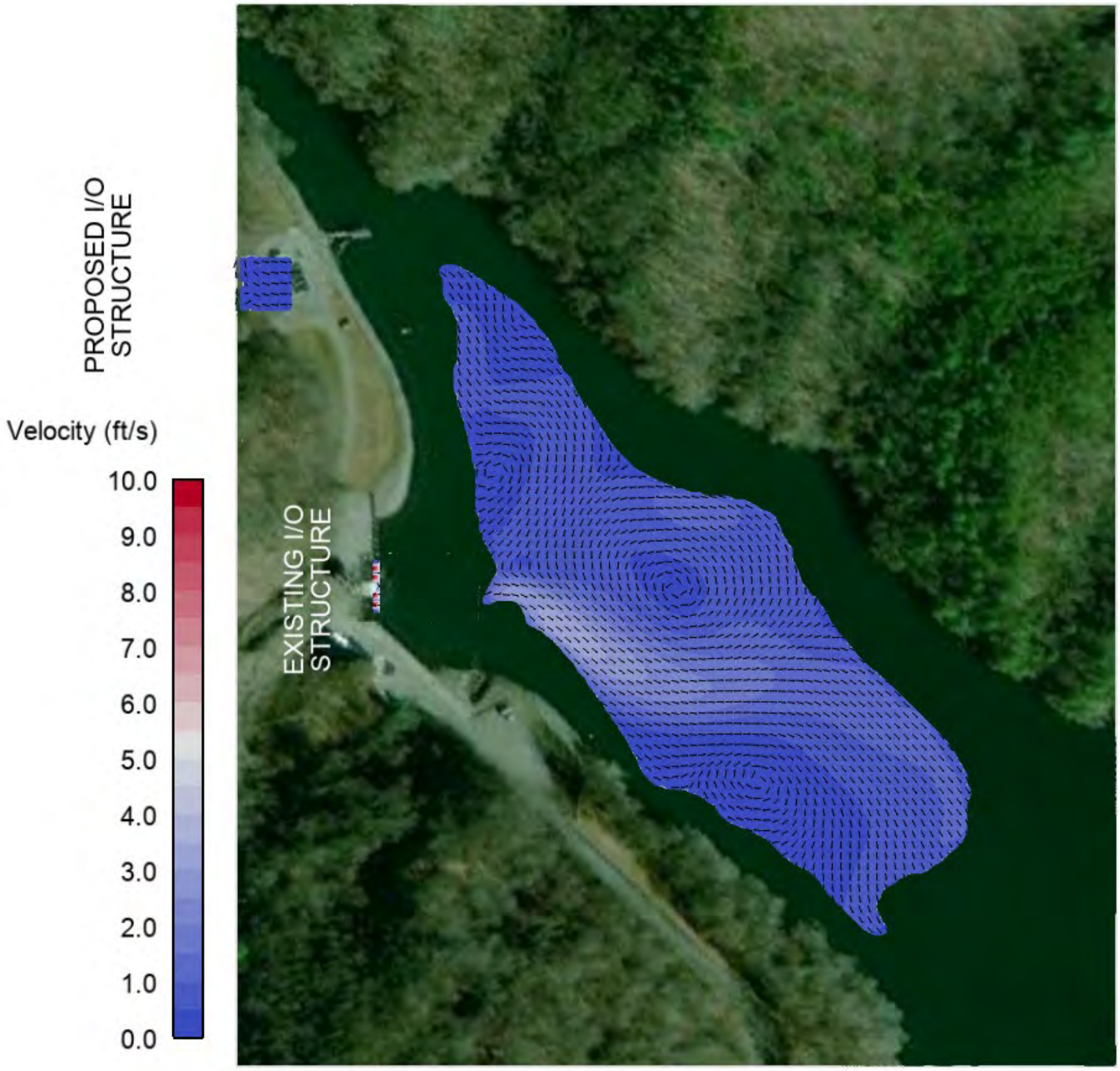

Figure 73. Case 10 (generating - minimum reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

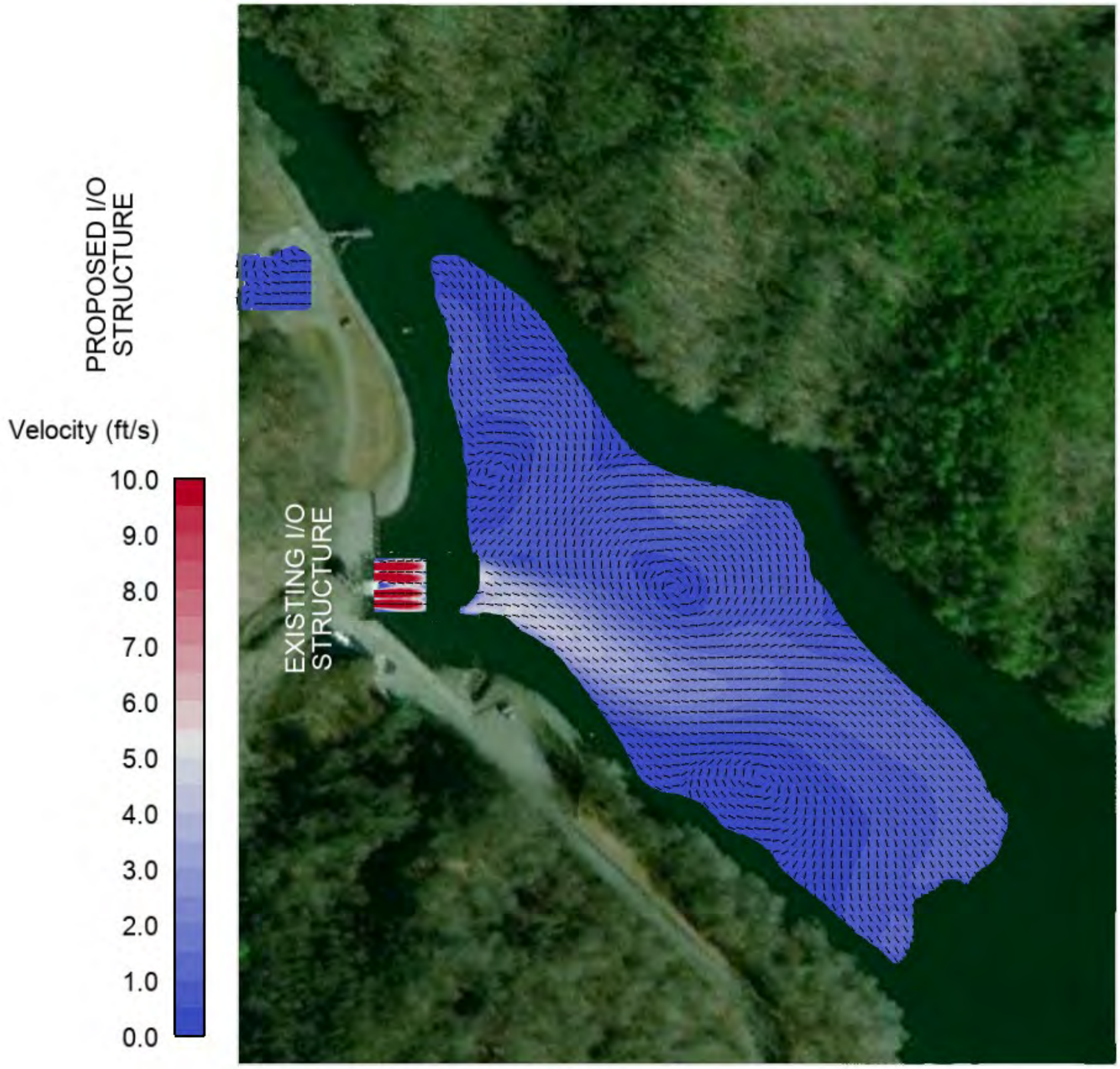

Figure 74. Case 10 (generating - minimum reservoir elevation) Velocity Vectors at Elevation 1,050 ft

