Bypass Reach Flow and Aquatic Habitat Study Report

Byllesby-Buck Hydroelectric Project
(FERC No. 2514)

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Acronyms and Abbreviations

1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
AEP	American Electric Power
Appalachian or Licensee	Appalachian Power Company
Buck	Buck Development
Byllesby	Byllesby Development
CFR	Code of Federal Regulations
cfs	cubic feet per second
FERC or Commission	Federal Energy Regulatory Commission
ft	feet/foot
HSC	habitat suitability criteria
HSI	habitat suitability index
LiDAR	light detection and ranging
mm	millimeter
NGVD	National Geodetic Vertical Datum of 1929
ICM	Integrated Catchment Model
ILP	Integrated Licensing Process
PM&E	protection, mitigation, and enhancement
POR	period of record
Project	Byllesby-Buck Hydroelectric Project
PSP	Proposed Study Plan
RSP	Revised Study Plan
SPD	Study Plan Determination
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VDGIF	Virginia Department of Game and Inland Fisheries
VDWR	Virginia Department of Wildlife Resources
WUA	weighted useable area

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1 Project Introduction and Background

Appalachian Power Company (Appalachian or Licensee), a unit of American Electric Power (AEP), is the Licensee, owner, and operator of the two-development Byllesby-Buck Hydroelectric Project (Project) (Project No. 2514), located on the upper New River in Carroll County, Virginia. The Byllesby Development (Byllesby) is located about 9 miles north of the city of Galax, and the Buck Development (Buck) is located approximately 3 river miles (RM) downstream of Byllesby and 43.5 RM upstream of Claytor Dam.

The Project is currently licensed by the Federal Energy Regulatory Commission (FERC or Commission). The Project underwent relicensing in the early 1990s, including conversion to run-of-river operations and incorporating additional protection, mitigation, and enhancement (PM&E) measures (FERC 1994). The current operating license for the Project expires on February 29, 2024. Accordingly, Appalachian is pursuing a subsequent license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. In accordance with FERC's regulations at 18 CFR §16.9(b), the licensee must file its final application for a new license with FERC no later than February 28, 2022.

In accordance with 18 CFR §5.11 of the Commission's regulations, Appalachian developed a Revised Study Plan (RSP) for the Project that was filed with the Commission and made available to stakeholders on October 18, 2019. On November 18, 2019 FERC issued the Study Plan Determination (SPD). On December 12, 2019, Appalachian filed a clarification letter on the SPD with the Commission. On December 18, 2019, Appalachian filed a request for rehearing of the SPD. The SPD was subsequently modified by FERC by an Order on Rehearing dated February 20, 2020.

On July 27, 2020, Appalachian filed an updated ILP study schedule and a request for extension of time to file the Initial Study Report (ISR) to account for Project delays resulting from the COVID-19 pandemic. The request was approved by FERC on August 10, 2020, and the filing deadline for the ISR for the Project was extended from November 17, 2020 to January 18, 2021. Stakeholders provided written comments in response to Appalachian's filing of the ISR meeting summary, which are addressed in this Updated Study Report (USR) along with study methods and results.

In accordance with 18 CFR §5.15, Appalachian has conducted studies as provided in the RSP as subsequently approved and modified by the FERC. This report describes the methods and results of the Bypass Reach Flow and Aquatic Habitat Study conducted in support of preparing an application for new license for the Project.

2 Study Goals and Objectives

As described in the RSP and SPD, the objectives of this study are to conduct a flow and habitat assessment for each of the development's tailrace and bypass reaches (excluding the Byllesby auxiliary spillway channel) using a combination of desktop, field survey, and hydraulic modeling methodologies with the following goals:

- Delineate and quantify aquatic habitats and substrate types in the Byllesby and Buck bypass reaches.

- Identify and characterize locations of habitat management interest located within each bypass reach.
- Develop an understanding of surface water travel times and water surface elevation responses under variable base flow and spillway release flow combinations in the tailrace and bypass reach of each development to:
  - Demonstrate the efficacy of existing ramping rates required by the existing license.
  - Demonstrate the efficacy of the existing powerhouse minimum flow requirement (i.e., 360 cubic feet per second [cfs] minimum flow to maintain aquatic resources, including resident fish species, downstream of each development consisting of the tailrace areas below each powerhouse and the bypass reaches below the main spillways).
  - Evaluate the impacts of providing seasonal minimum flows to the bypass reaches.

3 Study Area

The Study Area for the Flow and Bypass Reach Aquatic Habitat Study includes the tailrace, bypass reach, and a short stream segment downstream of where the tailrace and bypass reach waters join (see Figure 3-1 for the Byllesby Study Area and Figure 3-2 for the Buck Study Area).

Figure 3-1. Byllesby Development Bypass Reach Study Area

Figure 3-2. Buck Development Bypass Study Area

4 Background and Existing Information

The Byllesby bypass reach is approximately 475 feet (ft) long, consisting primarily of exposed bedrock and rock outcroppings. The Buck bypass reach is approximately 4,100 ft long, with a steep gradient (approximately 24 ft per mile) and consisting primarily of exposed bedrock. Both bypass reaches normally receive seepage and leakage unless flows are being spilled at the dams or the flashboards are breached. Under Appalachian's normal operating conditions, the developments use available flows for powerhouse generation, maintaining the elevation of the Byllesby reservoir between 2,078.2 ft and 2,079.2 ft National Geodetic Vertical Datum (NGVD of 1929) and the Buck reservoir between 2,002.4 ft and 2,003.4 ft NGVD.

Under Article 403 of the current license, Appalachian is also required to maintain 360 cfs minimum flow release or inflow, whichever is less, downstream of the Project powerhouses. When inflow to either Project exceeds the powerhouse discharge capacity (5,868 cfs for Byllesby and 3,540 cfs for Buck), the Obermeyer and/or Tainter gates are opened to pass the excess flow into the respective bypass reaches (Figure 4-1 and Figure 4-2).

Monthly flow data from the U.S. Geological Survey (USGS) 03165500 New River at Ivanhoe, VA flow gaging station is provided in Table 4-1. This gage is located approximately 2.8 miles downstream of Buck and reports daily average flow data starting in October 1929 through present, with a data gap from September 1978 to January 1996, providing a discontinuous 74-year period of record (POR). Monthly mean flow data, along with the 25th and 75th percentile flow data[1] is provided from January 1996 through December 2020 (a 25-year POR[2]) to put recent historic river flows in perspective with Byllesby and Buck maximum hydraulic capacities and current minimum downstream flow release requirements. For example, mean monthly flows recorded at the USGS 03165500 New River at Ivanhoe, VA gage are less than the hydraulic capacities of both the Byllesby and Buck developments. And while the monthly 75th percentile flows are less than the Byllesby powerhouse capacity, they exceed the smaller Buck powerhouse capacity. As a result, flow releases into the Buck bypass reach are more common than into the Byllesby bypass reach (see Table 4-2).

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[1] A percentile is a value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it. A flow percentile greater than 75 is considered to be wetter than normal; a flow percentile between 25 and 75 is considered normal; and a flow percentile less than 25 is considered to be drier than normal.

[2] The January 1996 – December 2020 POR is reflective of current land use and water use practices and uses more modern data collection and recording methods compared to the 1929 – 1978 POR. The more recent POR also contains a number of dry and wet periods that are sufficient for purposes of evaluating flow regimes relevant to the bypass reach flow and aquatic habitat study goals and objectives.

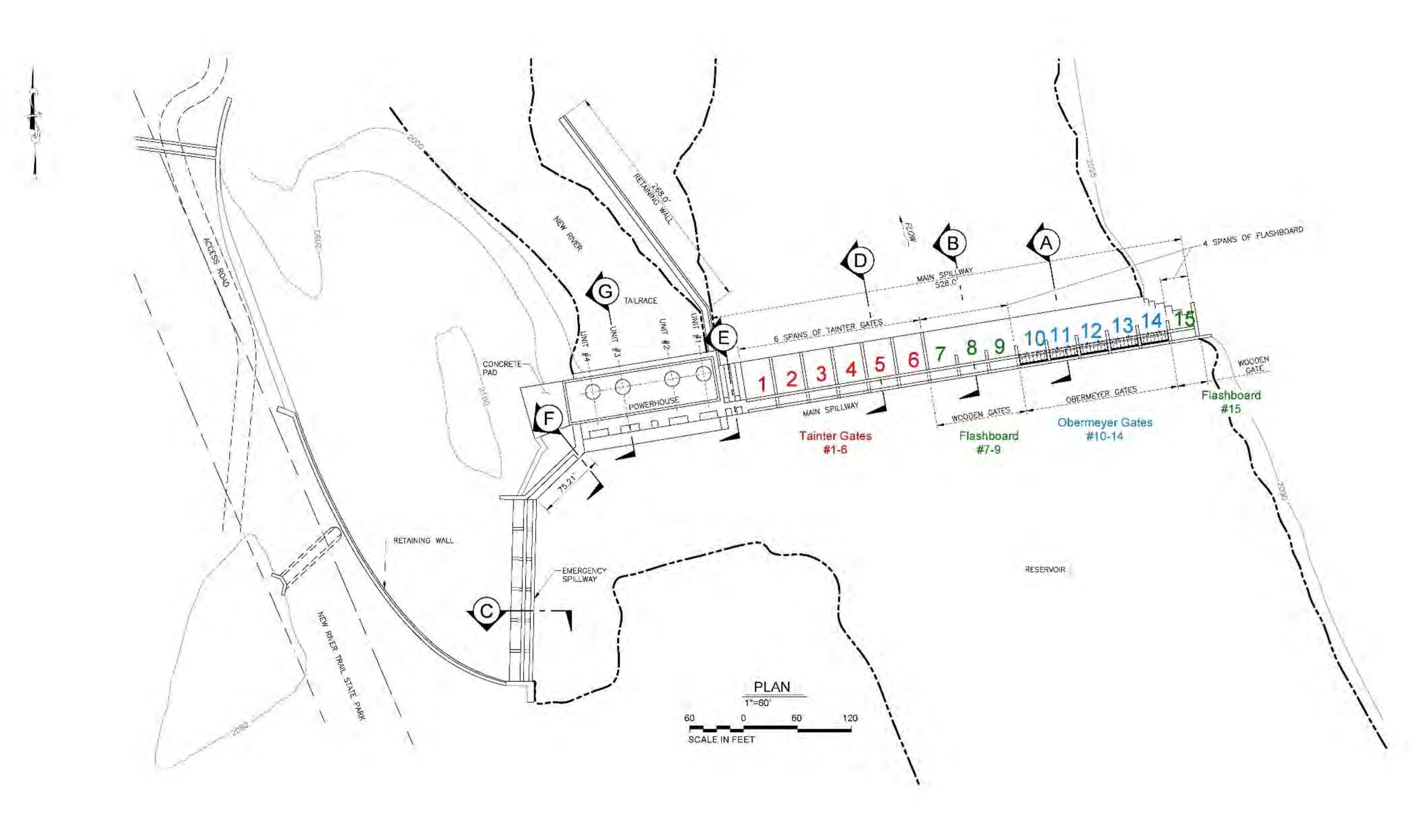


Figure 4-1. Byllesby Dam Spillway Gates

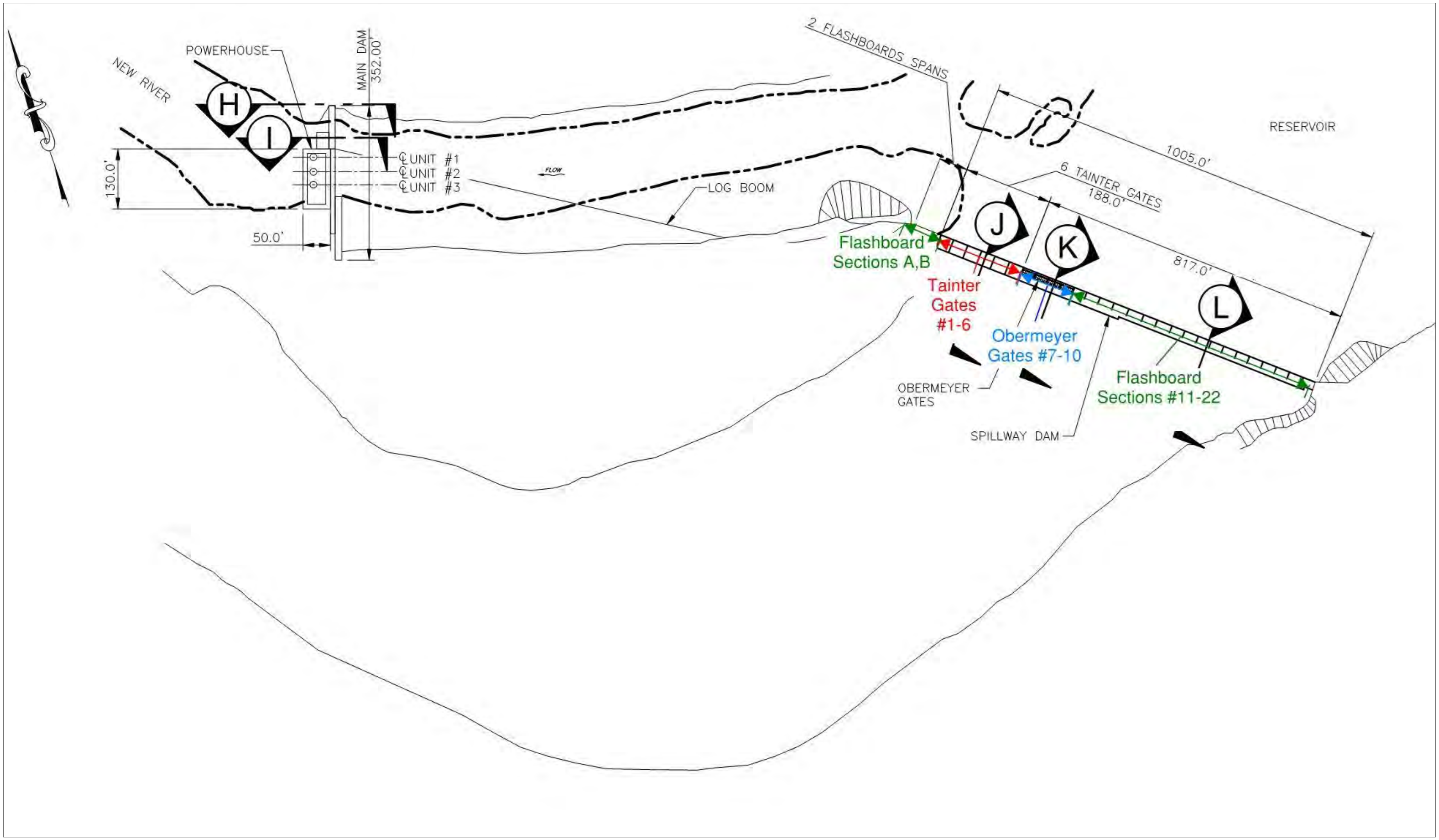


Figure 4-2. Buck Dam Spillway Gates

Table 4-1. USGS 03165500 New River at Ivanhoe, Virginia Monthly Flow Statistics, 1996 - 2020

Time Period	USGS 03165500 New River at Ivanhoe, VA		
	25th Percentile Flow (cfs)	Mean Monthly Flow (cfs)	75th Percentile Flow (cfs)
Annual	**1,331**	**2,275**	**2,774**
Jan	1,588	2,583	3,223
Feb	1,544	2,951	3,924
Mar	2,189	2,919	3,546
Apr	2,037	3,162	4,189
May	1,716	2,936	3,006
Jun	1,266	2,185	2,875
Jul	1,074	1,732	1,602
Aug	896	1,497	1,485
Sep	808	1,551	1,803
Oct	866	1,561	1,701
Nov	820	1,831	2,722
Dec	1,173	2,393	3,211

Table 4-2. Percentage of Days with Spillage to the Bypass Reaches for Byllesby and Buck Developments

Facility	Byllesby (powerhouse capacity 5,868 cfs)			Buck (powerhouse capacity 3,540 cfs)		
Time Period	1996-2020	1999 (dry year)	2013 (wet year)	1996-2020	1999 (dry year)	2013 (wet year)
Annual	10.8	1.4	30.7	15.5	1.9	40.0
Jan	14.7	6.5	32.3	20.5	12.9	32.3
Feb	15.8	0.0	14.3	22.0	0.0	17.9
Mar	16.4	0.0	12.9	25.3	0.0	29.0
Apr	18.1	3.3	40.0	27.1	3.3	63.3
May	14.7	3.2	54.8	21.7	3.2	74.2
Jun	10.0	0.0	33.3	14.1	0.0	43.3
Jul	5.3	0.0	93.5	5.9	0.0	96.8
Aug	5.8	0.0	51.6	8.0	0.0	74.2
Sep	5.3	0.9	0.0	6.8	0.0	0.0
Oct	5.4	0.0	0.0	7.7	0.0	3.2
Nov	7.6	3.3	6.7	10.9	3.3	6.7
Dec	11.0	0.0	25.8	16.3	0.0	35.5

In addition to the minimum flow requirements, and to further protect fish communities, ramping rates are required for the Buck bypass reach. Appalachian is required to discharge flows through a 2-ft gate opening for at least three hours following any spills released through a gate opened 2 ft or more. Appalachian is then required to reduce the opening to 1 ft for at least an additional three hours, after which Appalachian may close the gate. The gradual reduction of flow allows time for fish to respond to the receding water levels, thus avoiding stranding that can occur with sudden flow discontinuation.