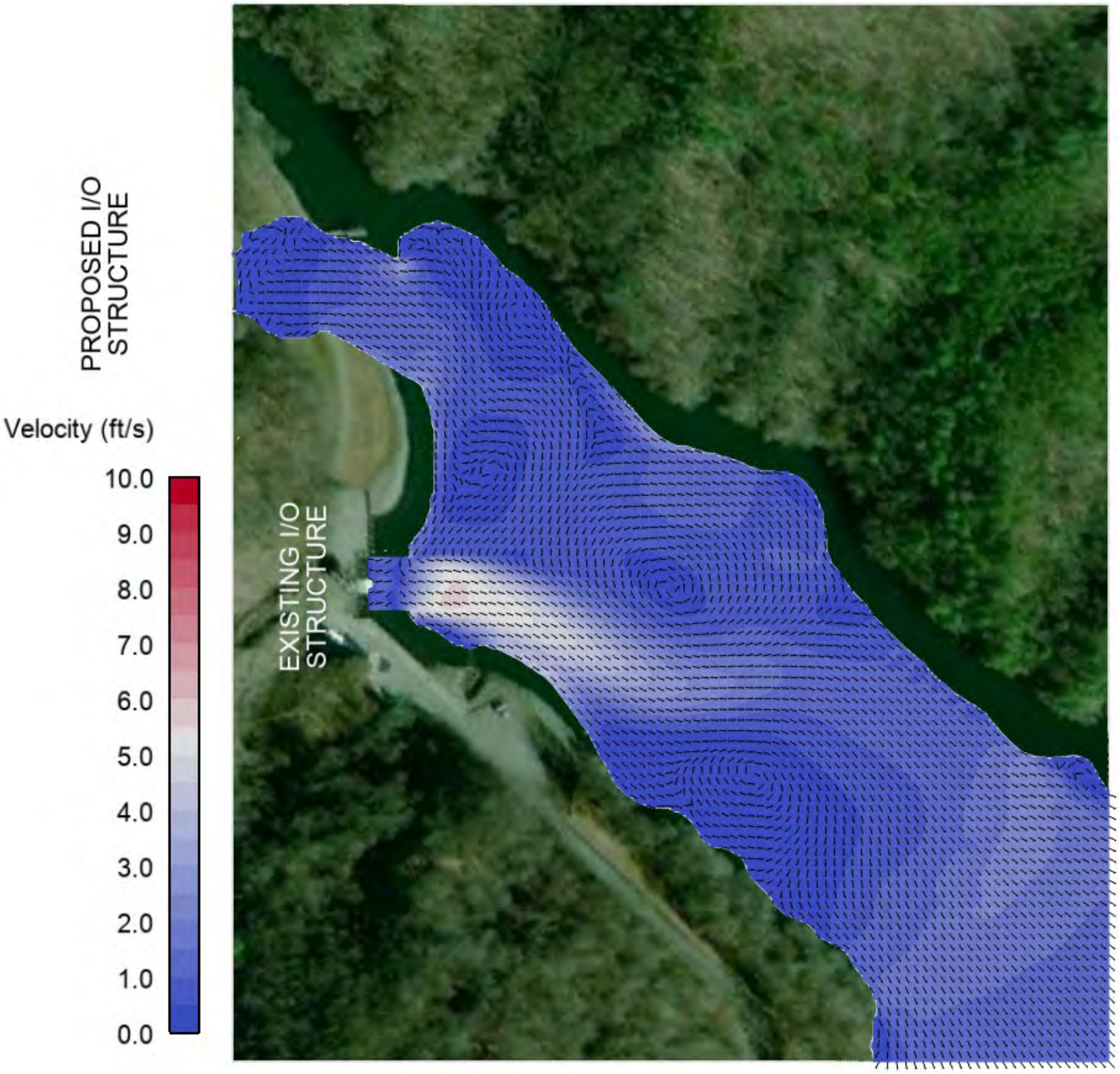

Figure 75. Case 10 (generating - minimum reservoir elevation) Velocity Vectors at Elevation 1,080 ft

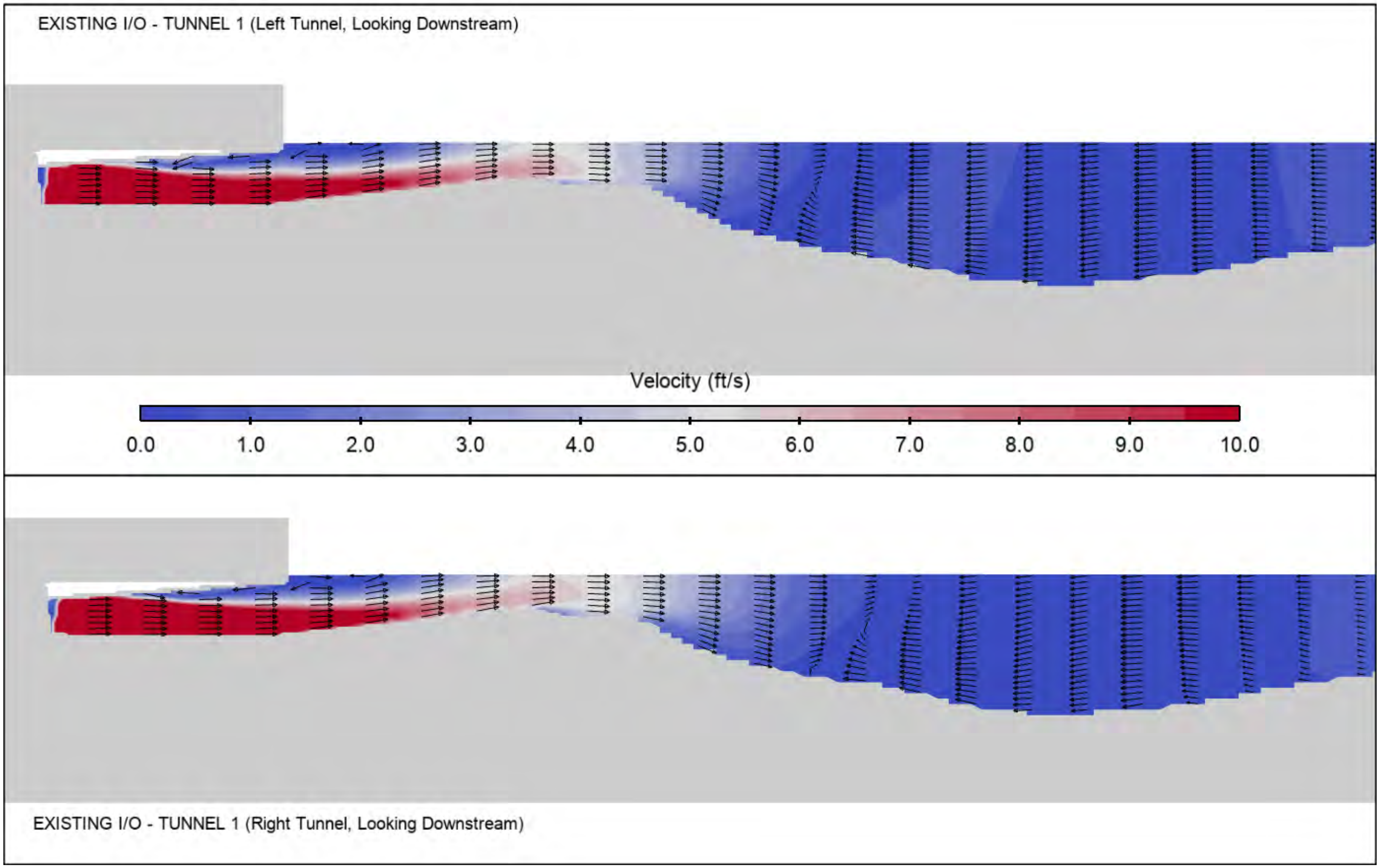

Figure 76. Case 10 (generating - minimum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

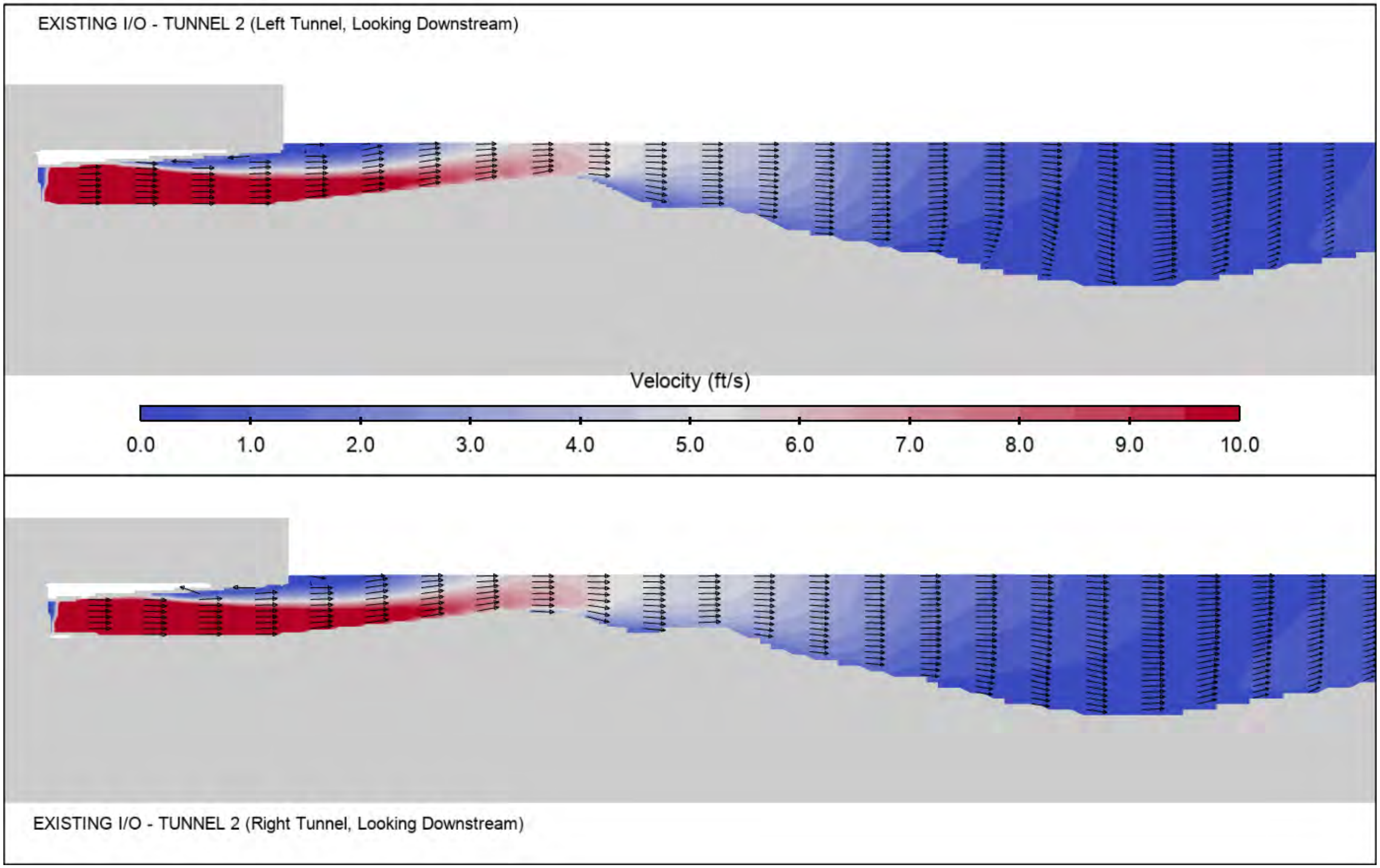

Figure 77. Case 10 (generating - minimum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

4.4.3 Case 11: Lake Jocassee Normal Full Reservoir Elevation 1,110 ft msl - Pumping

Results of the construction configuration and pumping at normal full reservoir elevation are presented on Figure 78 through Figure 84. Figure 78 shows the plan view of the streamlines. Velocities increase as flow approaches the existing I/O structure.

Figure 79 through Figure 82 show slices of the velocity vectors at four elevations within the water column: 1,040 ft msl, 1,050 ft msl, 1,080 ft msl, and at the surface (i.e., 1,110 ft msl). The flow patterns at each depth are relatively similar throughout the water column. The water velocities near the submerged weir were less than 1.5 fps.

Figure 83 and Figure 84 show model slices of velocity vectors and magnitudes through the two existing I/O structure tunnels centerlines. These slices show velocities on the east bank below 2.5 fps along tunnel centerlines.

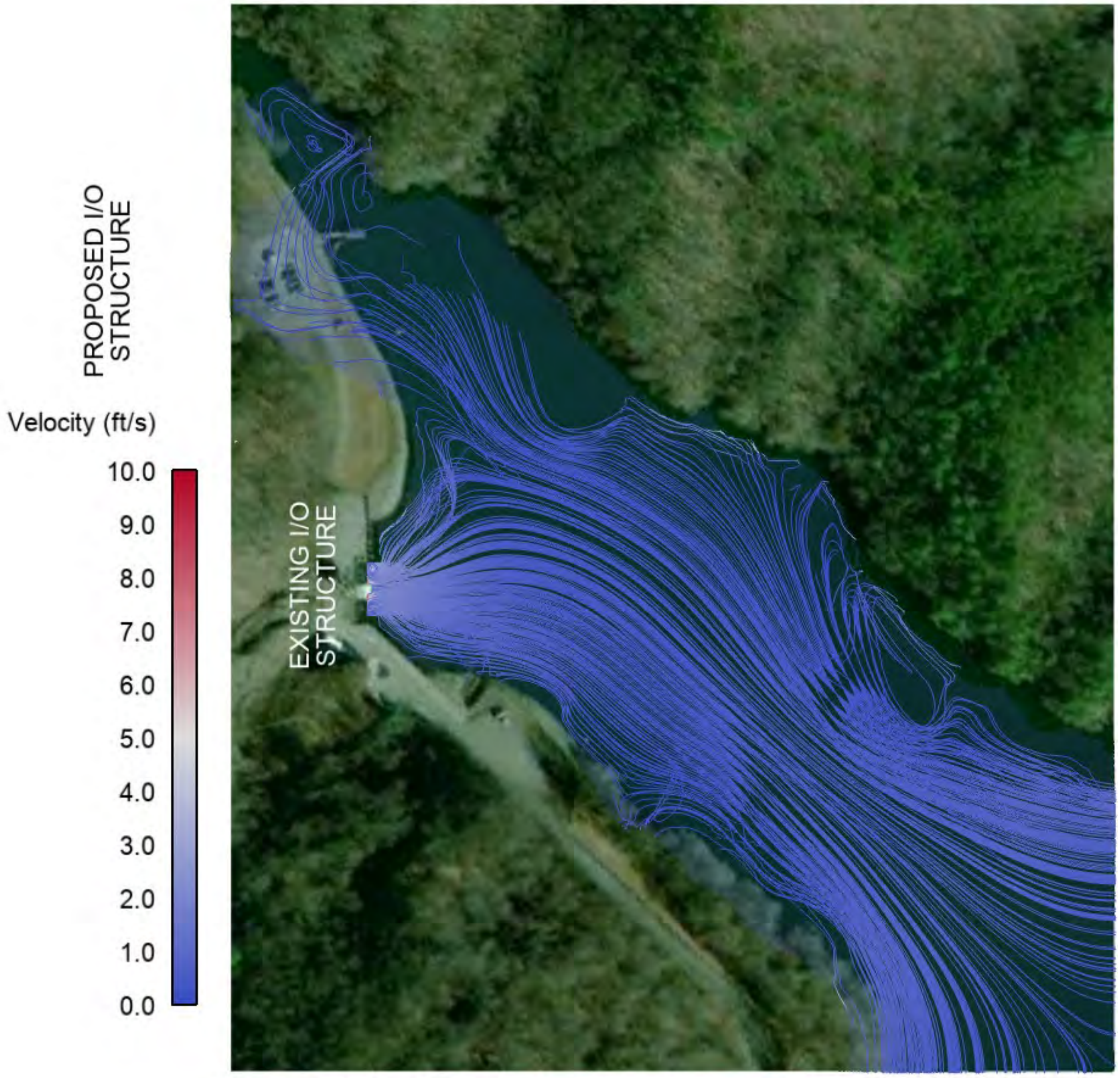

Figure 78. Case 11 (pumping - maximum reservoir elevation) Velocity Streamlines at Normal Full Pool Elevation

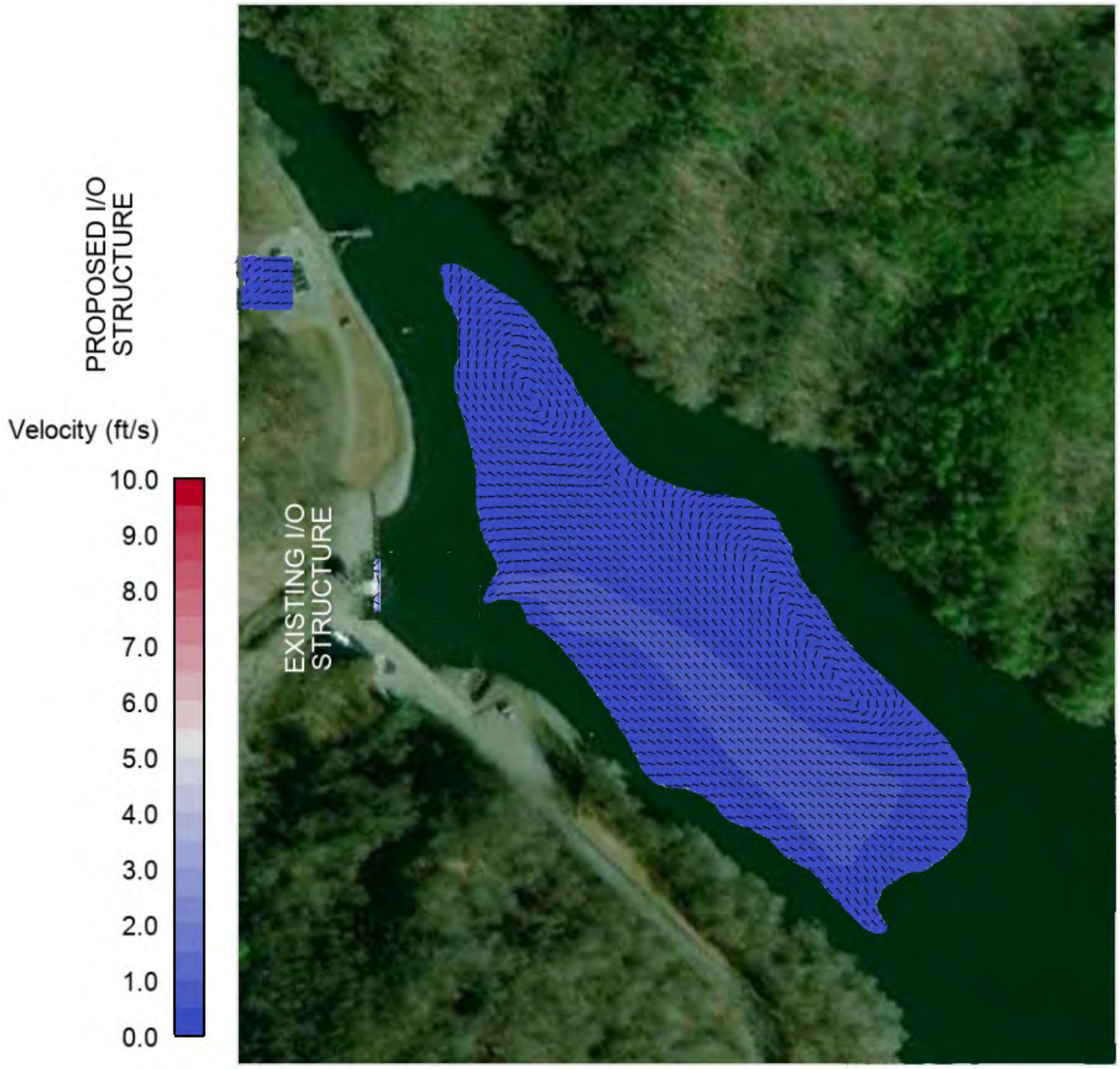

Figure 79. Case 11 (pumping - maximum reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