An assessment of the effectiveness of the ramping procedure for the protection of aquatic organisms in the Buck bypass was performed in 1997 (Appalachian 1997). Backpack electrofishing was conducted following the cessation of bypass releases in the range of 4,300 to 6,140 cfs. A total of 734 fish representing 24 species were collected. Several species, including Central Stoneroller (*Campostoma anomalum*), White Shiner (*Luxilus albeolus*), White Sucker (*Catostomus commersonii*), Northern Hogsucker (*Hypentelium nigricans*), darters, and Walleye (*Sander vitreus*) were collected in the flowing-water habitat immediately downstream of the spillway, whereas species such as Rock Bass (*Ambloplites rupestris*), Redbreast Sunfish (*Lepomis auritus*), Green Sunfish (*L. cyanellus*), and Bluegill (*L. macrochirus*) were collected in locations further downstream in habitat dominated by pools. The study concluded that fish stranding is not a substantial problem within the Buck bypass when ramping procedures are followed. On March 27, 1998, FERC approved Appalachian's ramping rate assessment report, which included recommendations for Appalachian to continue to retain the ramping rate protocol assessed in the 1997 study. The Virginia Department of Wildlife Resources (VDWR) (formerly the Virginia Department of Game and Inland Fisheries [VDGIF]) noted in comments on the PSP that this historical assessment may not apply under current Walleye population conditions.

5 Methodology

The USFWS requested an instream flow study with the goal of determining the impacts of modifying the discharge location and configuration (gate operation) on the current velocity and direction, sediment transport and deposition patterns, aquatic species and habitats, and recreation in the tailrace area and bypass reach below the Project dams.

Appalachian's goal in selecting a process for evaluating flows at the Project is to develop a technical basis for systematically evaluating and balancing the needs and priorities of the various flow-related resources. Therefore, the goal of this study is to characterize changes in quantity of aquatic habitat over a range of flows and operational scenarios. There are several types or combinations of methodologies that could be used to meet the study objectives, ranging from very quantitative to relatively qualitative data. Appalachian believes that the approach used for this study (i.e., development of a two-dimensional [2-D] flow and habitat model) provides the requested information at an appropriate level of effort. This approach also allows for an assessment of potential Project protection, mitigation, and enhancement measures for the benefit of the range of resources in the bypass reaches.

5.1 Literature Review and Desktop Assessment

A literature review of available information was performed to support the study goals, methodologies, and planning of field portions of the study. This task included a review of the hydrologic record for the Project reaches, existing spillway gate operating procedures maintained by Appalachian, existing topographic and geologic maps, and available recent and historical aerial imagery.

Several pieces of information were considered in the field study planning process. First, a desktop analysis of mesohabitat (i.e., pools, riffles, runs, bedrock, shoals) mapping of the bypass reaches was completed using high-resolution aerial imagery and topographic contour data collected as described in Section 5.2. Second, species of interest were determined based on stakeholder consultation and an evaluation of management objectives (e.g., Walleye spawning, minimizing fish stranding, habitat availability under different flow regimes using guild curves to represent fish species that are or may be present in the bypass reaches, etc.). The life history characteristics and habitat preferences of selected species, as well distribution of mesohabitat types, were considered in the selection of targeted flows and locations for field data collection. GIS figures delineating mesohabitat types are provided in Section 6.3.

5.2 Topography Mapping and Photogrammetry Data Collection

Light detection and ranging (LiDAR) data were collected during a period of no releases at the dams and minimal water levels in the bypass reaches to support development of comprehensive three-dimensional (3-D) elevation and visual surface layers of each bypass reach. These data were used for desktop mesohabitat mapping as well as to produce a digital terrain map of each bypass reach. The topographic information was then incorporated as a base layer for subsequent field data collection and hydraulic modeling efforts. LiDAR data collection and digital terrain models are discussed further in the Byllesby and Buck Bypass Reach ICM Model Development reports, which are included in Attachment 1.

5.3 Desktop Mesohabitat Mapping

Using the high-resolution photogrammetry data (see Section 5.2), polygons were drawn in GIS to encompass the study areas according to presence or type of cover (e.g., no cover, overhead vegetation, etc.) and substrate size (e.g., sand, gravel, cobble, etc.) (Table 5-1). If multiple types of cover were present, the most immediate cover type was selected assuming it would have greater influence over aquatic organism behavior (e.g., if instream cover and overhead vegetation both exist, instream cover was selected). While substrate could be composed of several types/sizes, the dominate size class was selected. Mesohabitats were delineated based on typical stream and river morphological, longitudinal sequences (i.e., riffle, run, pool, glide) (Wildland Hydrology 1996) and aerial signatures denoting flow and turbulence at leakage, low-flow, or moderate-flow conditions.

Table 5-1. Desktop Mesohabitat Delineation Codes Used for the Byllesby-Buck Flow and Aquatic Habitat Study

Substrate-Cover Classifications		
Code	**Cover**	**Substrate**
01	No Cover	and silt or terrestrial vegetation
02	No Cover	and sand
03	No Cover	and gravel
04	No Cover	and cobble
05	No Cover	and small boulder
06	No Cover	and boulder, angled bedrock, or woody debris

Substrate-Cover Classifications		
07	No Cover	and mud or flat bedrock[1] (unsuitable as cover)
08	Overhead vegetation	and terrestrial vegetation
09	Overhead vegetation	and gravel
10	Overhead vegetation	and cobble
11	Overhead vegetation	and small boulder, angled bedrock[3], or woody debris
12	Instream cover	and cobble
13	Instream cover	and small boulder, angled bedrock[3], or woody debris
14	Proximal[2]	and cobble
15	Proximal[2]	and small boulder, angled bedrock[3], or woody debris
16	Instream or proximal[2]	and gravel
17	Overhead, instream, or proximal[2]	and silt or sand
18	Aquatic vegetation	and aquatic macrophytes

Mesohabitat Classifications	
Code	**Mesohabitat Type**
00	Upland[4]
01	Pool
02	Riffle
03	Run
04	Glide
05	Shoal
06	Backwater

[1] Flat bedrock consists of bedrock that is smooth, with or without crater-like divots, or otherwise unsuitable as instream cover.
[2] "Proximal" is defined as within four feet of suitable cover.
[3] Angled bedrock is angular, jutting or semi-vertical, slab-like bedrock. Angled bedrock was categorized as instream cover, regardless of presence of overhead vegetation.
[4]. Upland areas are areas that are inundated during spill events.

5.4 Field Data Collection

5.4.1 Flow and Water Level Assessment

In this task, field data was collected to support development of a 2-D hydraulic model of each development's tailrace and bypass reach. Calibration flows were released into the tailrace and bypass reaches for purposes of collecting water surface elevation, depth, velocity, and wetted area data under four bypass reach and tailrace flow regimes. The model enables a comparison between powerhouse operations (i.e., flow releases into the tailrace areas) and dam operations (i.e., flow releases into the bypass reaches via spillway gates).

A proposed framework for model scenarios was developed and the opportunity for agencies to review and comment was provided (prior to collecting data) in late August of 2020. The objective of the proposed flow test scenario study was designed to capture existing (baseline) Project operations and also to support the development and calibration of hydraulic models that allowed for visualization and evaluation of flow releases from set Tainter gate openings.

For Byllesby, the target flow scenarios (Table 5-2) were designed to evaluate the effect of passing the entire minimum downstream flow requirement of 360 cfs through the bypass reach. Tainter Gate #6 was used to pass flows into the bypass reach as it is near the center of the spillway structure and under existing operating procedures is the first gate operated for releases into the bypass reach (see Figure 4-1). The four target flows proposed in Table 5-2 would allow a hydraulic model simulation range from leakage up to approximately 500 cfs.

For Buck, the target flow scenarios (Table 5-2) were designed to evaluate the effect of the existing ramping rate requirements. Appalachian is required to discharge flows through a 2-ft gate opening for at least three hours following any spills released through a gate opened 2 ft or more. Appalachian must then reduce the opening to 1 ft for at least an additional three hours, after which time the gate may be completely closed. This gradual reduction of flow allows adequate time for fish that may have traveled upstream into the bypass reach to respond to receding water levels, reducing instances of fish stranding that can potentially occur with sudden flow discontinuation.

Tainter Gate #1 (see Figure 4-2) was utilized at the Buck development to pass the target flows since this reflects current operations (i.e., Tainter Gate #1 is first to open and last to close during high flow events where flows are routed into the bypass reach). Gate openings of 2 ft and 1 ft were evaluated (as per existing ramping rate operating protocols) as well as a gate opening of 0.5 ft to represent flows that would occur between a 1-ft gate opening and leakage conditions. The four target flows proposed in Table 5-2 allowed for a hydraulic model simulation range from leakage up to approximately 2,250 cfs.

Water level data loggers (pressure transducers that measure water stage changes) were strategically deployed in the tailrace, bypass, and downstream study reaches prior to releasing the calibration target flows. The instrumentation remained in place for several weeks afterwards to collect additional data during several rainfall runoff events, which captured depth and surface flow travel time information under a variety of flow regimes (i.e., powerhouse operations and spillway gate openings).

A level logger was also placed at the downstream end of the Buck study area to capture changes in water surface elevations created by Project operations. This downstream boundary was requested by the VDWR (formerly the VDGIF) to help better understand the potential effect Project operations may have on mussel habitat in this area.

Table 5-2. Byllesby-Buck Bypass Reach Aquatic Habitat Study proposed Flow Test Scenarios

Byllesby Bypass Reach				
Pool Range: 2078.2 - 2079.2 NGVD 29; Assume starting Pool Elevation is 2078.7 NGVD 29)				
Powerhouse Discharge Capacity: 5,868 cfs				
Powerhouse Minimum Discharge Capacity: 85 cfs/unit				
Tainter Gate #6				
Opening* (ft)	Proposed Target Flows (cfs)	Flow Test Duration (hours)	Volume (acre-ft)	Model Simulation Range (cfs)
0.0	Leakage	NA	0	Leakage
0.25	105	8	69	↓
0.5	203	4	67	
1.0	398	4	132	500
Buck Bypass Reach				
Pool Range: 2002.4 - 2003.4 NGVD 29; Assume starting Pool Elevation is 2002.9 NGVD 29				
Powerhouse Discharge Capacity: 3,540 cfs				
Powerhouse Minimum Discharge Capacity: 73 cfs/unit				
Tainter Gate #1				
Opening* (ft)	Proposed Target Flows (cfs)	Flow Test Duration (hours)	Volume (acre-ft)	Model Simulation Range (cfs)
0.0	Leakage	NA	0	Leakage
0.5	224	8	148	↓
1.0	448	8	296	
2.0	897	8	593	2,000

Notes: * Assume starting point is midpoint of operating range with adequate inflow to maintain pond levels during flow tests.

5.4.2 Particle Size Distribution

A Wolman pebble count (Wolman 1954) was performed along three transects in the Byllesby bypass reach study area to characterize the existing grain size distribution of substrate. The transects were located in (1) the bypass reach, (2) the cross-over channel between the tailrace and main channel, and (3) the upper end of the side channel to evaluate differences in substrate between the three transect locations. Substrate particle sizes were plotted by size class and frequency to determine distributions within the bypass reach study area; plots are shown in Section 6.4.3.

A similar Wolman pebble count was also performed along three transects in the Buck bypass reach. The transects were located in (1) the upper, (2) middle, and (3) lower portions of the bypass reach to evaluate differences in substrate between the three locations. Substrate particle sizes were plotted by size class using the Wentworth grain size scale (Wentworth 1922) and frequency to determine distributions within the mesohabitats of each of the bypass reaches; plots are shown in Section 6.4.3.

5.5 Hydraulic Model Development

5.5.1 General Model Description

Development of a 2-D hydraulic model was carried out as part of the Bypass Reach Flow and Aquatic Habitat Study. A 2-D model incorporates detailed terrain data obtained by topographic mapping technologies and provides options for building one-dimensional (1-D) and 2-D geometries. It also utilizes a 1-D/2-D model development approach which optimizes the simulation of observed hydraulic behavior for specific project requirements. This study used the Innovyze Infoworks Integrated Catchment Model (ICM) software (version 7.0), which is capable of simulating depth and velocities in a 2-D grid pattern over a wide range of flow conditions.

The advantage of implementing a 2-D model is that it provides more stable results over a wider range of flows than a 1-D model, thus reducing troubleshooting during model development; however, simulation speed is generally slower. The ICM software performs 2-D unsteady flow hydraulic calculations based on conservation of mass and momentum to dynamically route the spillway release flood wave downstream and uses a finite-volume solution algorithm to allow for 2-D cells to be wet or dry and handle a sudden rush of water, subcritical, supercritical, and mixed-flow regimes. For instance, a spillway release is a highly dynamic flood wave that rises and falls quickly; therefore, the 2-D unsteady flow calculation must use the full momentum form of the St. Venant equations (the full momentum equation accounts for the change in velocity both spatially and temporally).

The model geometry is defined by digital terrain model elevation values, user inputs based on Project drawings and survey information, and Manning's roughness coefficient inputs (used to establish terrain roughness) and calculates the flood wave hydrograph resulting from a spillway release based on input gate operation parameters. The ICM is also capable of simulating reservoir inflow and rate of reservoir rise, dynamic gate operations scenarios, release travel times, and rates of rise at locations within and downstream of the bypass reach.

5.5.2 Byllesby and Buck Bypass Reach ICM Model Development

The morphology of the approximately 475-ft long Byllesby bypass reach extending from the spillway to the vicinity of the powerhouse tailrace is variable and includes deep and shallow pools, runs, shoals, and steep cascades with large boulders. The Byllesby model domain extends approximately 1,800 ft downstream of the bypass reach/tailrace confluence and includes a cross-over channel with shallow pool/glide habitat with a mostly sandy bottom, a wide main channel consisting of mostly run habitat with undulating bedrock, and a narrow side channel with shallow pools, runs, and riffles with a mostly cobble and gravel substrate. This complex study area impacts flow travel times differently at varying flows and is most accurately represented by a 2-D model. Results of the modeling effort for the Byllesby Bypass study area are included in Attachment 1 (Byllesby Bypass Reach ICM Model Development); this report presents the final 2-D Byllesby bypass reach model developed using the ICM software, which was used to predict hydraulic regimes in the study area under varying flow conditions.