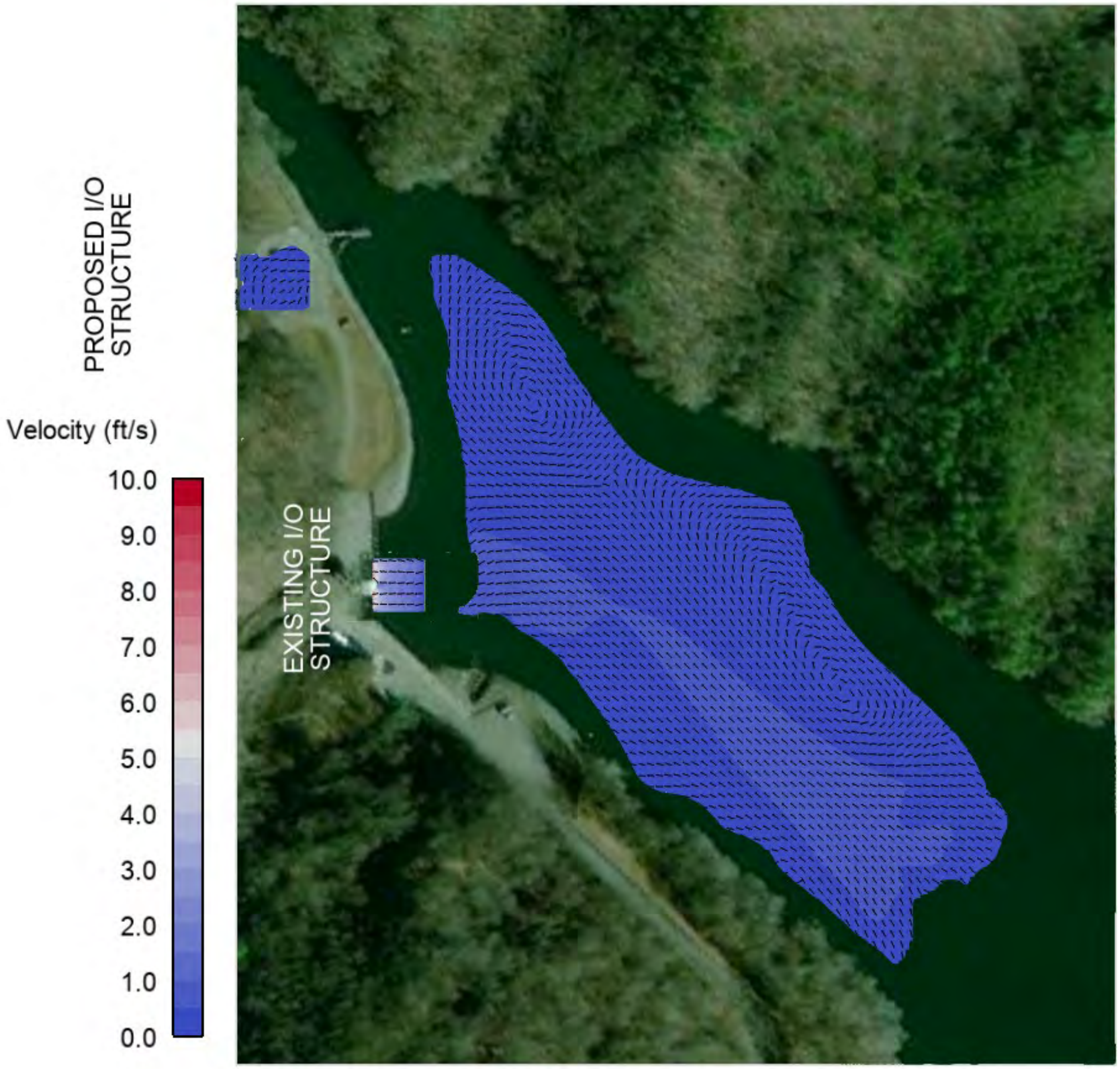

Figure 80. Case 11 (pumping - maximum reservoir elevation) Velocity Vectors at Elevation 1,050 ft

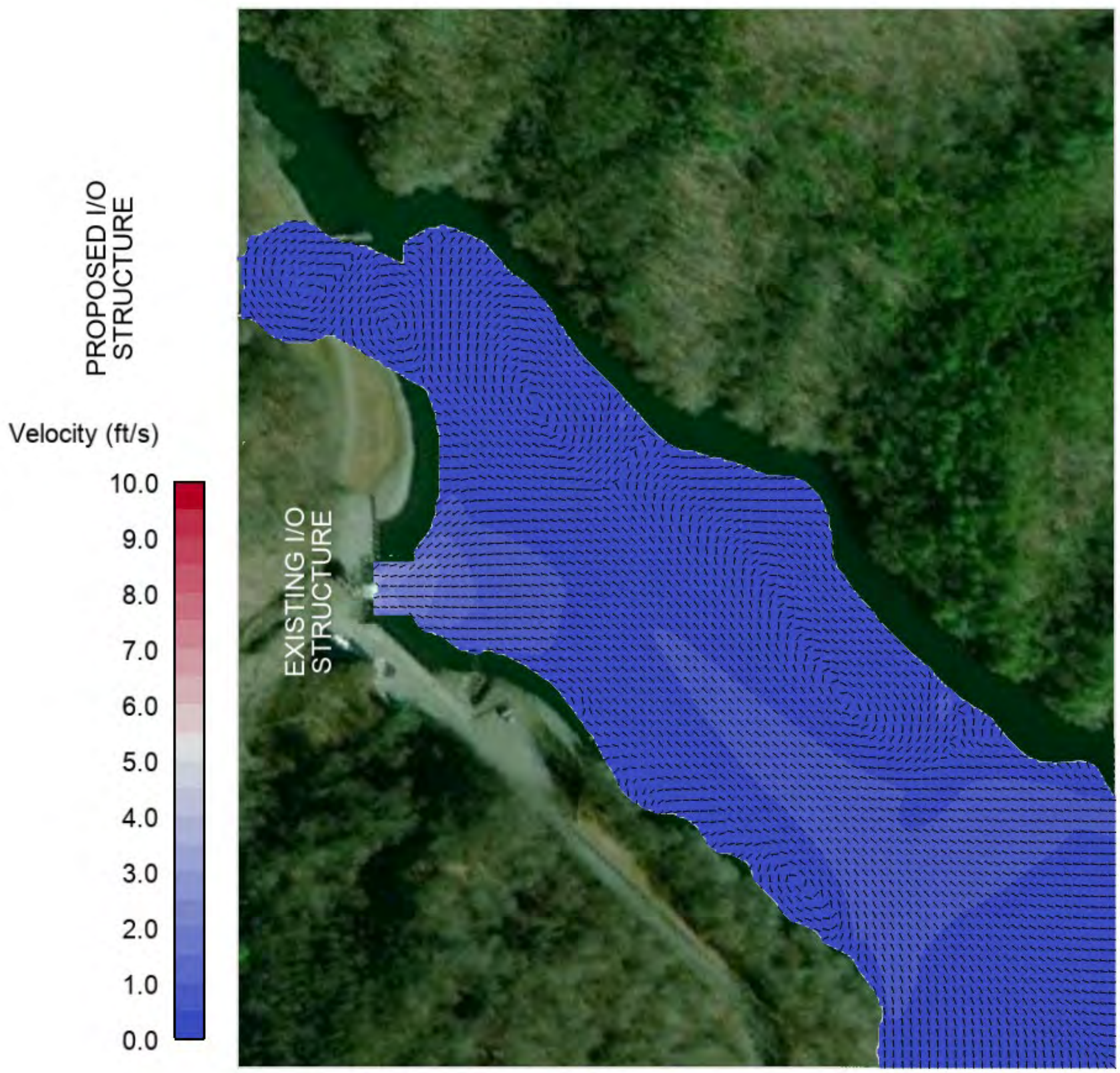

Figure 81. Case 11 (pumping - maximum reservoir elevation) Velocity Vectors at Elevation 1,080 ft

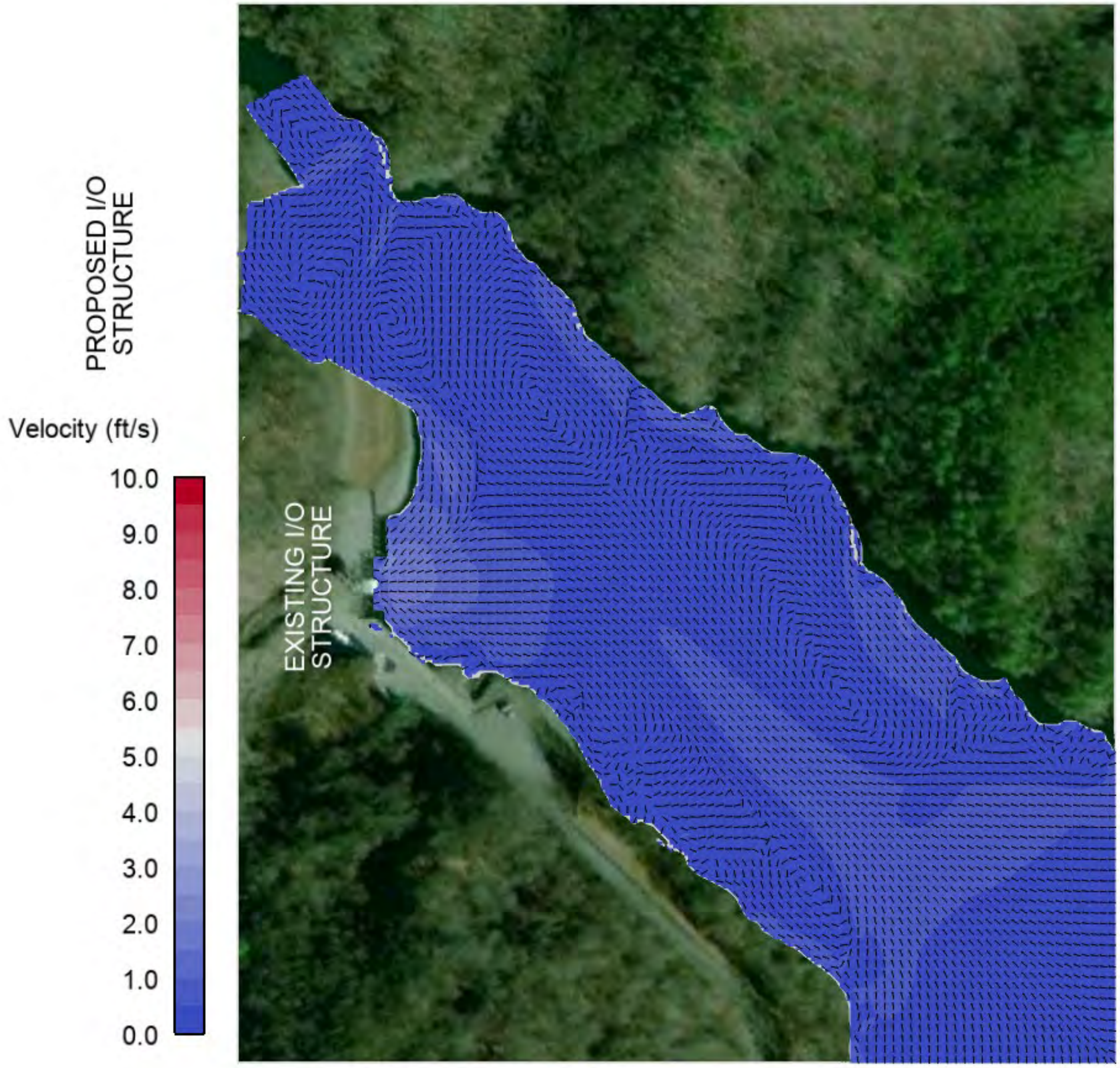

Figure 82. Case 11 (pumping - maximum reservoir elevation) Velocity Vectors at Elevation 1,110 ft msl

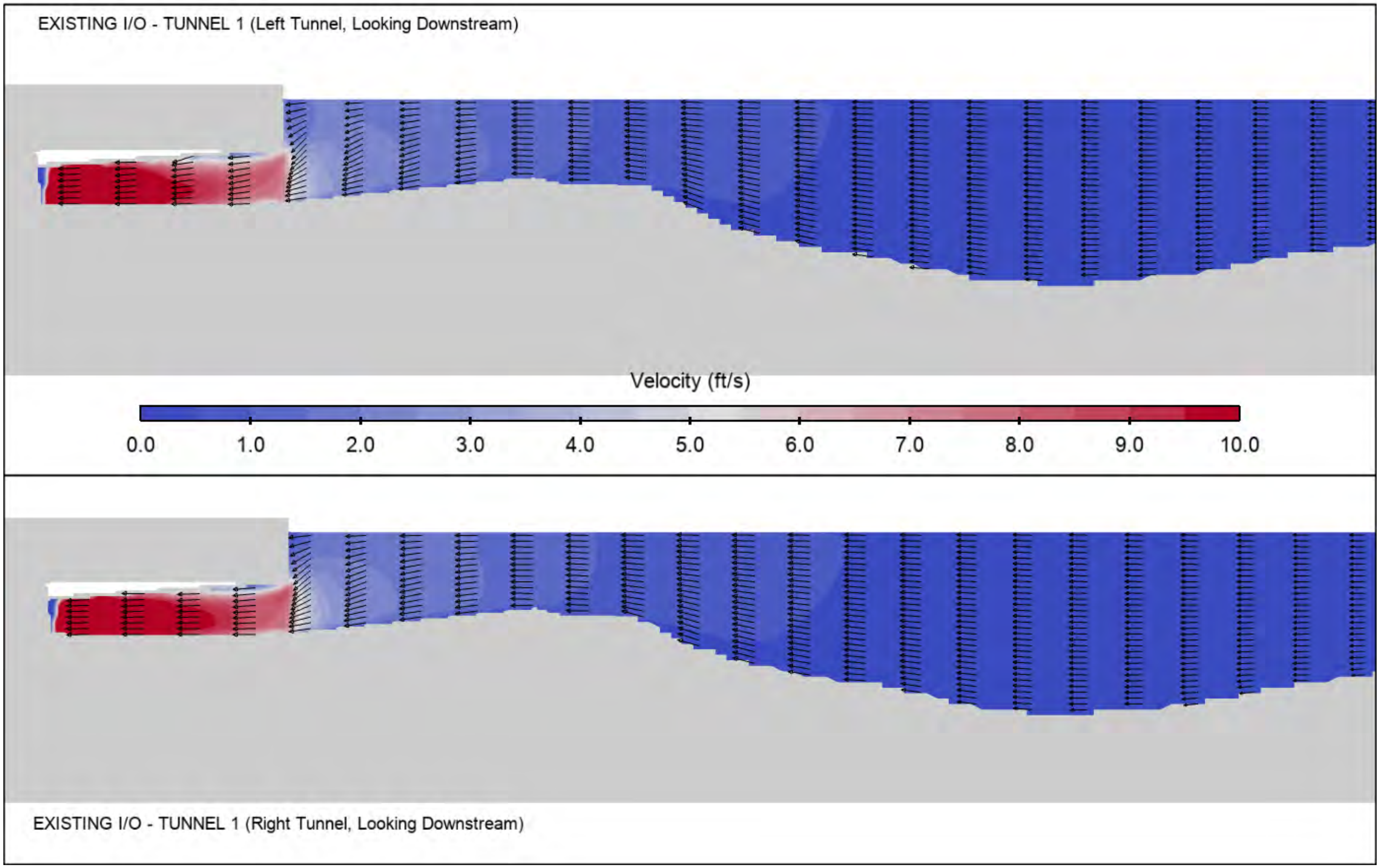

Figure 83. Case 11 (pumping - maximum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

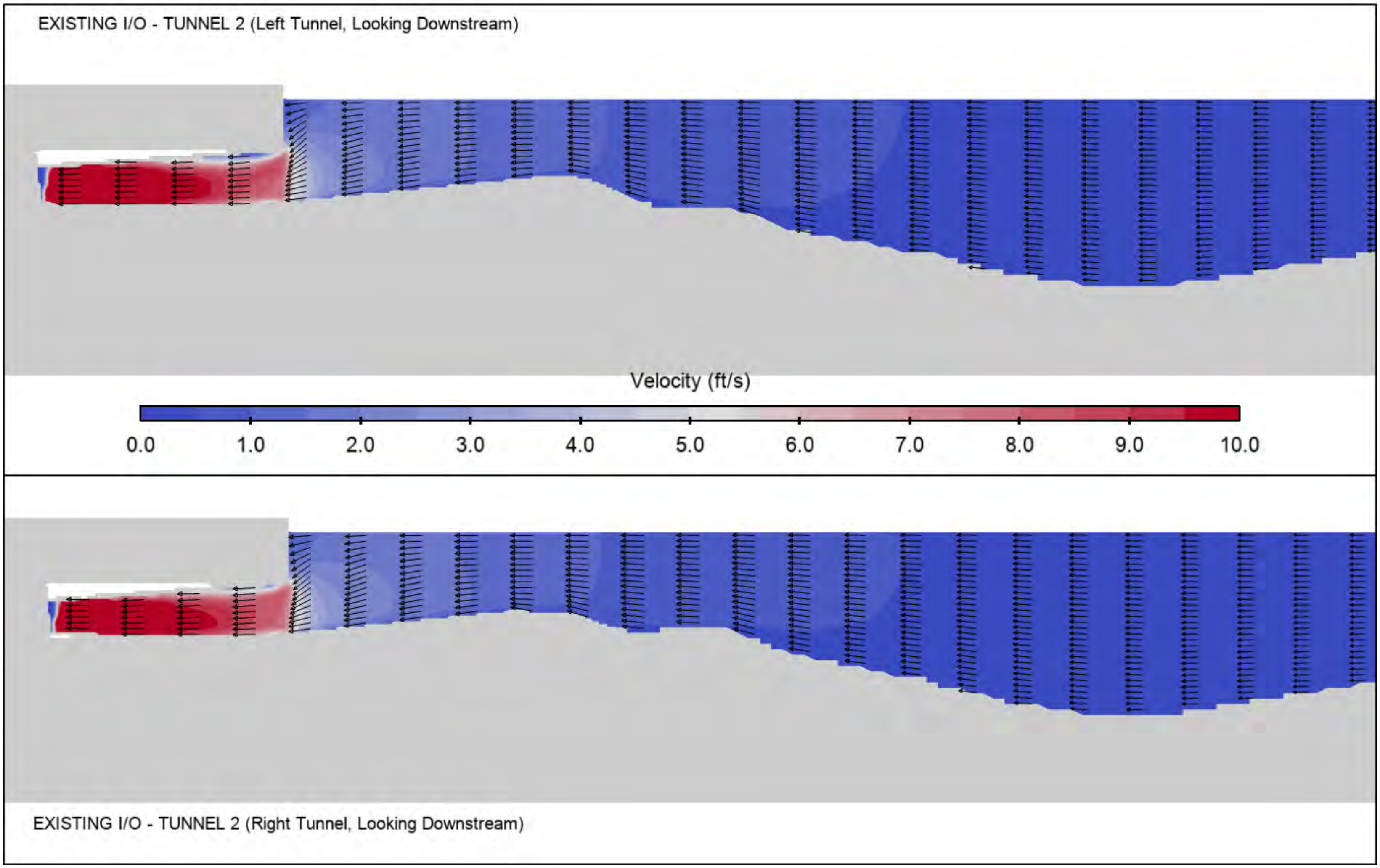

Figure 84. Case 11 (pumping - maximum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

4.4.4 Case 12: Lake Jocassee Normal Minimum Reservoir Elevation 1,080 ft msl - Pumping

Results of the construction configuration at normal full reservoir elevation are presented on Figure 85 through Figure 90. Figure 85 shows the plan view of the streamlines. Velocities increase upstream of the I/O structures but were lower than velocities in the generation simulations.