The morphology of the approximately 4,100-foot long Buck bypass reach extending from the spillway to the vicinity of the powerhouse tailrace is variable and includes deep and shallow pools, runs, shoals, steep cascades, and side channels with large boulders. This channel variability impacts flow travel times differently at varying flows and is most accurately represented by a 2-D model. Results of the modeling effort for the Buck Bypass are included in Attachment 1 (Buck Bypass Reach ICM Model Development); this report presents the final 2-D Buck bypass reach model developed using the ICM software, which was used to predict hydraulic regimes in the bypass reach under varying flows and from varying spill locations.

Flow and water depth data collected at four target flows for each development were used to calibrate and validate the hydraulic models to allow simulation of flow conditions and gate operations other than those that were explicitly sampled during data collection. Recorded gate operations (provided by Appalachian), flow, and level-logger data from each tailrace and bypass study reach were processed to provide operation sequences and flow and elevation hydrographs used for the calibration of gate and bypass reach model hydraulic parameters. Operational procedures for spilling and ramping rates that affect upstream-downstream connectivity were also assessed. Analyzing the results of varying spill events and spill configurations can provide insight to potential adverse effects on the fish and other aquatic species or recreational fishing opportunities in each bypass reach. Simulations were used to establish matrices of travel time, rise in water surface elevation, and velocities at locations of interest under the different flow regimes.

It is noted that any model is a representation of actual physical processes and has inherent uncertainty, especially when used to simulate conditions that were not explicitly observed and recorded. The level of model accuracy is influenced by the quality of data used to build the model, such as channel geometry, geometry, and hydraulic parameters of controlling structures (i.e. gates and spillways), the quality of data used to calibrate the model, and choice of model (e.g., uncertainty inherent in numerical methods, flow calculation equations).

5.6 Aquatic Habitat Evaluation

Activities described above (i.e., literature review and desktop assessment, topographic mapping and photogrammetry, field data collection, and hydraulic model development) were used to develop a flow and aquatic habitat assessment of each tailrace and bypass reach. Specifically, for each flow scenario evaluated, incremental changes in depth and wetted area were determined. The water level logger data in combination with the 2-D model results were used to determine rate of rise and fall of water elevation (i.e., water depth) in the tailrace and bypass reaches and evaluate flow patterns and hydraulic connectivity under each flow regime evaluated. In addition, substrate and mesohabitat mapping along with the 2-D model depth and velocity simulation results were used in combination with aquatic species habitat suitability criteria (HSC) (i.e., using depth, velocity, and substrat/cover preferences) to evaluate potential available habitat under each modeled flow scenario in the study areas.

5.6.1 Target Species and Habitat Suitability Criteria

Walleye was selected as the target species for this study along with a total of eight species-guild representatives including three shallow-slow, one shallow-fast, two deep-slow, and two deep-fast guilds. Guild representatives were selected from a variety of regionally representative sources, represent a wide range of habitat characteristics, and were selected to represent a wide range of species. In some cases, general non-species-specific criteria were used. In other cases specific species were used to represent a guild category; these include Redbreast Sunfish (*Lepomis auritus*), Silver Redhorse (*Moxostoma anisurum*), and Shorthead Redhorse (*Moxostoma macrolepidotum*) (Table 5-3).

5.6.1.1 Target Species

Walleye is the largest member of the Percidae family and attains average adult sizes of 300-780 millimeters (mm) total length (Lee et al. 1980; Stauffer et al. 1995). The fish is native to most of North America, excluding the arid west where it has been widely introduced for its recreational importance (Lee et al. 1980). The species is a voracious predator that begins feeding solely on fish at the size of only 30 mm (Li and Mathias 1982). Walleye are yellow to green dorsally, slightly fade laterally, and become white ventrally. Dark bands across the dorsum can be present in some individuals. Fins are mostly clear with some spotting, but the posterior margin of the anterior dorsal fin has a dark blotch and the ventral tips of the caudal and anal fins are white (Stauffer et al. 1995).

Walleye are most commonly associated with large rivers in deep water habitat such as pools and runs. They only leave the protection of deep water at night when they feed in the shallows (Lee et. al. 1980; Stauffer et. al. 1995). Spawning takes place during early spring at temperatures ranging from 3-16 degrees Celsius. Shallow gravel substrate is necessary for successful spawning (Lee et. al. 1980).

5.6.1.2 Guild Species

Redbreast Sunfish

As a representative of the deep/slow guild, the Redbreast Sunfish, is a Centrarchid. The redbreast is native along the Atlantic slope of the Appalachians from southern Canada to Florida west to the Apalachicola River (Lee et al. 1980). Like most sunfishes the Redbreast Sunfish is an opportunistic insectivore that incorporates smaller fish into its diet as it obtains larger sizes (Levine et al. 1986; Wallace 1984). Superficially, the Redbreast Sunfish resembles most other sunfish, particularly the bluegill (*Lepomis macrochirus*). However, unlike the bluegill, the redbreast lacks a black blotch on the dorsal fin and has shorter gill rakers. The redbreast can be distinguished from all other sunfish, except the bluegill, by black on the opercular flap that extends to the posterior margin. Adults range from 60-155 mm total length (Lee et. al. 1980).

More than any other sunfish, the Redbreast dwells almost entirely in lotic environments (Lee et al. 1980; Stauffer et al. 1995). Gravel spawning nests are constructed from spring through summer when water temperatures reach 23° C (Levine et al. 1986; Stauffer et al. 1995).

Redhorse

Representing both shallow/slow (i.e., young-of-year) and deep/fast (i.e., adults) guilds, Catostomidae are members of the genus *Moxostoma*, the redhorses. Specifically, Silver Redhorse and Shorthead Redhorse habitat suitability information is included in the guild habitat modeling.

The redhorses are indigenous to the Atlantic slope of the Appalachians, the Mississippi River Drainage, and the Great Lakes Basin. All the redhorses possess subterminal mouths used to forage the streambed for benthic macroinvertebrates. Like other catostomids, they are drab olive bronze dorsally and fade to white ventrally. They possess complete, well developed lateral lines and develop tubercles during breeding. These fish can attain lengths up to 600 millimeters standard length (Lee et al. 1980; Stauffer et al. 1995).

The redhorse can inhabit both lentic and lotic environments, but they prefer medium to large streams and rivers with clear water and assorted rock substrates. While they are usually associated with deep pools and backwaters, they spawn in spring and early summer on coarse gravel (Lee et al. 1980; Stauffer et al. 1995).

5.6.1.3 Habitat Suitability Criteria

HSC define the range of microhabitat variables that are suitable for a particular species and lifestage of interest. Variables typically defined with HSC include depth, velocity, instream cover, and bottom substrate. HSC provide the biological criteria input to the ICM 2-D model, which combines the physical habitat data and the habitat suitability criteria into a site-wide habitat suitability index (i.e., weighted usable area or WUA) over a range of simulation flows. The habitat suitability index (HSI) is a numerical scale that represents habitat suitability with values ranging from 0.0 to 1.0 indicating habitat conditions that are unsuitable to optimal, respectively. WUA is defined as the sum of stream surface area within a nodal area model domain or stream reach, weighted by multiplying area by habitat suitability variables (most often velocity, depth, and substrate or cover), which range from 0.0 to 1.0 each.

HSC for target species and lifestages were obtained from three previous instream flow investigations: (1) Sutton Hydroelectric Project, Elk River, WV (HDR 2010); (2) Smith Mountain Hydroelectric Project, Roanoke River, Virginia (TRPA & Berger 2007); and (3) Claytor Hydroelectric Project, New River, Virginia (TRPA & Berger 2008). These three recent studies represent the best available sources for regionally applicable species information due to their close proximity to the study location, the similarity in river condition and species community modeled, and the collaborative HSC review process that each underwent.

Velocity, depth, and substrate HSC curves for Walleye, shallow water guilds, and fast water guilds are shown on Figure 5-1 through Figure 5-6. HSC data tables are included in Attachment 2 and habitat maps for Byllesby and Buck bypass reaches are presented in Attachment 3.

Table 5-3. Target Species Habitat and Suitability Criteria Source and Code Table

Species	Lifestage/ Category	Representative	Source Study	HSC Code
Walleye	Fry	--	Sutton Hydroelectric Project, Elk River, WV	WLEF
	Juvenile	--	Sutton Hydroelectric Project, Elk River, WV	WLEJ
	Adult	--	Sutton Hydroelectric Project, Elk River, WV	WLEA
	Spawning	--	Sutton Hydroelectric Project, Elk River, WV	WLES
Shallow-Slow Guild	Fine substrate, no cover	Redbreast Sunfish spawning	Smith Mountain Hydroelectric Project, Roanoke River, VA	RBSFS
	All substrate with aquatic vegetation	Silver Redhorse young-of-year	Sutton Hydroelectric Project, Elk River, WV	SRHAV
	Coarse substrate	Generic Shallow-Slow Guild	Sutton Hydroelectric Project, Elk River, WV	SHSLO
Shallow-Fast Guild	Moderate velocity with coarse substrate	Generic Shallow-Fast Guild	Claytor Hydroelectric Project New River, VA	SHFST

Species	Lifestage/ Category	Representative	Source Study	HSC Code
Deep-Slow Guild	Cover	Redbreast Sunfish adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	RBSFA
	No cover	Generic Deep-Slow Guild	Sutton Hydroelectric Project, Elk River, WV	DSLON
Deep-Fast Guild	Slightly weighted for fine substrate, Cover	Silver Redhorse adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	SRHAD
	Coarse-mixed substrate	Shorthead Redhorse adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	SHRHA

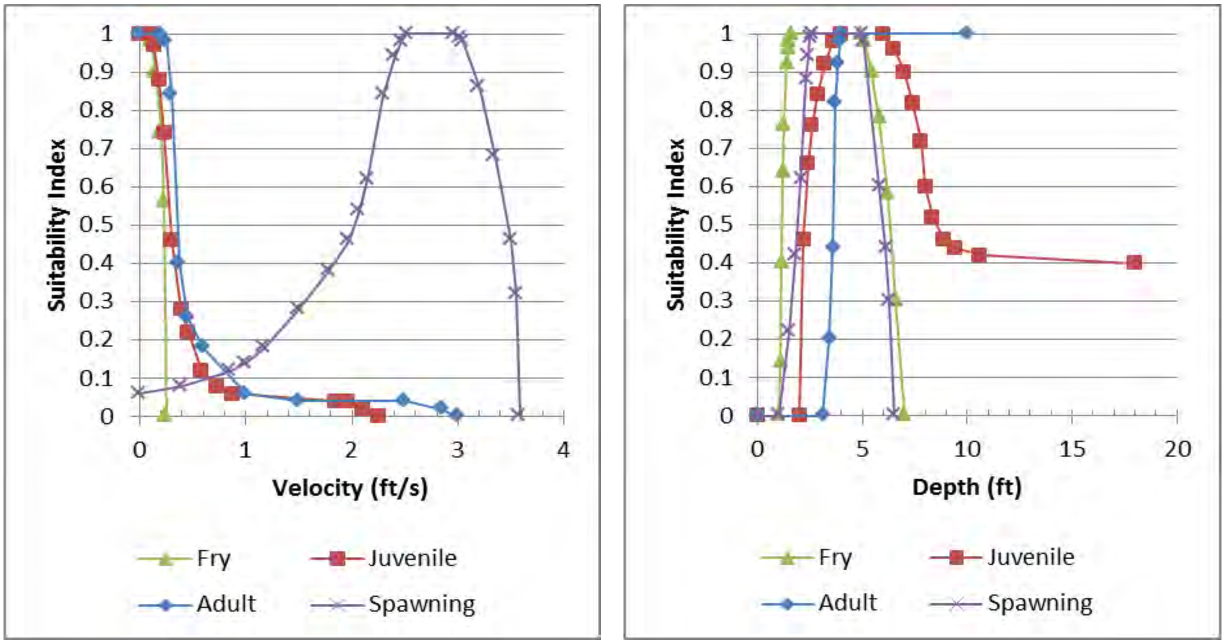


Figure 5-1. Velocity HSC (left) and Depth HSC (right) for Walleye

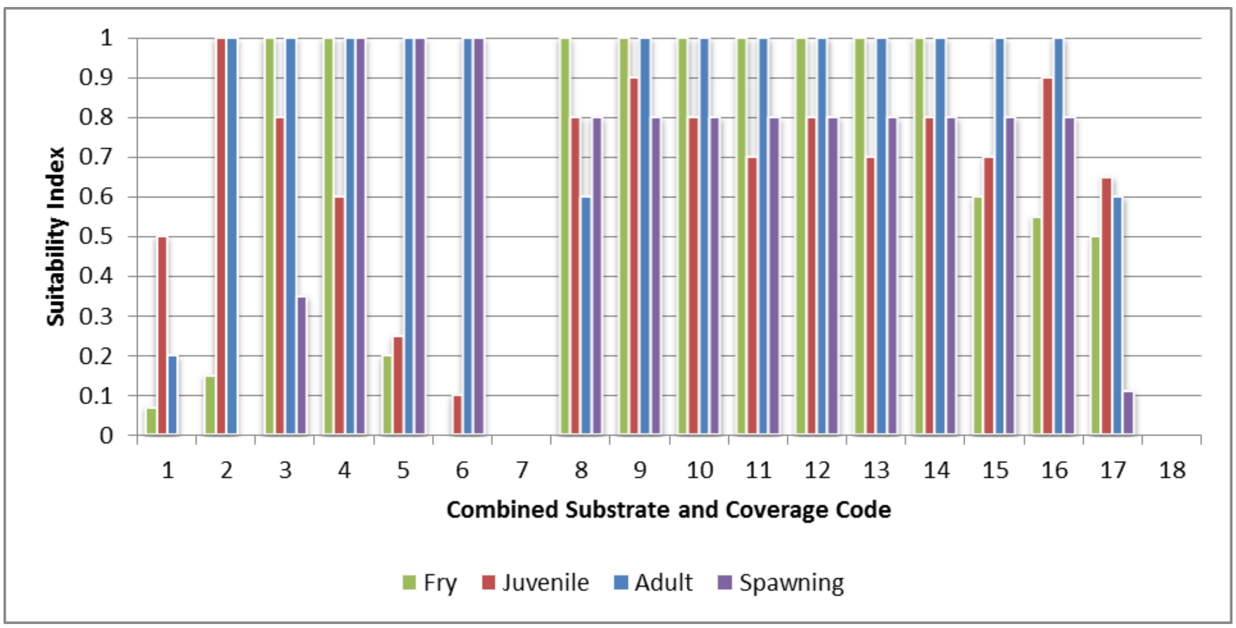


Figure 5-2. Substrate HSC for Walleye

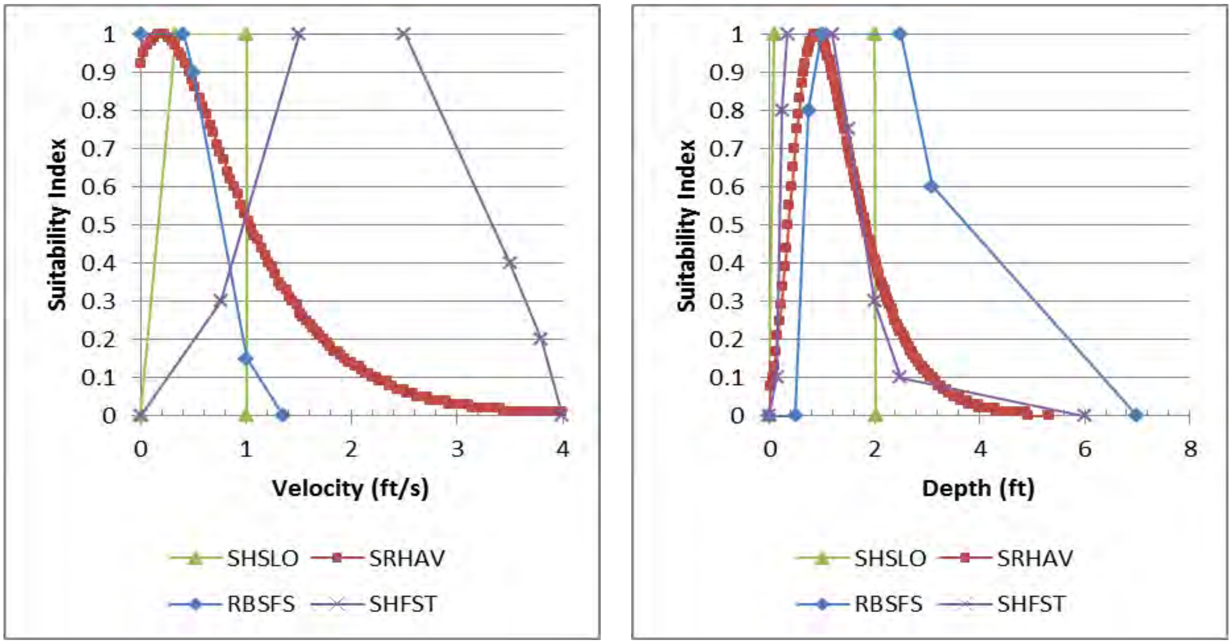


Figure 5-3. Velocity HSC (left) and Depth HSC (right) for Shallow Water Guilds

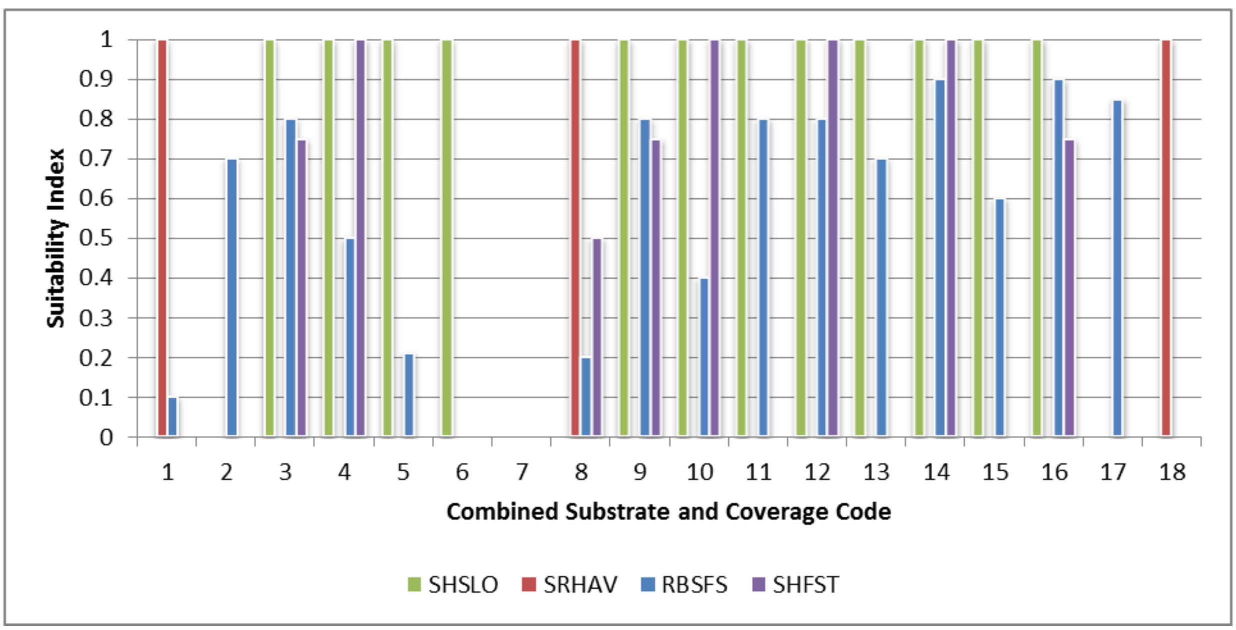
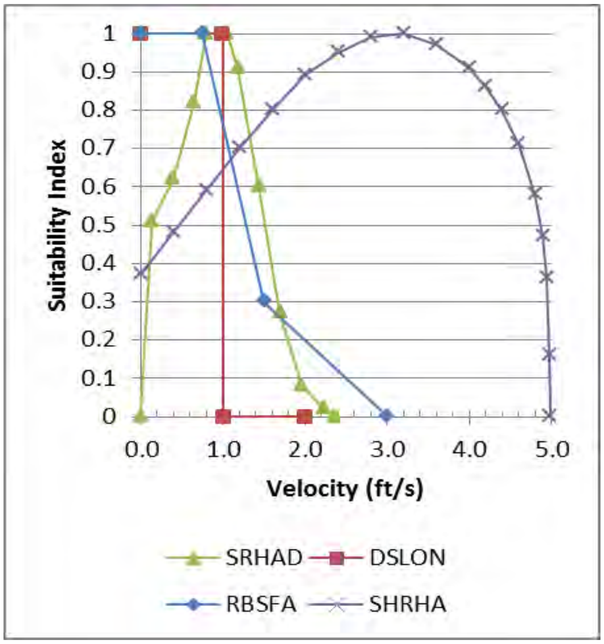


Figure 5-4. Substrate HSC for Shallow Water Guilds



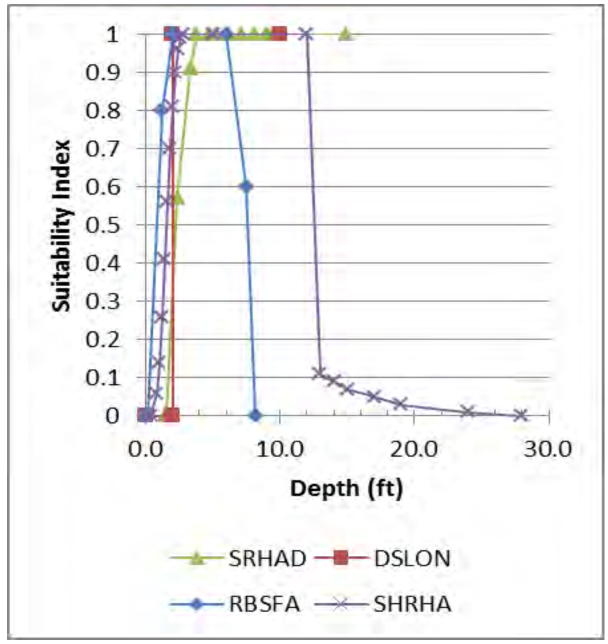


Figure 5-5. Velocity HSC (left) and Depth HSC (right) for Deep Water Guilds

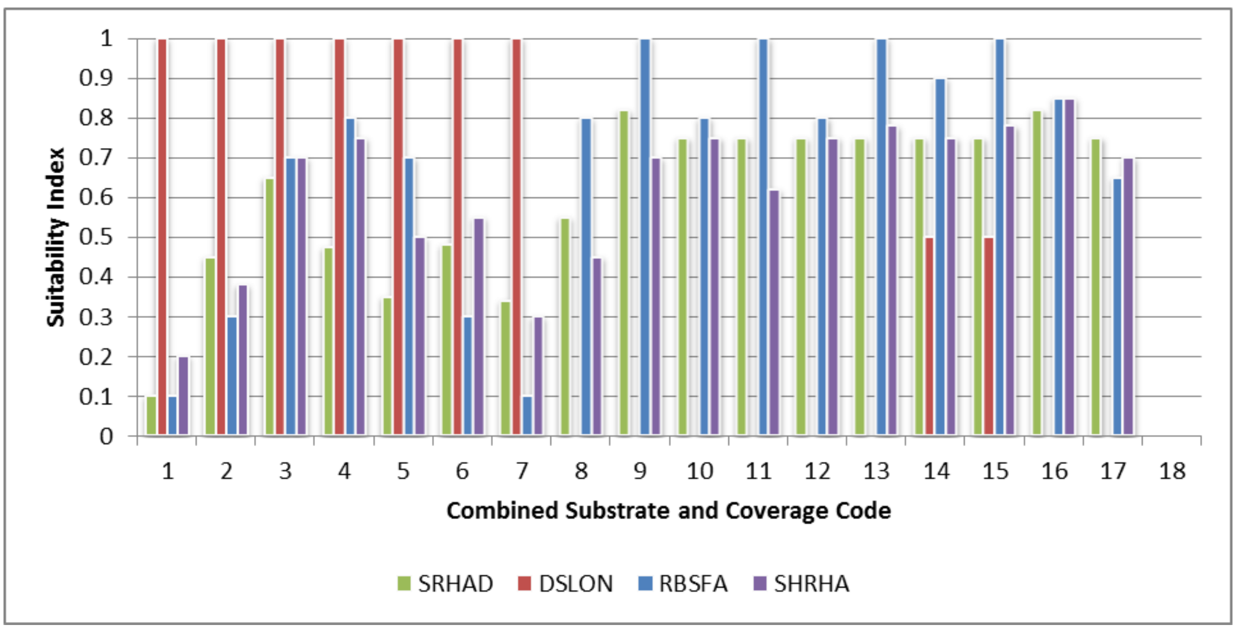


Figure 5-6. Substrate HSC for Deep Water Guilds

6 Study Results

6.1 Literature Review and Desktop Assessment Results

The literature review included several key reports and documents, which are included in the references section, as well as USGS and Project flow data as described in Section 5. The results of the desktop mesohabitat mapping of the bypass reaches, which was completed using high-resolution aerial imagery and topographic contour data, are included in Section 6.3. The 2-D hydraulic model results are included in Section 6.5 and Attachment 1. The aquatic habitat evaluation results including the life history characteristics and habitat preferences of selected species, as well distribution of mesohabitat types, are provided in Section 6.6.

6.2 Topography Mapping and Photogrammetry Data Collection Results

LiDAR data were collected during a period of no releases at the dams and minimal water levels in the bypass reaches to support development of comprehensive 3-D elevation and visual surface layers of each bypass reach. These data were used for desktop mesohabitat mapping as well as to produce a topographic map of each bypass reach. Maps of the habitat modeling results are included in Attachment 3 (Habitat Suitability Maps) and digital terrain models are included in the ICM Buck Model Development reports for Byllesby and Buck (Attachment 1).

6.3 Desktop Mesohabitat Mapping Results

The habitat mapping codes described in Section 5.3 were used to delineate the Byllesby and Buck bypass reaches. Habitat types were verified and/or updated in GIS as necessary based on field observations. Substrate-cover and mesohabitat classifications were reviewed by a senior scientist and polygons were processed using quality control procedures to ensure data integrity throughout the aquatic habitat modeling process.

6.3.1 Byllesby Bypass Reach

The total area evaluated for the Byllesby bypass reach was 40.1 acres. Cover and substrate characterization was reviewed, verified, and/or updated (as necessary) by a field investigation in July 2021. The majority of the Byllesby bypass reach had some kind of cover as either instream cover or overhead vegetation (46.5 and 22.7 percent, respectively) (Table 6-1). Concurrent with the pebble count (Section 6.4.3.1), boulder, bedrock, or woody debris was the most dominant substrate category (43.4 percent). Cobble (20.1 percent) and sand (15.9 percent) consisted of the next-two most prevalent substrate types in the desktop analysis. Run and riffle habitats were the most common within bypass the reach (44.2 and 41.0 percent, respectively), followed distantly by shoal, glide, upland, pool, and backwater mesohabitats. A photo of the Byllesby bypass reach is presented below (Figure 6-1) and a figure depicting the habitat desktop delineation is shown on Figure 6-2.

Table 6-1. Summary of Habitat Characteristics of the Byllesby Bypass Reach

Habitat Characteristic	Area (acres)	Percent (%)
Cover		
Instream Cover	18.7	46.5
No Cover	12.3	30.8
Overhead Vegetation	9.1	22.7
Substrate		
Boulder, Bedrock, or Woody Debris	17.4	43.4
Cobble	8.0	20.1
Sand	6.4	15.9
Mud or Flat Bedrock	3.2	7.9
Silt or Sand	2.6	6.5
Small Boulder	1.5	3.7
Gravel	1.1	2.6
Mesohabitat		
Run	17.7	44.2
Riffle	16.4	41.0
Shoal	2.9	7.2
Glide	1.3	3.3
Upland	0.9	2.2
Pool	0.6	1.4
Backwater	0.3	0.7

Figure 6-1. Byllesby Bypass Reach at Byllesby-Buck Hydroelectric Project

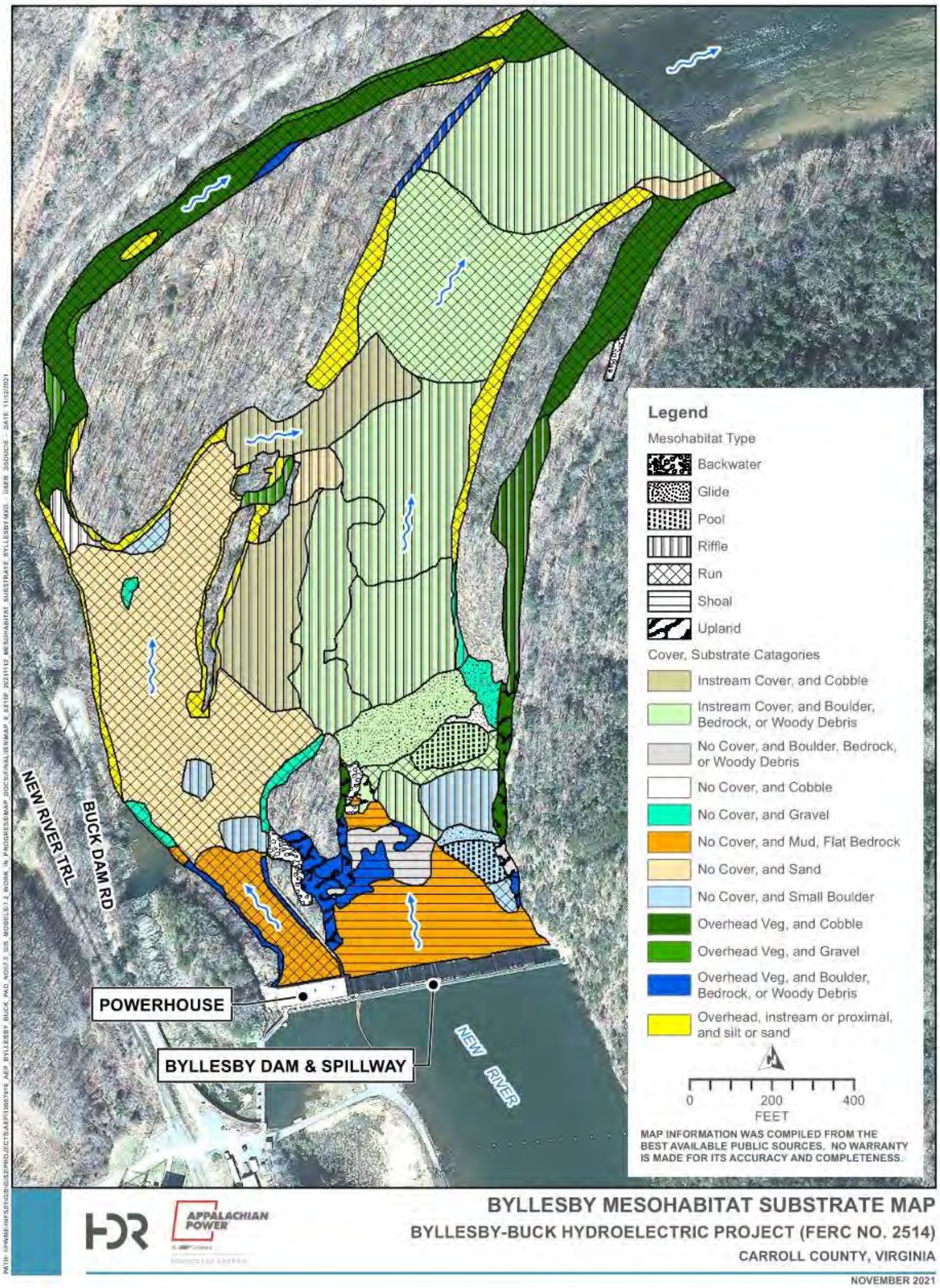


Figure 6-2. Byllesby Bypass Reach Desktop Habitat Delineation at Byllesby-Buck Hydroelectric Project

6.3.2 Buck Bypass Reach

The total area evaluated for the Buck bypass area was 99.4 acres. Cover and substrate characterization was reviewed, verified, and/or updated (as necessary) by a field investigation in September 2020. The majority of the Buck bypass reach has some form of cover consisting of either instream cover (58.1 percent) or overhead vegetation (17.2 percent) (Table 6-2). Concurrent with Wolman pebble count data (see Section 6.4.3), most of the substrate identified through the desktop habitat analysis was designated as a cobble or larger (including bedrock) (84.9 percent).