Figure 86 through Figure 87 show slices of the velocity vectors at four elevations within the water column: 1,040 ft msl, 1,050 ft msl, and at the surface (i.e., 1,080 ft msl). The flow patterns at each depth are relatively similar throughout the water column. The water velocities near the submerged weir were less than 3.5 fps.

Figure 89 and Figure 90 show model slices of velocity vectors and magnitudes through the two existing I/O structure tunnels centerlines. These slices show velocities on the east bank below 1.0 fps along tunnel centerlines.

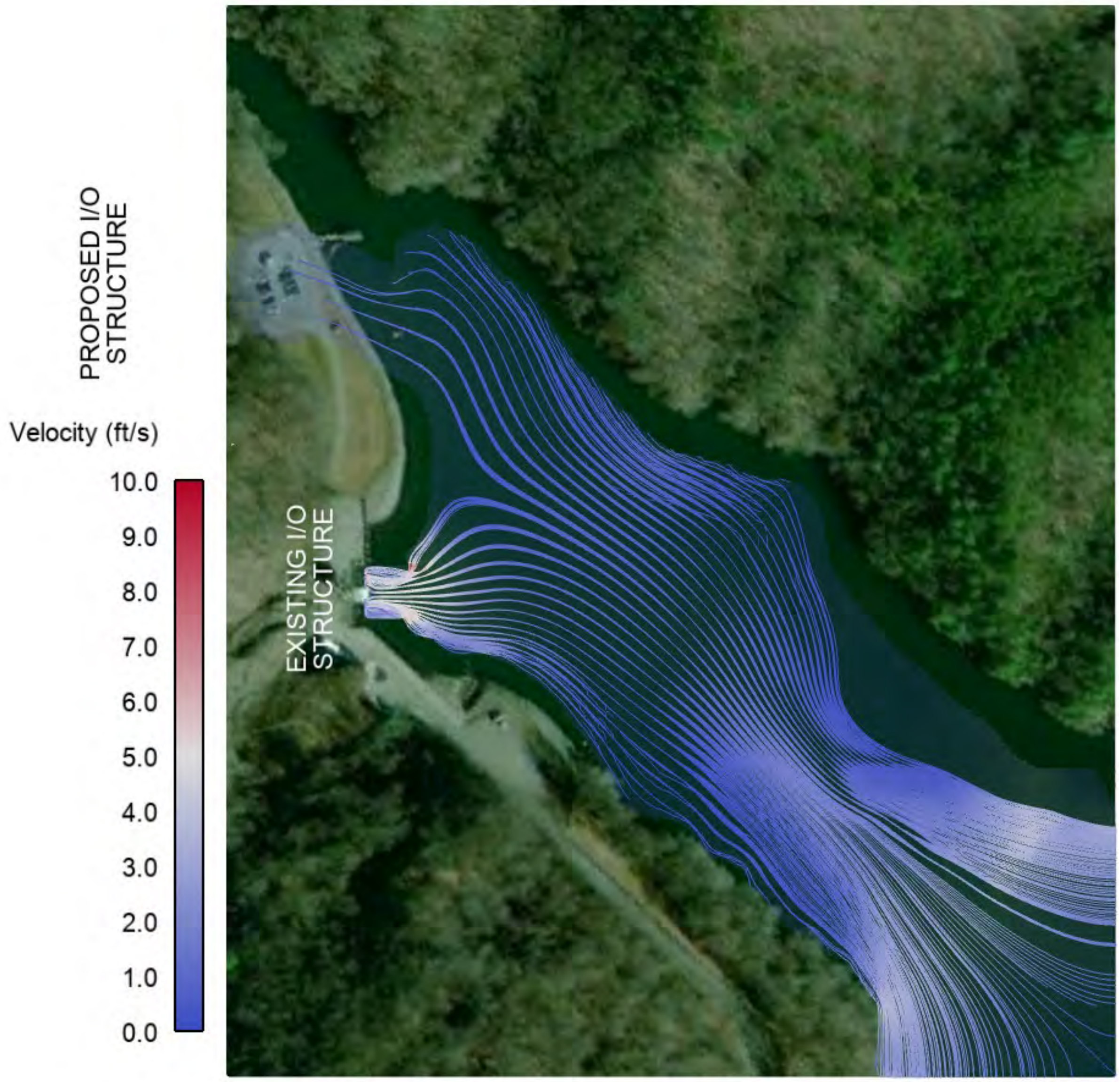

Figure 85. Case 12 (pumping - minimum reservoir elevation) Velocity Streamlines at Normal Minimum Pool Elevation

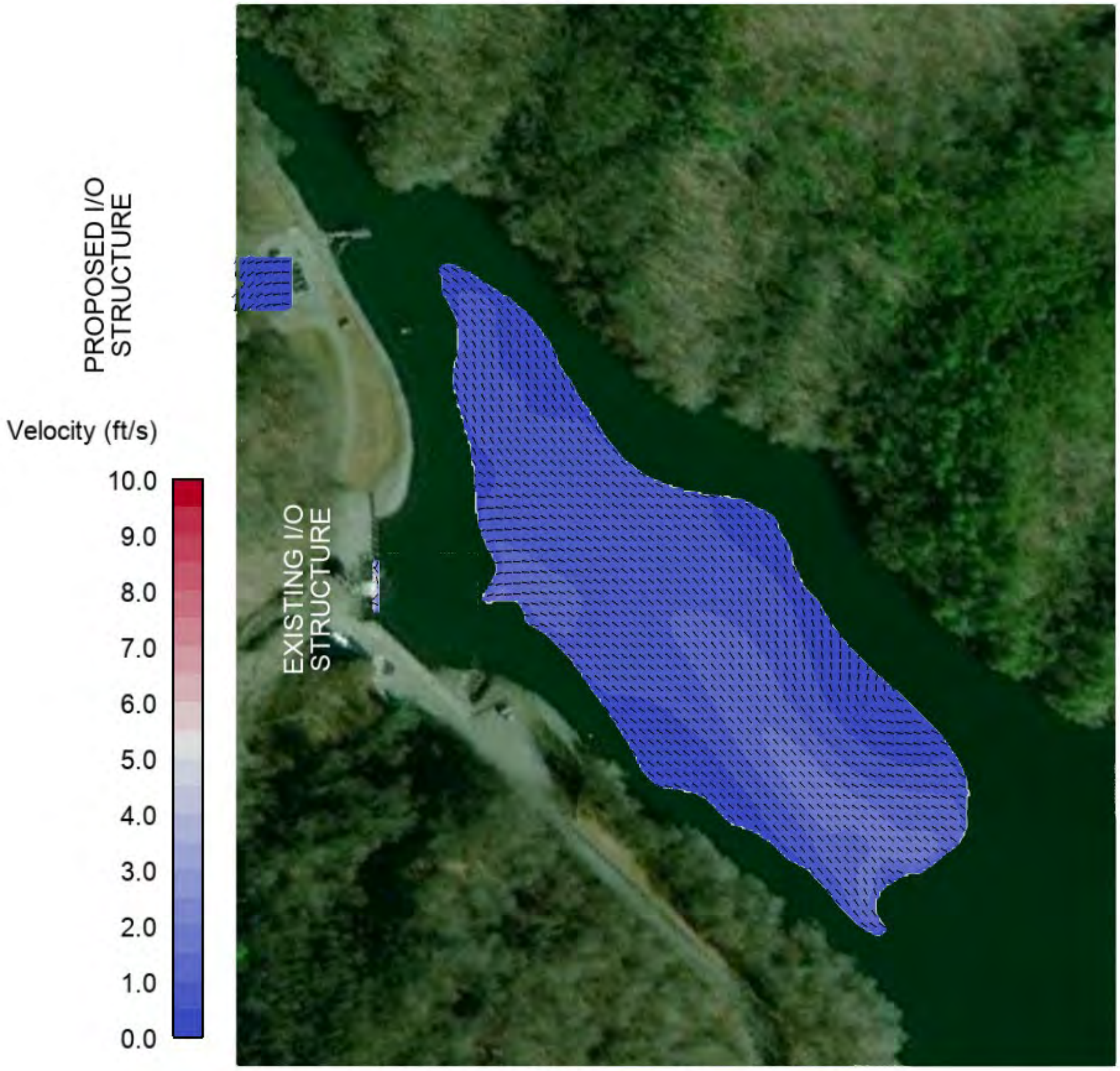

Figure 86. Case 12 (pumping - minimum reservoir elevation) Velocity Vectors at Elevation 1,040 ft msl