The mesohabitat desktop mapping and field-verification showed that different shapes/sizes and orientation of bedrock exist at the Byllesby and Buck bypass reaches. At Byllesby, flat bedrock with or without divots provides little or no instream cover (Figure 6-1); conversely at Buck, the bedrock is angular and vertically slanted, resulting in microhabitats as instream cover available for aquatic organisms. The bedrock slabs in the upper portion of the bypass reach are oriented parallel to flow resulting in scour of smaller substrate sizes, whereas in the middle-to-lower portion of the bypass reach, the bedrock is angled perpendicular to flow, resulting in substrate buildup (i.e., deposition) on the downstream side of the bedrock slabs. The difference in bedrock types is captured in the substrate-cover classifications below and is depicted in Figure 6-3 (i.e., the upper photograph is representative of the upper portion of the bypass reach and the lower photograph is representative of the mid-to-lower portion of the bypass reach). The desktop delineation of habitat types is presented in Figure 6-4 (upper bypass), Figure 6-5 (middle bypass), and Figure 6-6 (downstream of bypass reach).

Table 6-2. Summary of Habitat Characteristics of the Buck Bypass Reach

Habitat Characteristic	Area (acres)	Percent (%)
Cover		
Instream Cover	57.8	58.1
No Cover	24.5	24.7
Overhead Vegetation	17.1	17.2
Substrate		
Boulder, Bedrock, or Woody Debris	61.6	61.9
Cobble	15.0	15.1
Silt or Sand	8.0	8.1
Gravel	4.3	4.3
Small Boulder	3.8	3.8
Mud or Flat Bedrock	3.8	3.8
Sand	2.6	2.7
Boulder	0.4	0.4
Mesohabitat		
Run	31.1	31.2
Shoal	20.6	20.7
Riffle	20.2	20.4
Upland	14.5	14.6

Habitat Characteristic	Area (acres)	Percent (%)
Pool	12.6	12.7
Glide	0.4	0.4
Backwater	0.0	0.0

Figure 6-3. Buck Bypass Reach with Flow Arrows (upper photo = Upper transect, bottom photo = Lower and Middle transects)

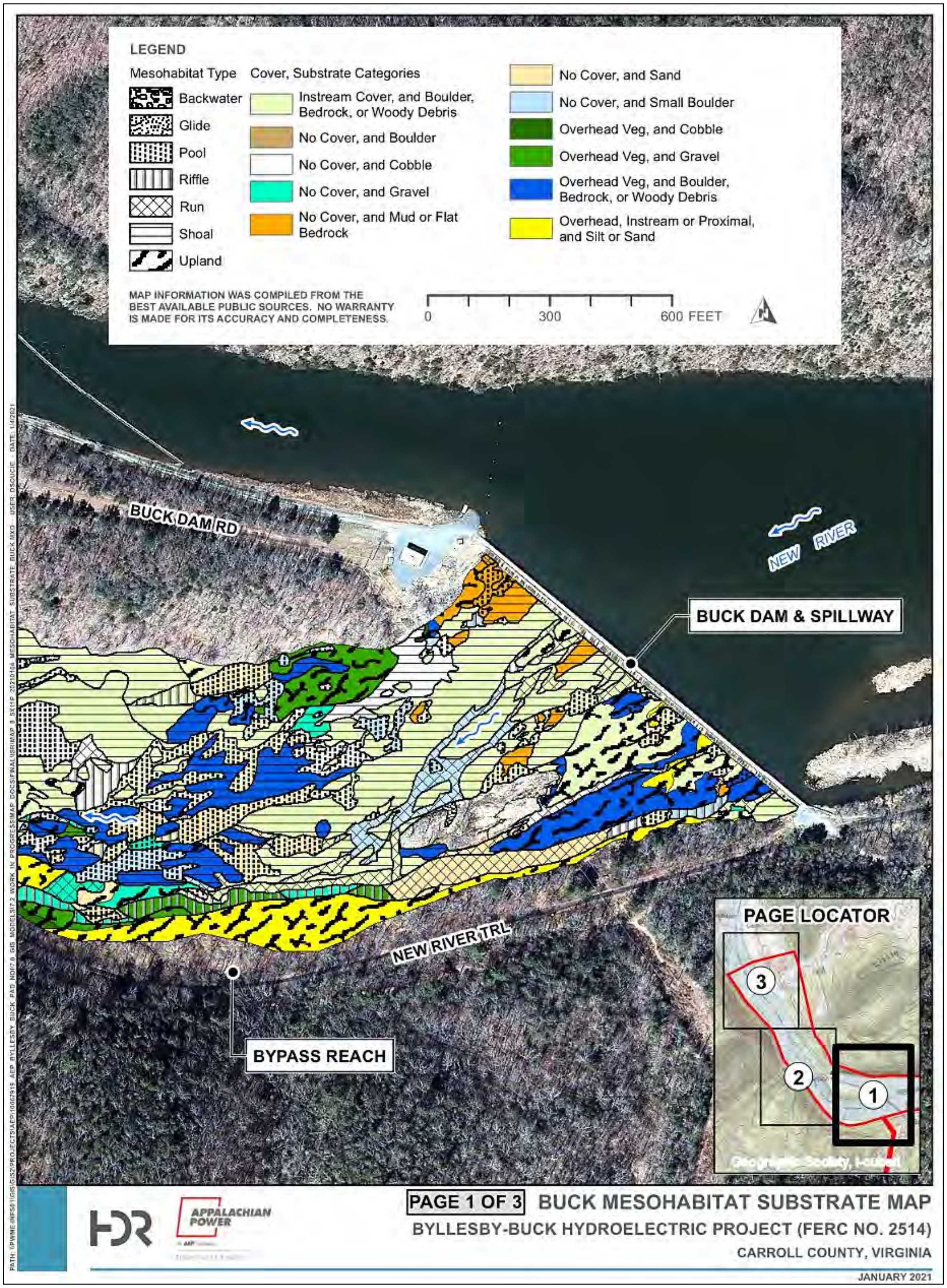


Figure 6-4. Desktop Habitat Delineation of the Upper Buck Bypass Reach

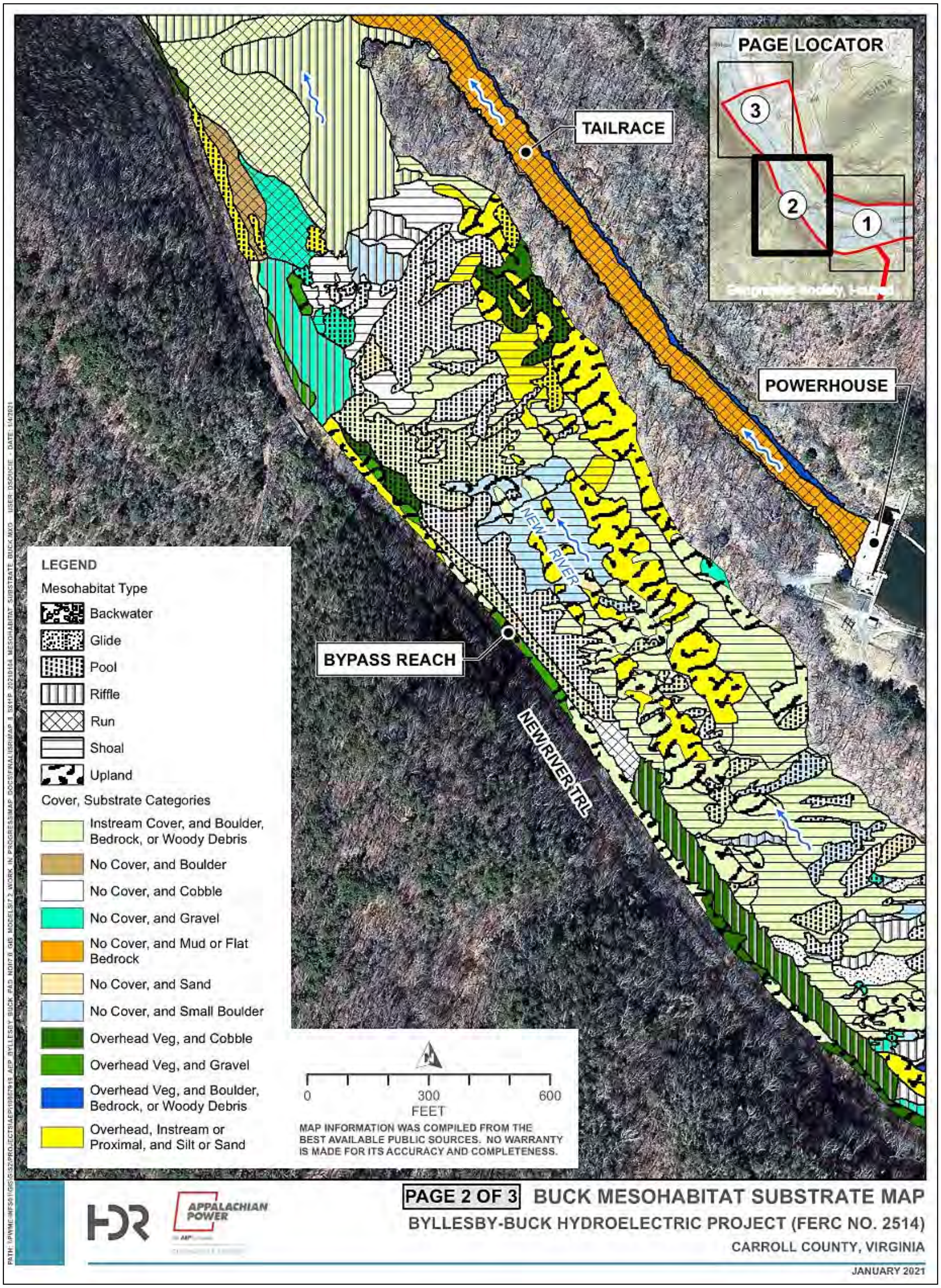


Figure 6-5. Desktop Habitat Delineation of the Middle Buck Bypass and Powerhouse Tailrace

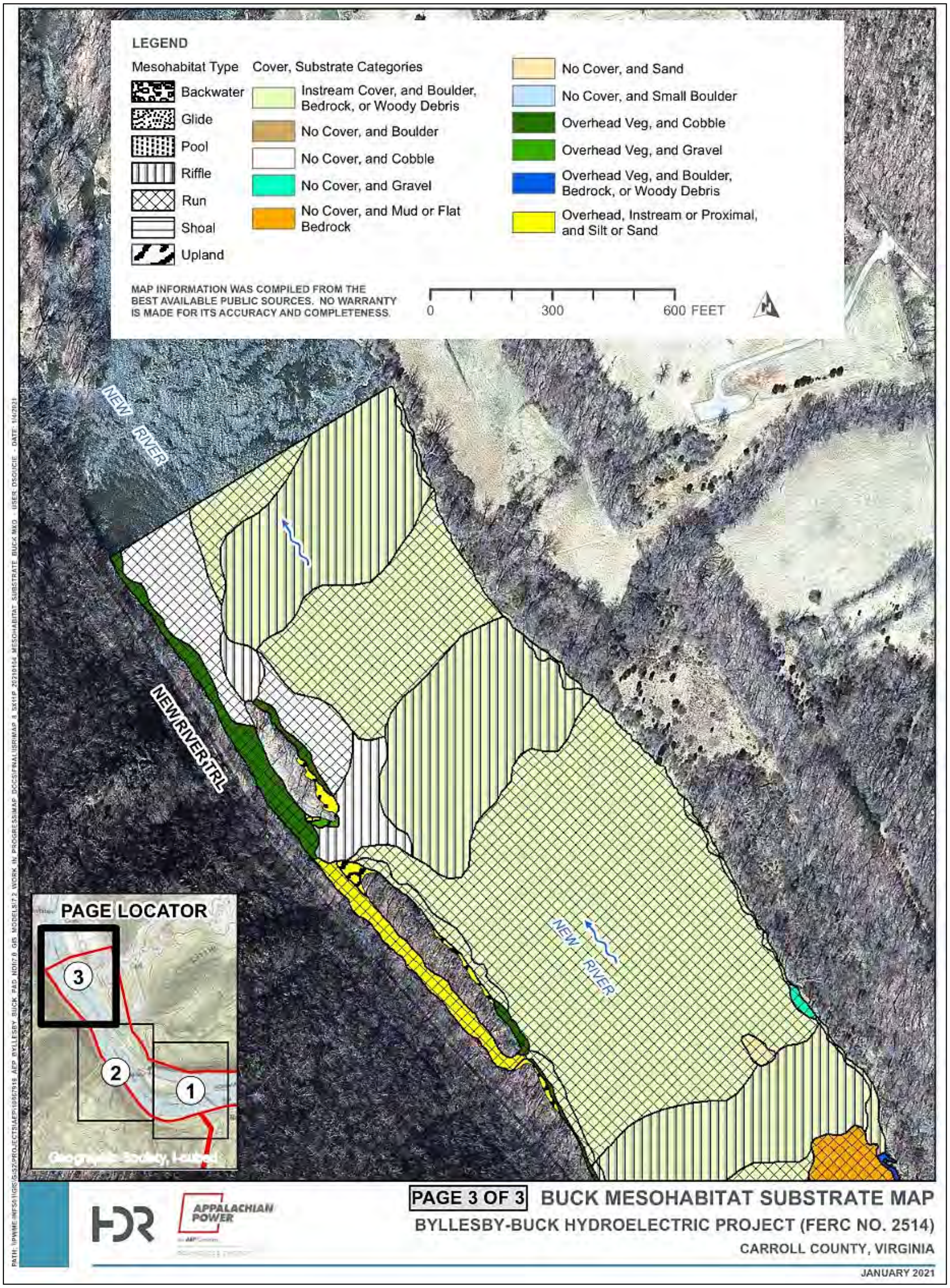


Figure 6-6. Desktop Habitat Delineation of the Lower Buck Reach (Downstream of Bypass Reach and Powerhouse Tailrace)

6.4 Field Data Collection Results

6.4.1 Byllesby Flow and Water Level Assessment Results

Four target flow releases were performed over three days and two separate trips, July 28, 2021 and September 8–9, 2021. Each target flow was designed to capture a specific/stable flow in the bypass reach. Flow was delivered to the bypass reach via leakage through the closed spillway gates, flashboard bays, and/or Tainter Gate #6. Total flows in the bypass reach were recorded using an acoustic Doppler current profiler at a transect location near the downstream end of the bypass reach. Gate settings and resulting flows are provided in Table 6-3. Additional details on the target flow measurements (including location in the bypass reach) is provided in Attachment 1. The Proposed Flow Test Scenarios technical memo was emailed by Appalachian to key agency stakeholders on August 18, 2020. On August 25, 2020, VDWR requested a conference call with Appalachian and key agency stakeholders, which was held on August 28, 2020. The Proposed Flow Test Scenarios technical memo, the Bypass Flow Test Scenario meeting notes, and emails with agency concurrence are included in Attachment 4 (Germane Correspondence).

Table 6-3. Byllesby Tainter Gate #6 Settings and Measured Bypass Reach Flow

Tainter Gate #6 Opening (ft)	Bypass Reach Flow (cfs)
Day 1: Closed (Leakage Flow)	11
Day 2: Broken Flashboards (Low Flow)	88
Day 3: 0.5 (Mid Flow)	158
Day 4: 1.0 (High Flow)	194

To aid calibration and validation of the ICM 2-D model in the Byllesby bypass reach study area, water surface elevations were collected during the target flow releases described in Section 5.4.1 using Onset U-20 level loggers set to record data at 5-minute intervals. This data was also used to determine flow travel times during the target flow releases to determine the amount of time required for each target flow to stabilize within the study area and also the amount of time it took for the target flow to recede once Tainter Gate #6 was closed. Locations of the deployed level loggers are shown in Figure 6-7 for the Byllesby bypass reach.

Level logger data during the bypass flow field data collection period (July 26 – September 13, 2021) is shown on Figure 6-8 for the bypass reach and main channel immediately downstream from the bypass reach and on Figure 6-9 for the tailrace, cross-over channel between the tailrace and main channel, and side channel. Summary results/observations pertinent to the Bypass Reach Flow and Aquatic Habitat Study include:

- Depths increased in the bypass reach approximately 0.8 ft from Leakage Flow to Low Flow range (11 cfs to 88 cfs), approximately 0.2 ft from Low Flow to Mid Flow (88 cfs to 158 cfs), and approximately 0.5 ft from Mid Flow to High Flow (158 cfs to 194 cfs). The overall depth increase was approximately 1.5 ft from Leakage Flow to High Flow (11 cfs to 194 cfs).

- Depth increases in the main channel immediately downstream from the bypass reach were much lower than the bypass reach increasing a maximum of only 0.25 ft between Leakage Flow and High Flow.

- Bypass flow releases did not influence water surface elevations in the tailrace, cross-over channel, or side channel areas. These areas are influenced by powerhouse flow releases and not bypass flow releases.
- Because the Byllesby bypass reach is relatively short (i.e., 475 ft long), travel times of flow releases from Tainter Gate #6 to the downstream end of the bypass reach are also relatively short. For example, the Mid Flow and High Flow releases reached the downstream end of the bypass reach in 6 minutes and 2 minutes, respectively.

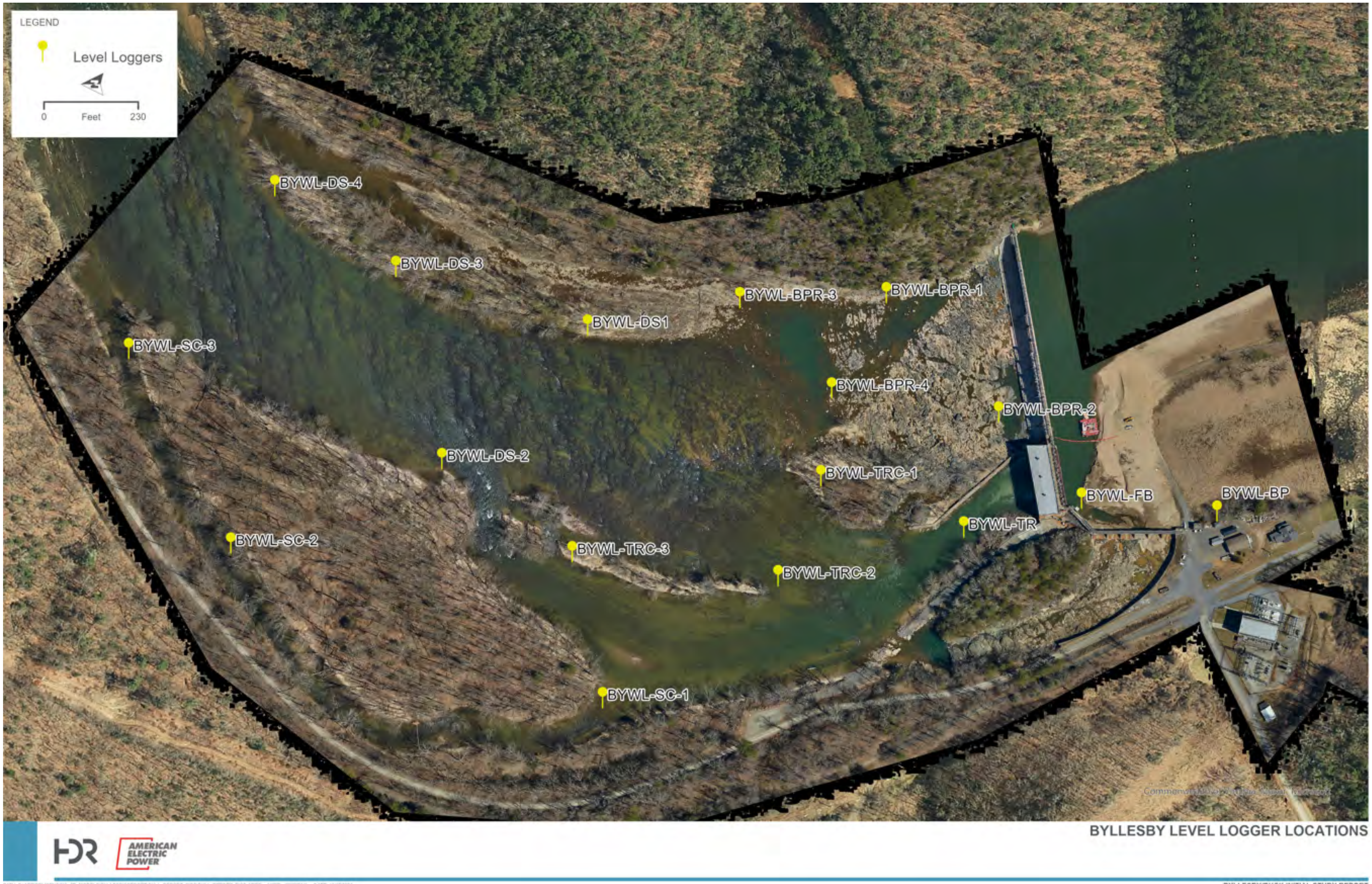


Figure 6-7. Byllesby Bypass Reach Level Logger Locations

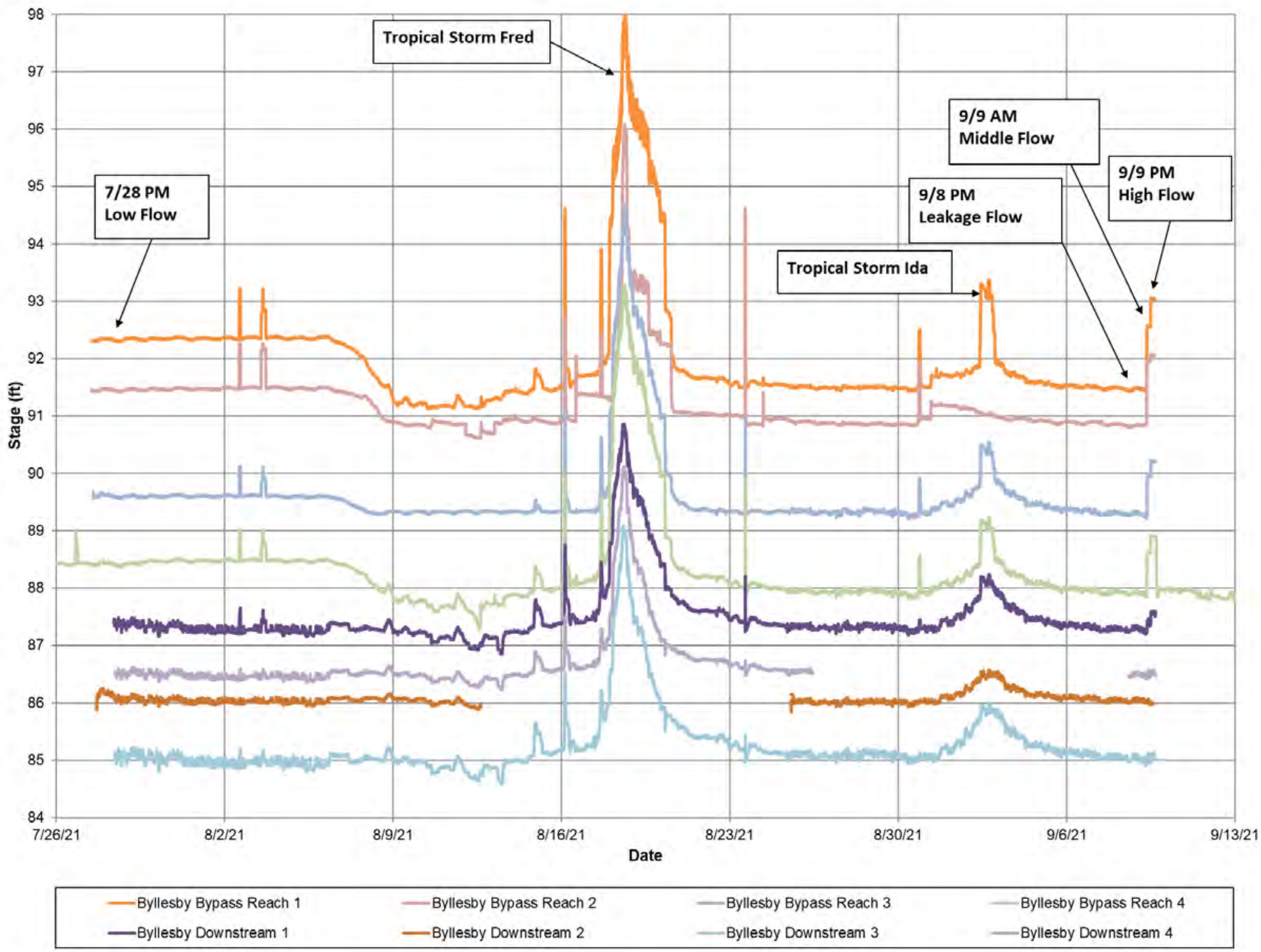


Figure 6-8. Byllesby Bypass Reach and Downstream Main Channel Level Logger Data during Study Period

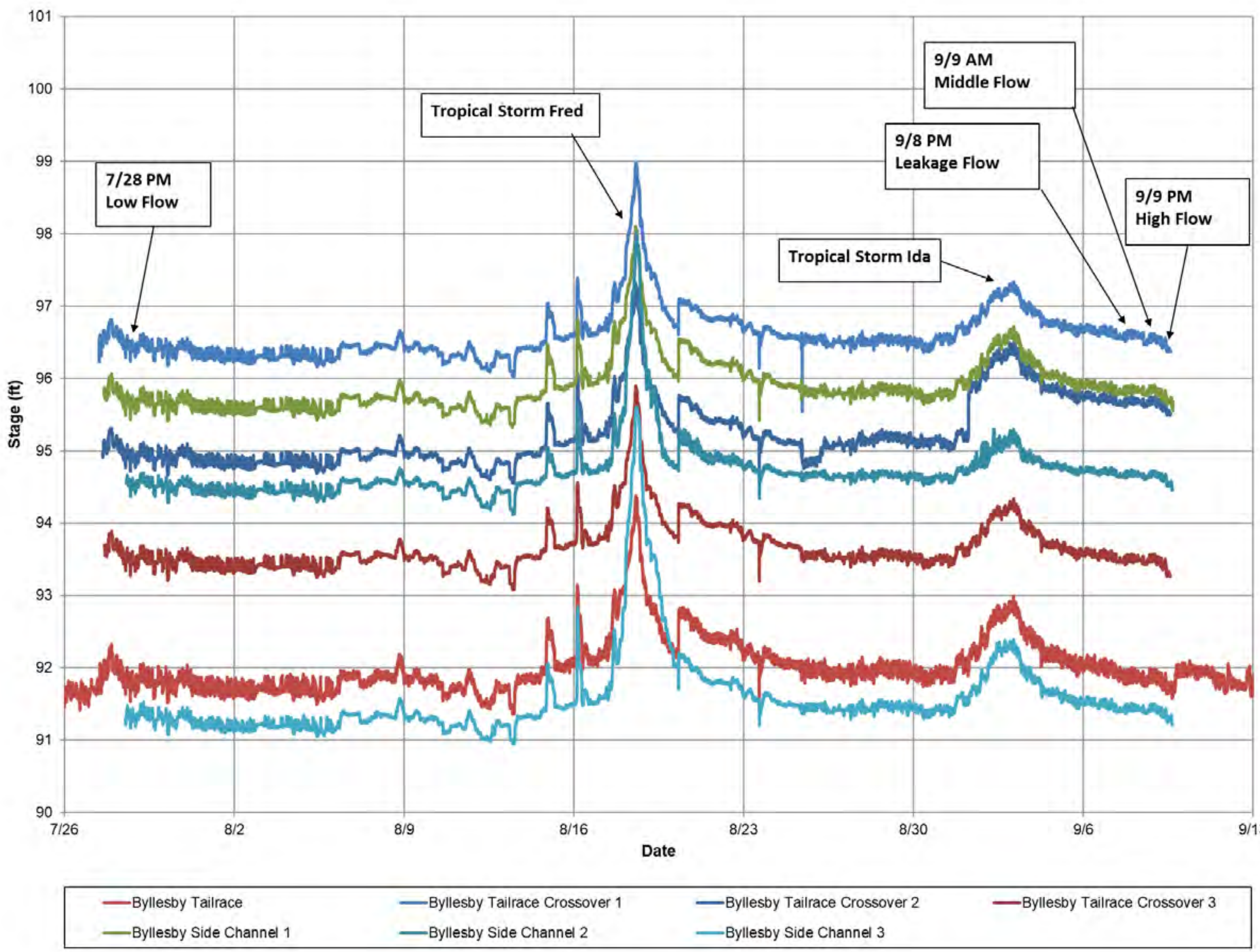


Figure 6-9. Byllesby Tailrace, Cross-over Channel, and Side Channel Level Logger Data during Study Period

6.4.2 Buck Flow and Water Level Assessment Results

Four target flow releases were performed over four days and two separate trips, September 8–10, 2020 and September 15–17, 2020. Each target flow was designed to capture a specific/stable flow in the bypass reach. Flow was delivered to the bypass reach via leakage through the closed spillway gates and flashboard bays and/or Tainter Gate #1. Total flows in the bypass reach were recorded using a handheld manual Swoffer® flow meter for the Day 1 (leakage) and Day 2 (0.5 ft gate opening) target flows and using an acoustic Doppler current profiler for the Day 3 and Day 4 (1 ft and 2 ft gate opening, respectively) target flows. Gate settings and resulting flows are provided in Table 6-4. . Additional details on the target flow measurements (including location in the bypass reach) is provided in Attachment 1. The Proposed Flow Test Scenarios technical memo was emailed by Appalachian to key agency stakeholders on August 18, 2020. On August 25, 2020, VDWR requested a conference call with Appalachian and key agency stakeholders, which was held on August 28, 2020. The Proposed Flow Test Scenarios technical memo, the Bypass Flow Test Scenario meeting notes, and emails with agency concurrence are included in Attachment 4 (Germane Correspondence).