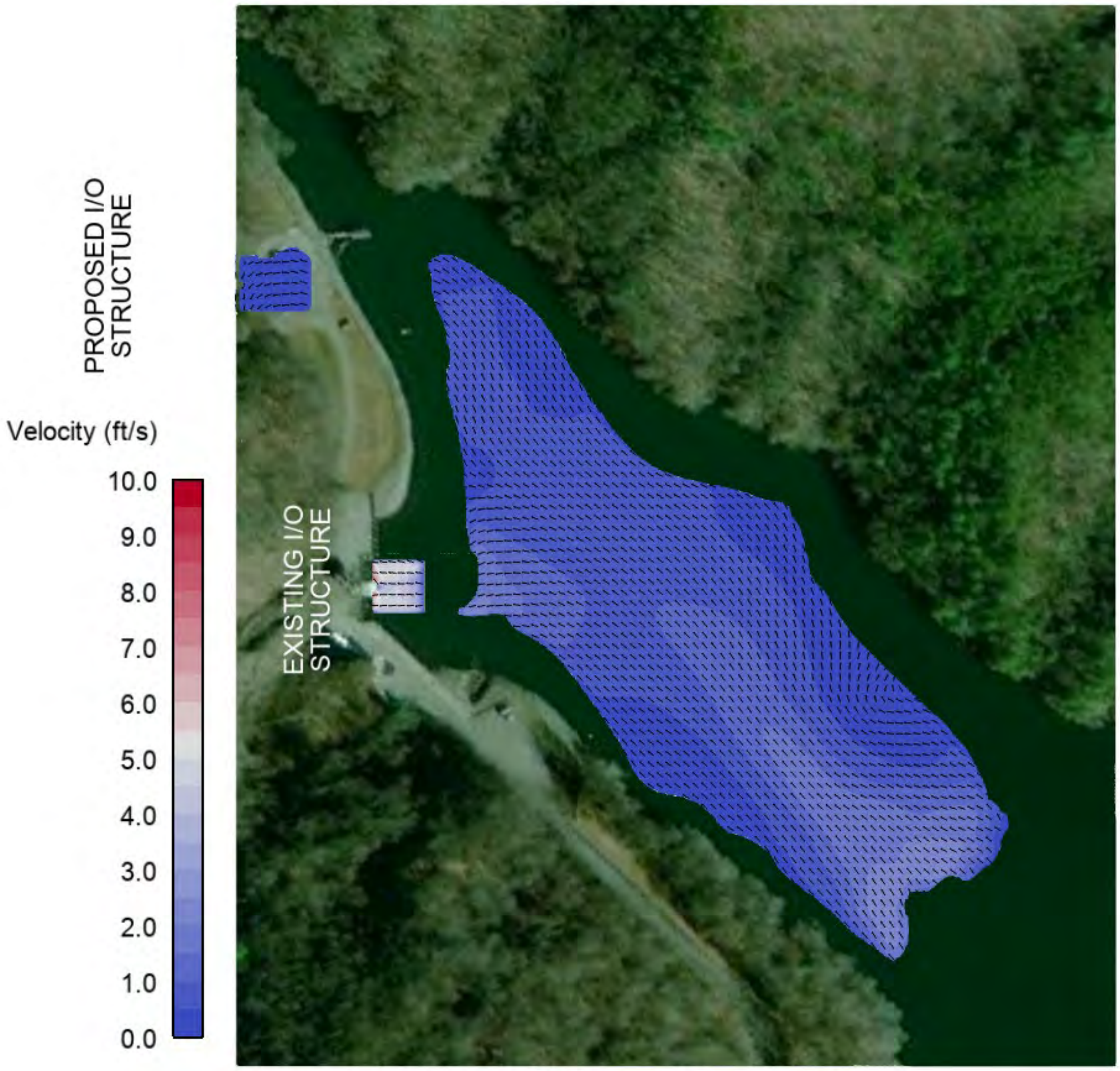

Figure 87. Case 12 (pumping - minimum reservoir elevation) Velocity Vectors at Elevation 1,050 ft

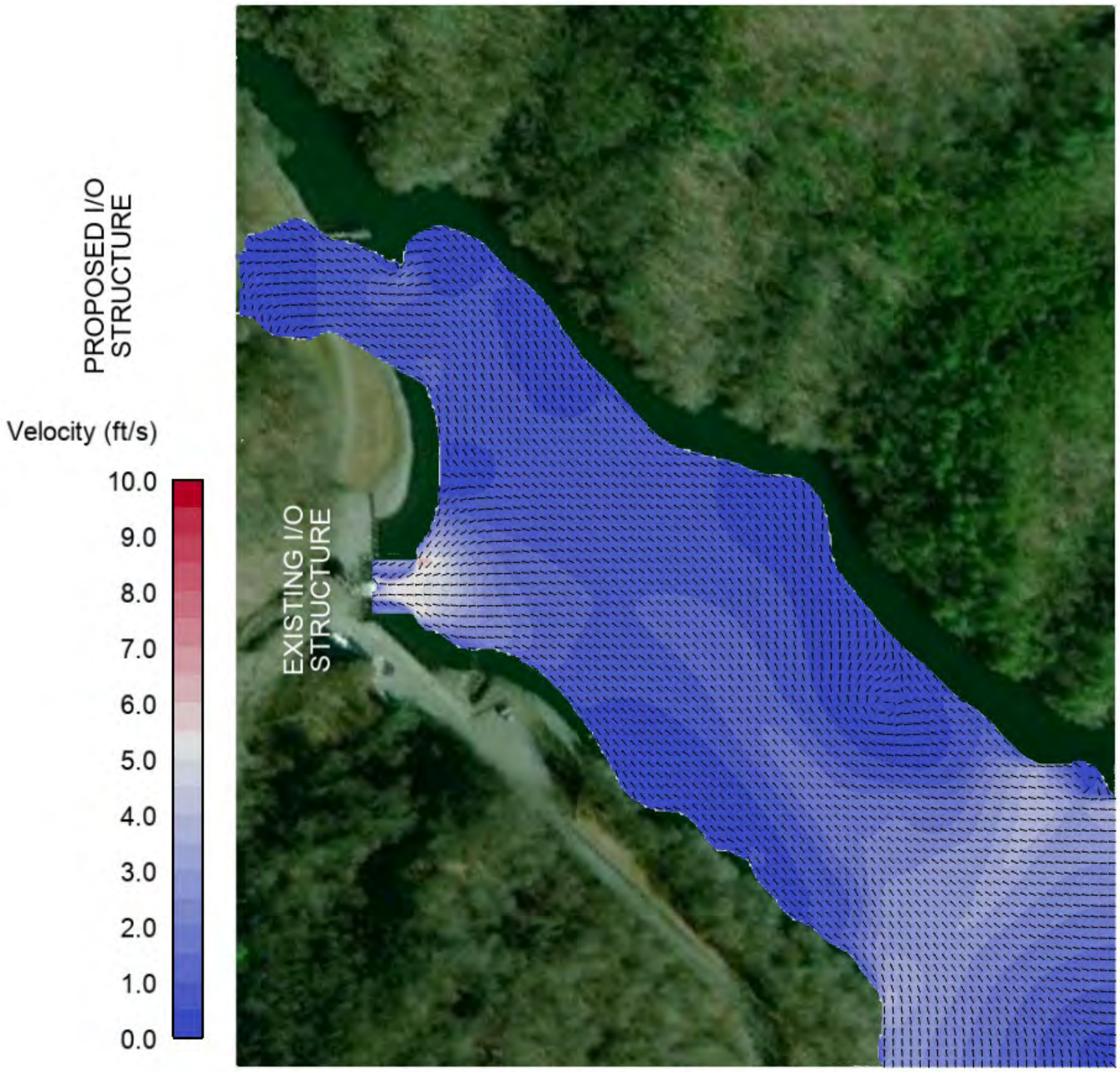

Figure 88. Case 12 (pumping - minimum reservoir elevation) Velocity Vectors at Elevation 1,080 ft