Table 6-4. Buck Tainter Gate #1 Settings and Measured Bypass Reach Flow

Tainter Gate #1 Opening (ft)	Bypass Reach Flow (cfs)
Day 1: Closed (Leakage Flow)	17.1
Day 2: 0.5 (Low Flow)	210.7
Day 3: 1.0 (Mid Flow)	354
Day 4: 2.0 (High Flow)	714

To aid calibration and validation of the ICM 2-D model in the Buck bypass reach, water surface elevations were collected during the target flow releases described in Section 5.4.1 using Onset U-20 level loggers set to record data at 5-minute intervals. This data was also used to determine flow travel times during the target flow releases to determine the amount of time required for each target flow to stabilize within the study area and also the amount of time it took for the target flow to recede once Tainter Gate #1 was closed. Locations of the deployed level loggers are shown on Figure 6-10. for the Buck bypass reach.

Level logger data during the two-week target flow field data collection period is shown on Figure 6-11 and the full period of level logger deployment (i.e., August 20 – October 6, 2020) is shown on Figure 6-12. Summary results/observations pertinent to the Bypass Reach Flow and Aquatic Habitat Study include:

- From the Leakage Flow to Low Flow range (17.1 cfs to 210.7 cfs), depths increased approximately 1.0 to 1.5 ft along the main flow path (i.e., center of upper reach and along the left descending bank in the lower portion of the reach). As the target flows increased to the Mid (354 cfs) to High (714 cfs) flow range, corresponding depths along the main flow path were approximately 2.5 ft deeper than at leakage flow.

- Target flow releases up to the High Flow range (714 cfs) did not influence water depth along the upper portions of the left descending side channel (BK_LL2); and resulted in a small depth increase (< 0.5 ft) relative to leakage flows at BK_LL4 (which is just outside the main flow path).

- Depths along the left descending side channel were only impacted during rainfall runoff events that resulted in bypass reach flow releases that were much higher (i.e., at least 5,000 cfs) than the target flow scenarios (several flow events in this range are shown on Figure 6-12.
- Water depths at the downstream study area boundary were not influenced by the target flow releases as this location is downstream of the confluence of the tailrace and bypass reach. However, depths at this location are influenced by the overall magnitude of Project inflows. For example, as flows increased from approximately 2,000 cfs to 8,000 cfs, this resulted in a depth increase of approximately 2 ft at this location. As flows increased from approximately 2,500 cfs to 5,000 cfs resulted in a depth increase of approximately 0.75 ft (see Figure 6-12, location BK_LLDS).
- Water surface elevations in the lower portion of the bypass reach (i.e., near BK_LL10 and BK_LL11) are not influenced by flow releases from the spillway as the backwater effect from the New River extends upstream into this area.
- Flow travel time from the uppermost level logger (BK_LL1) to the most downstream level logger not influenced by the New River backwater effect (BK_LL8) ranged from approximately 1 hour (Low Flow release) to approximately 15 minutes (High Flow release). Time for flow stabilization at each location typically took less than 15 minutes once the flow arrived.
- Target flow releases were stable during the entire data collection period each day as evidenced by a steady water surface elevation for at least 8–10 hours each day.
- Once the target flow release stopped each day, water surface elevations in the Buck bypass reach dropped almost immediately and returned to leakage levels within approximately 2 hours.
- The existing ramping rate effect on bypass reach water surface elevations is clearly shown at the end of the Day 4 (High Flow) target flow release as the Tainter Gate #1 2-ft opening paused at a 1-ft opening for 3 hours before closing (Figure 6-11). This allowed water surface elevations in the bypass reach main flow path to decrease approximately 0.5 ft before the gate was closed completely.
- Tainter gate operations are evident during a rainfall runoff event that occurred between the two target flow measurement weeks (see September 13 – 15, 2020 on Figure 6-11).

Figure 6-10. Buck Bypass Reach Level Logger Locations

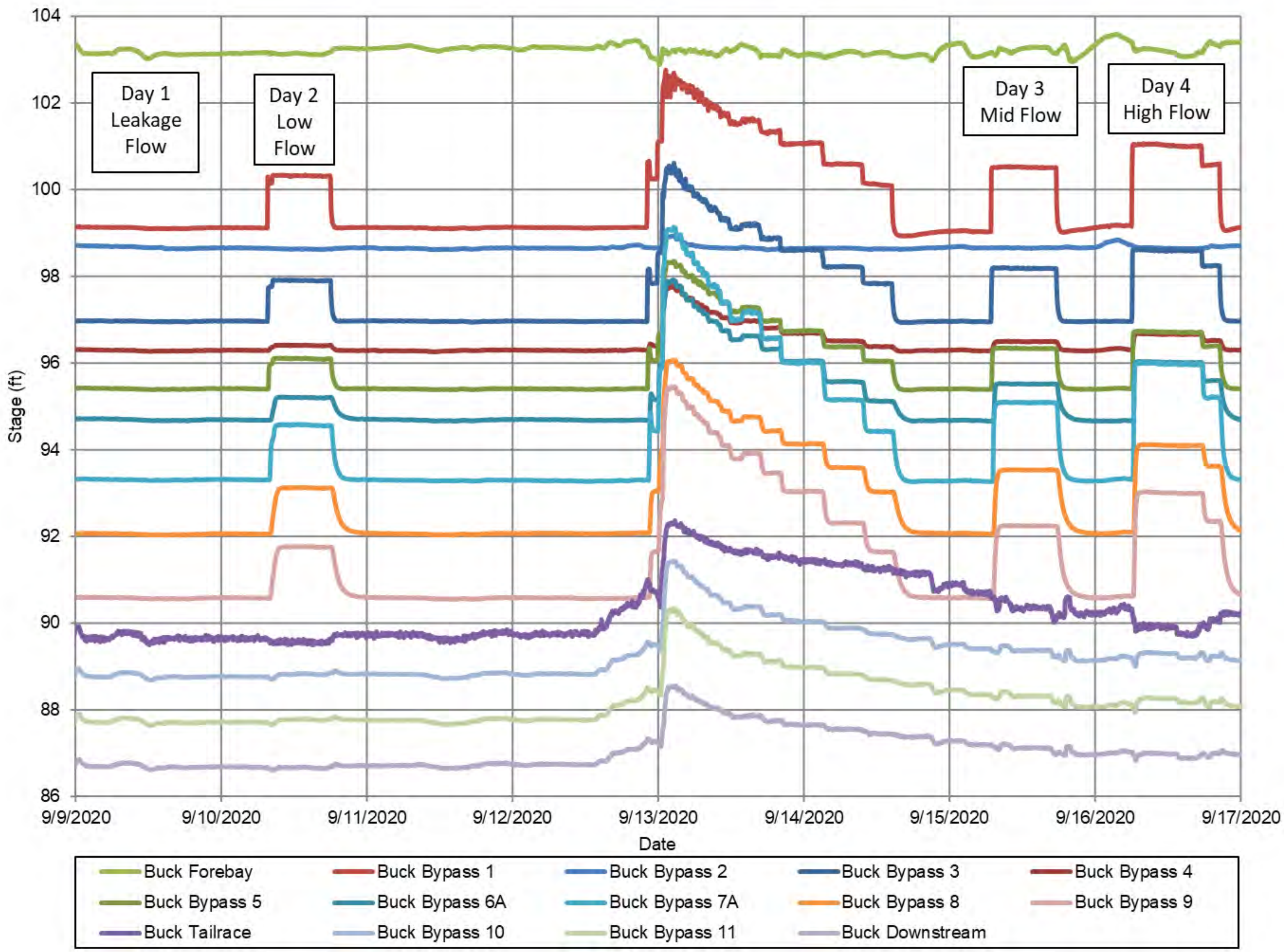


Figure 6-11. Buck Bypass Reach Level Logger Data during Target Flow Measurements

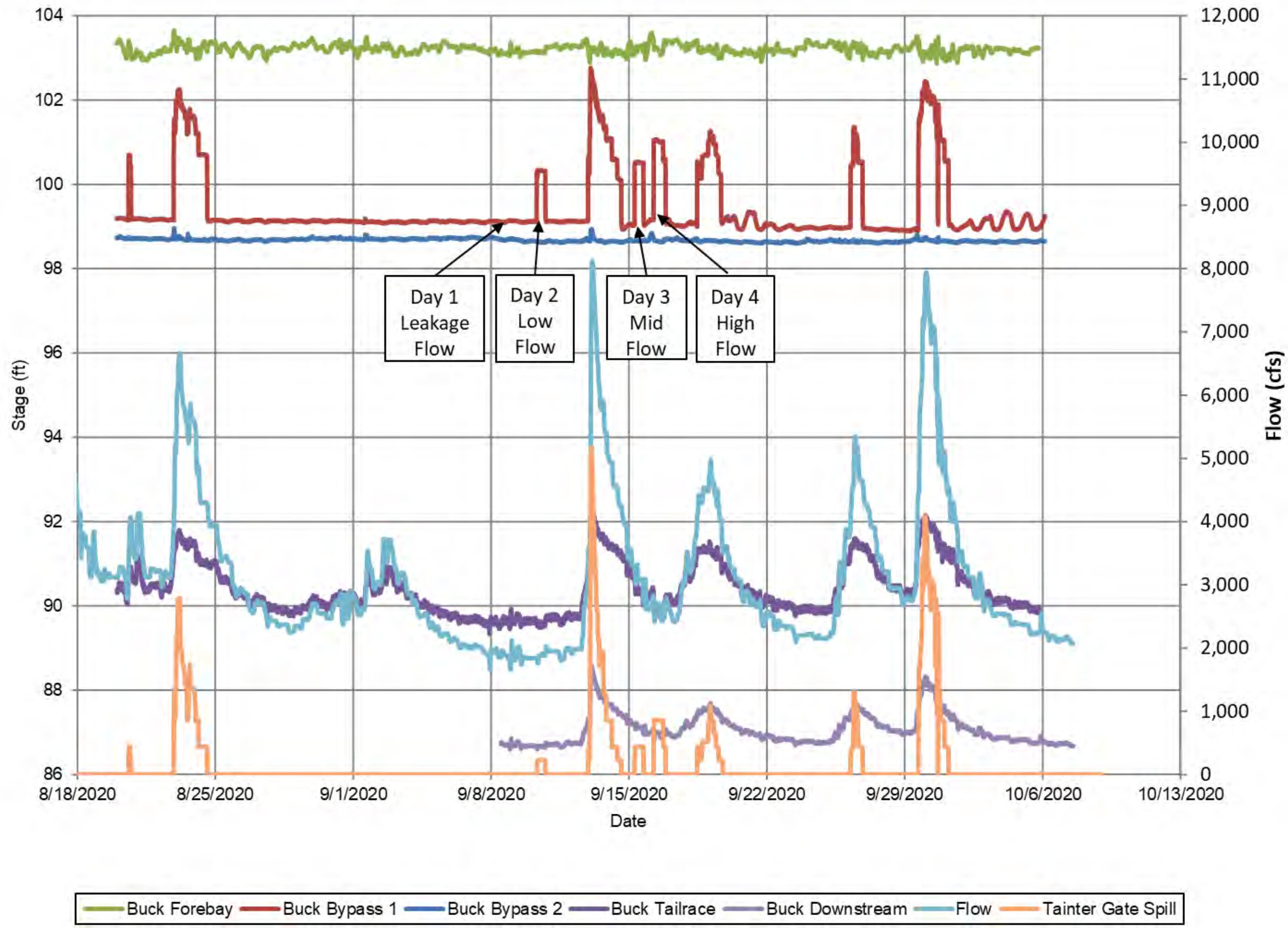


Figure 6-12. Buck Bypass Reach Level Logger Data during Study Period

6.4.3 Particle Size Distribution Results

6.4.3.1 Byllesby Bypass Reach

The locations of the three Wolman pebble count transects at the Byllesby bypass flow study area are shown on Figure 6-13. The transects were located at the bypass reach, the cross-over channel between the tailrace and main channel, and the upper end of the side channel to evaluate differences in substrate particle size distribution within the Study Area. Substrate particle sizes (Wentworth 1922) were plotted by size class and frequency for each transect in Figure 6-14 (bypass reach transect), Figure 6-15 (cross-over channel transect), and Figure 6-16 (side channel transect).

The bypass reach was dominated by bedrock, which covers approximately 66 percent of the width. Gravel (2-64 mm) was the second most abundant discrete size class along the upper transect (approximately 16 percent of the total), and particle sizes between 16.1 mm and 362 mm (i.e., coarse gravel to small boulders) were fairly evenly distributed, comprising the remaining 28.5 percent of the transect. There was a notable absence of sand and particle sizes ranging from 2.0 mm to 16 mm (clay/silt/sand/medium gravel), as those substrate sizes are likely swept downstream during high-flow events (or become wedged between the dominant angular bedrock slabs).

Gravel was the dominant substrate for both the cross-over and side channels, comprising 69.5 percent and 55 percent of the transects, respectively. Cobble was the second-most abundant particle size in these channels as well, comprising 14.5 to 31.5 percent of the reach. Distribution of particle sizes between 11.3 mm and 180 mm (i.e., medium gravel to medium boulders) was similar between the cross-over and side channel transects, with particles between 22.6 and 32 mm being the most abundant (coarse to very coarse gravel).

As described in Section 6.3.1, the dominant instream cover type in the Byllesby bypass reach is bedrock, boulder, and woody debris. However, both the cross-over and side channel had very little bedrock and an increased abundance of sand and fine gravel within each transect compared to the bypass reach. As powerhouse flows travel downstream from the tailrace, the channel widens significantly which results in slower velocities in cross-over channel and side channel (compared to much higher scouring velocities in the bypass reach during large rainfall runoff events), reducing sediment transport.