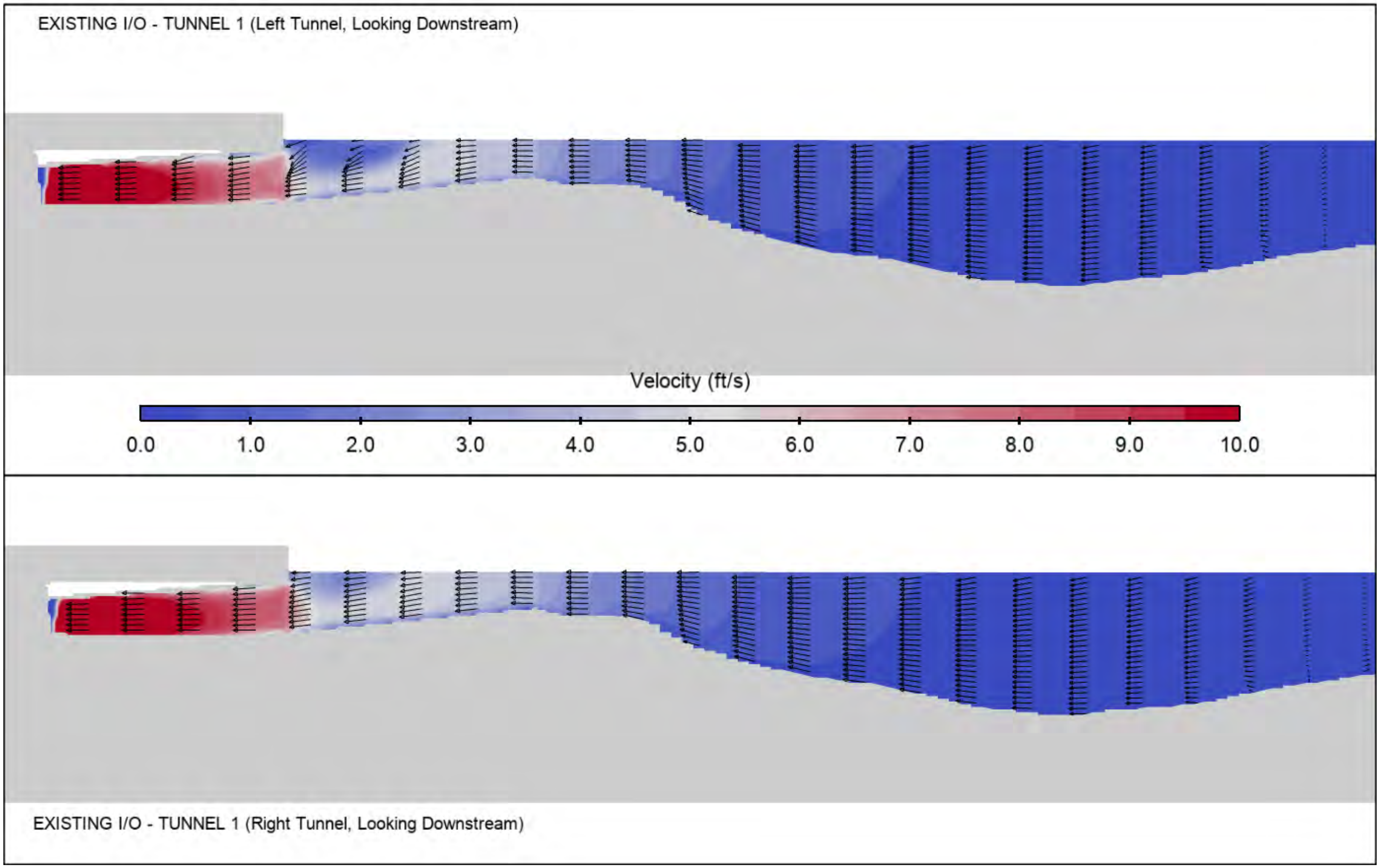

Figure 89. Case 12 (pumping - minimum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

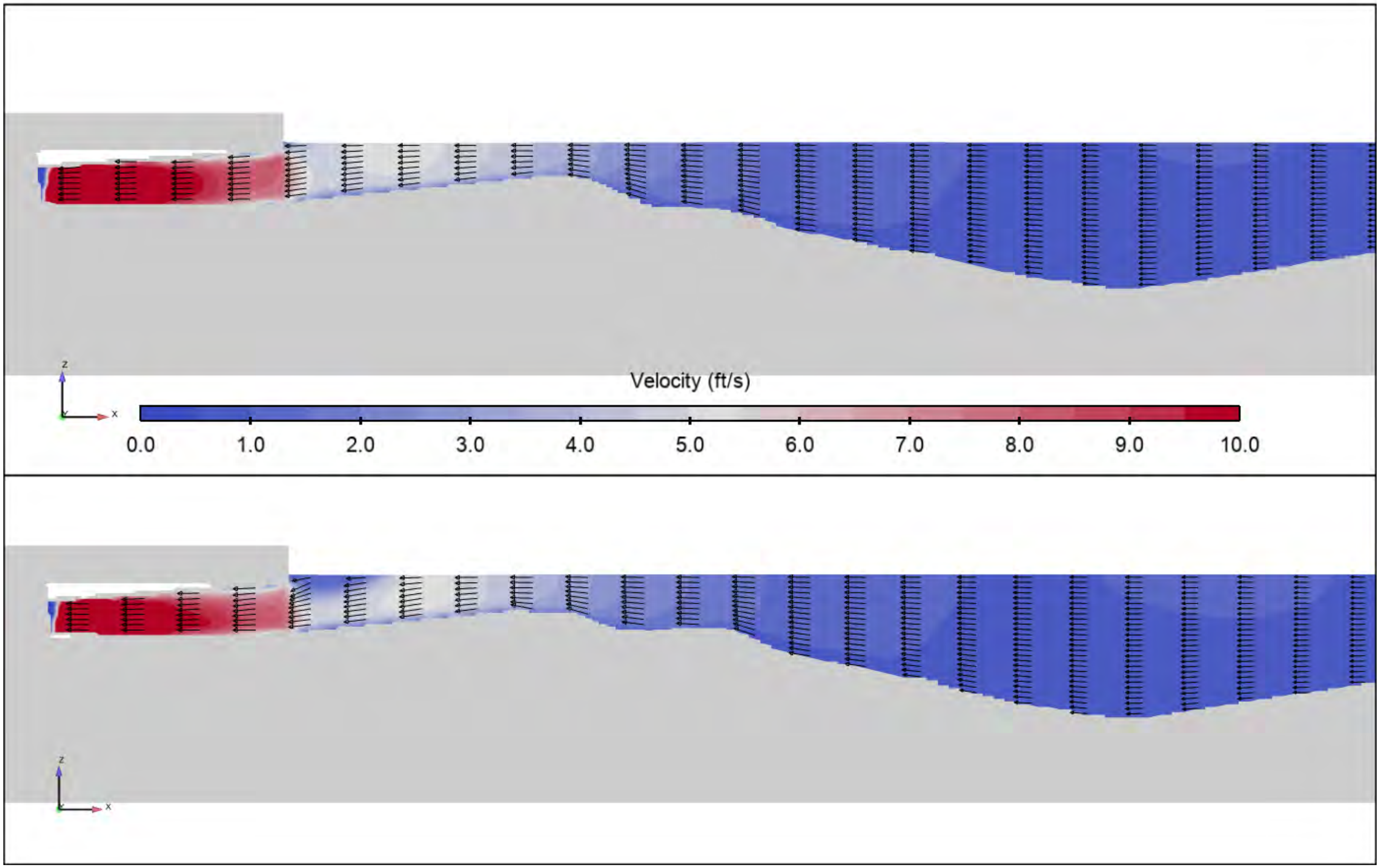

Figure 90. Case 12 (pumping - minimum reservoir elevation) Slices through Existing I/O Structure Tunnel Centerlines - Velocity Vectors

5 Conclusion

A lower reservoir CFD flow model was developed for the existing Bad Creek and proposed Bad Creek II and I/O structure configurations.

The CFD model was verified by comparing flow and velocity patterns from Cases 1 and 2 against the ARL 1986 physical model results (Larsen and White 1986), which utilized the original Bad Creek turbine flows. Flow patterns predicted by the CFD model existing configuration (16,000 cfs) reasonably replicated the physical model results and velocities at the east bank of the Whitewater River cove opposite of the I/O structures and along the I/O structure centerline for both cases.

The proposed Bad Creek II I/O structure was added to the model and six additional scenarios were run. Cases 3 through 5 provide results for each assumed Lake Jocassee water surface elevation. These cases increased the total flow generating flow from 16,000 cfs to 39,560 cfs assuming both I/O structures were discharging maximum flow and utilizing the uprated Bad Creek turbine flows. Cases 6 through 8 focused on the pumping operations at the three reservoir elevations.

During generation, velocity and flow patterns were analyzed throughout the water column and along the east bank opposite of the I/O structures. The proposed I/O structure had a distinct effect on both velocity flow and patterns, and this effect was more prominent at the lower reservoir elevation (Case 4). The concentrated flow from the proposed I/O structure reduced the size of recirculation patterns and directed flow from the existing I/O structure towards the center of the Whitewater River channel. This effect reduced the existing Bad Creek region of high velocity along the east bank but created a new region of high velocity approximately 600 ft upstream (i.e., north). Peak velocities along the east bank were less than 3.5 fps for Cases 3 through 5.

The pumping operations shows distinct flow paths for each I/O structure. Along the east bank, water flows north and enters the proposed I/O structure. Flow along the west bank enters the existing I/O structure. Increased velocities and non-direct flow were shown in the approach to the proposed I/O structure. The simulated flow patterns may lead to uneven loading of the tunnels and ineffective flow areas. The maximum velocity near the submerged weir was 3.5 fps (Case 12) shown during the minimum reservoir pumping operations.

The peak velocities for the proposed Bad Creek II I/O configuration along the east bank do not exceed the modeled velocities shown in the existing Bad Creek configuration at Lake Jocassee elevation 1,110 ft msl. The proposed Bad Creek II I/O configuration predicted minor increases to peak velocities along the east bank when compared to the existing Bad Creek modeled velocities. The location of the peak velocities is spatially closer to the proposed Bad Creek II I/O structure and similar in magnitude to the physical model simulation results (Larsen and White 1986).

The results of this preliminary study indicate that the additional generation flows resulting from Bad Creek II (in combination with the Bad Creek Station) do not appear to increase the potential for erosion along the east/opposite bank of the Whitewater River cove in Lake Jocassee, assuming the geology is consistent along the bank (i.e., predominantly bedrock). The modeled velocities were approximately equivalent to the physical model study velocities, which are representative of the existing conditions. To HDR’s knowledge, flow from the existing configuration and operations have not resulted in erosion along the east bank and velocities are within the general range from the proposed configuration. For a preliminary desktop evaluation regarding potential environmental impacts, please refer to the Feasibility Study Report, Volume 6 – Environmental Studies Report.

6 References

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