Figure 6-13. Byllesby Study Area Pebble Count Transect Locations

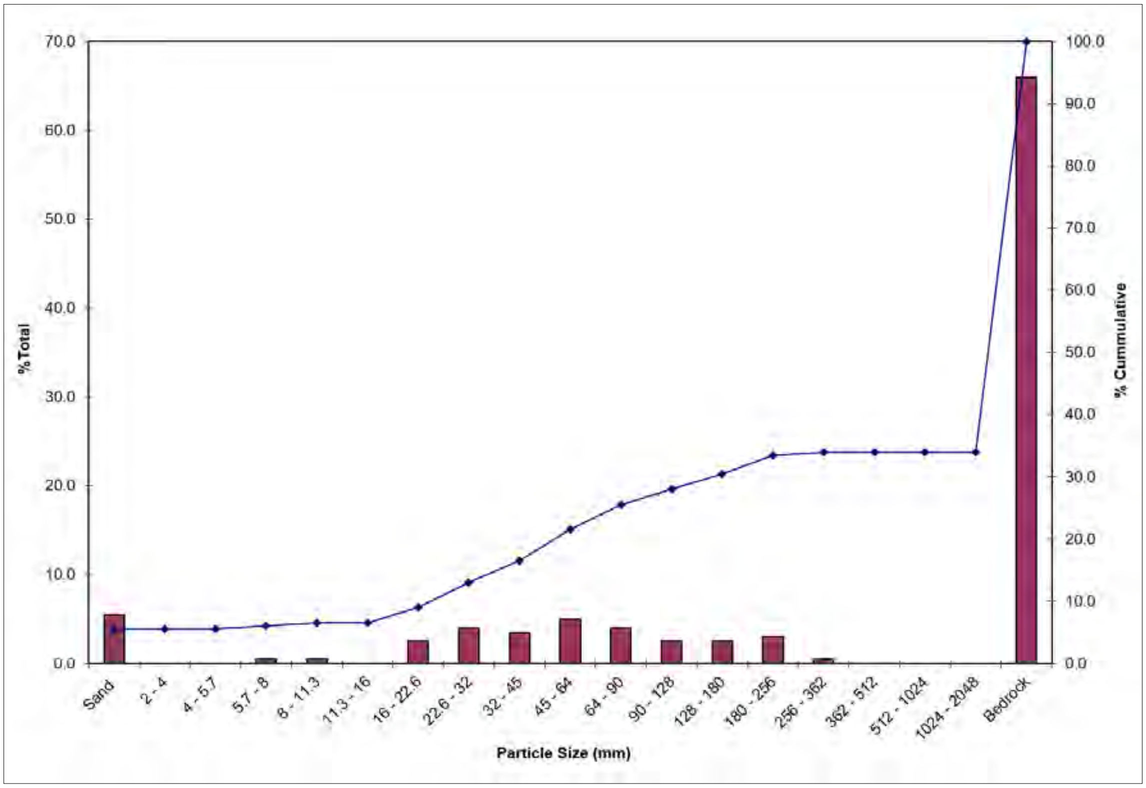


Figure 6-14. Pebble Count Particle Size Data at Byllesby Bypass Reach Transect

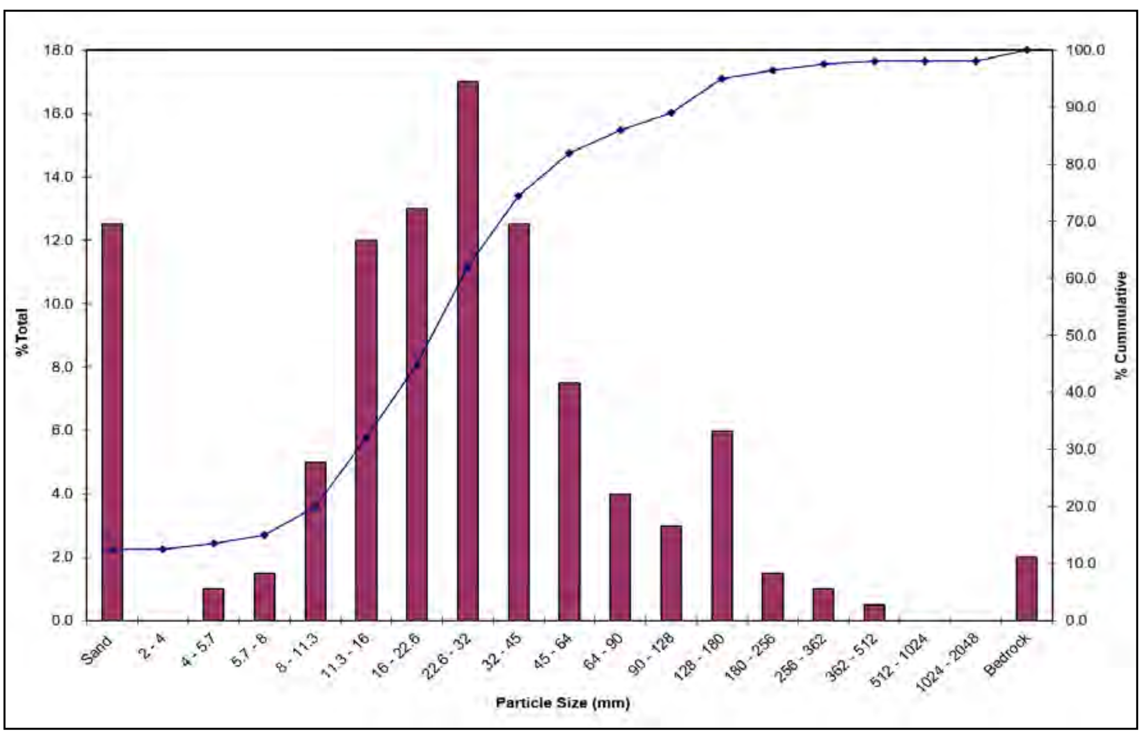


Figure 6-15. Pebble Count Particle Size Data at Byllesby Cross-over Channel Transect

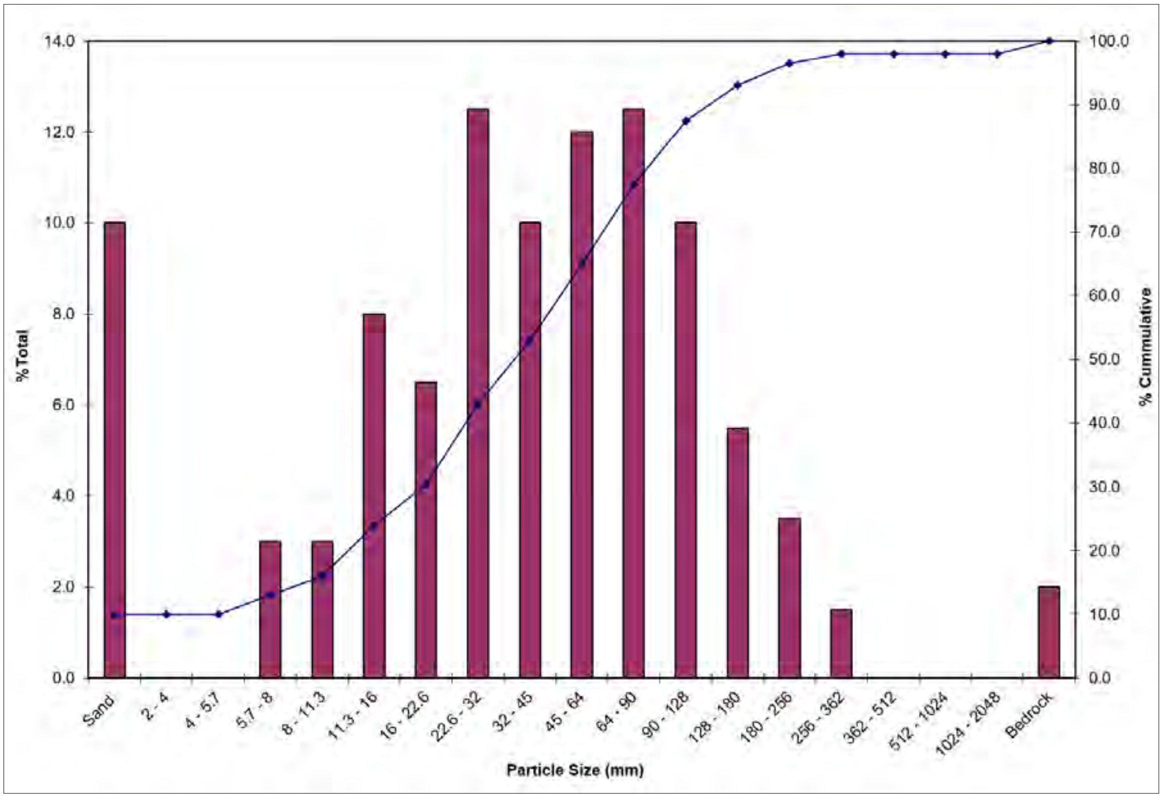


Figure 6-16. Pebble Count Particle Size Data at Byllesby Side Channel Transect

6.4.3.2 Buck Bypass Reach

The locations of the three Wolman pebble count transects are shown on Figure 6-17. The transects were located in the upper, middle, and lower portions of the bypass reach to evaluate differences in substrate particle size distribution along the bypass reach. Substrate particle sizes are plotted by size class and frequency for each transect in Figure 6-18 (upper transect), Figure 6-19 (middle transect), and Figure 6-20. (lower transect).

The upper transect is dominated by bedrock, which covers approximately 50 percent of the width. Sand (<2 mm) is the second most abundant discrete size class along the upper transect (approximately 8 percent of the total) and particle sizes between 11.3 mm and 1,024 mm (i.e., medium gravel to medium boulders) are fairly evenly distributed, comprising the remaining 42 percent of the transect. There is a notable absence of particle sizes in the 0.5-mm to 11.3-mm range (clay/silt/sand/medium gravel) as those substrate sizes are likely scoured out during frequent high flow events. Most sediment of smaller particle size classes was wedged between the dominant angular bedrock slabs.

Bedrock was also the dominant substrate for the middle and lower reaches but comprised only 21 – 26 percent of the reach (compared to double that for the upper transect). Distribution of particle sizes between 11.3-mm and 1,024-mm was similar between the middle and lower transects. Similar to the upper transect, the overall substrate lacked particle sizes between 0.5-mm and 11.3-mm, which is likely due to scouring during high flow events; however, sand deposits (some large in surface area) were identified in velocity shelters downstream of bedrock slabs in the lower half of the bypass reach.

As described in Section 6.3.2, one of the major differences between the upper and middle-to-lower portions of the Buck bypass reach is the orientation of the angled bedrock. In the upper portion of the bypass reach, the bedrock is oriented parallel to flow resulting in scour of smaller substrate sizes, whereas in the middle-to-lower portion of the bypass reach, the bedrock is angled perpendicular to flow, resulting in sediment deposition on the downstream side of the bedrock slabs.

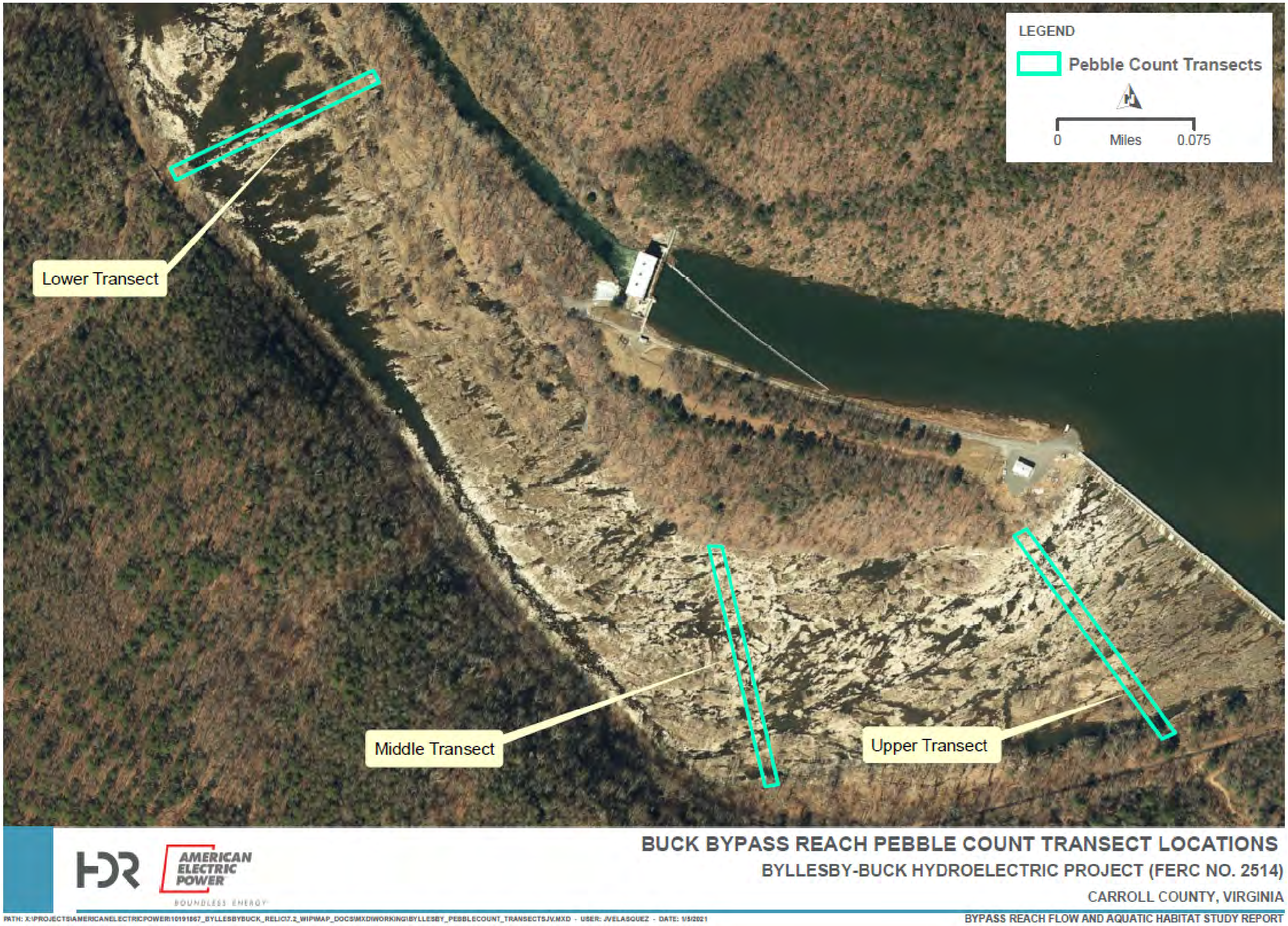


Figure 6-17. Buck Bypass Reach Pebble Count Transect Locations

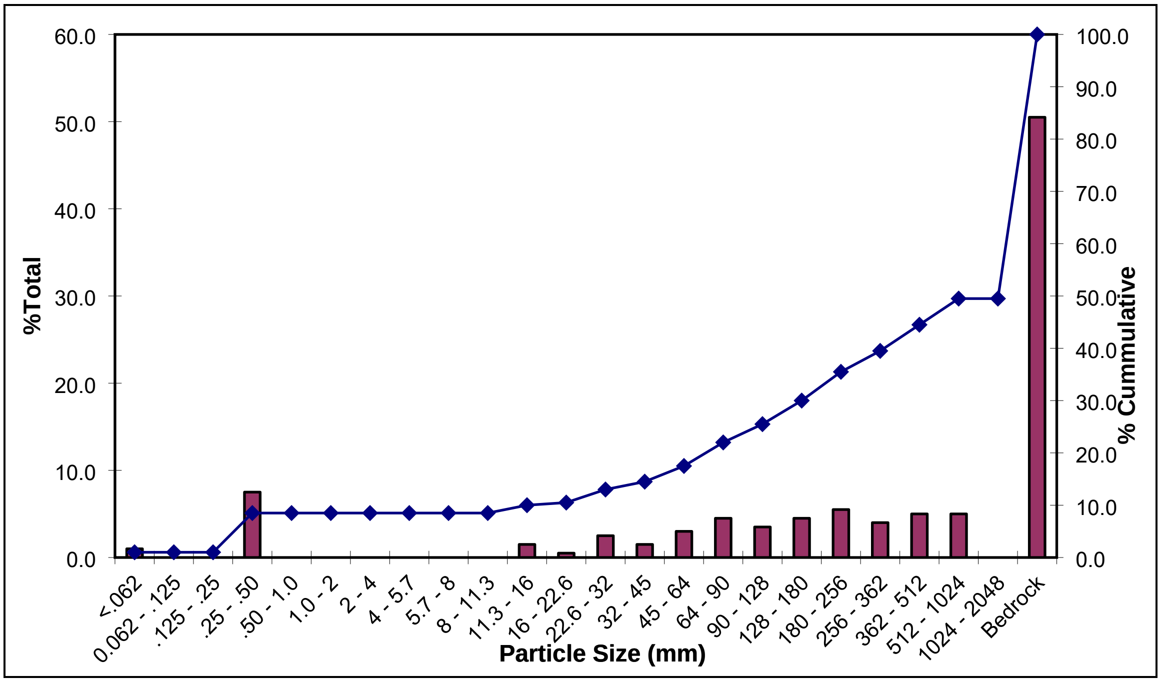


Figure 6-18. Pebble Count Particle Size Data at Upper Transect

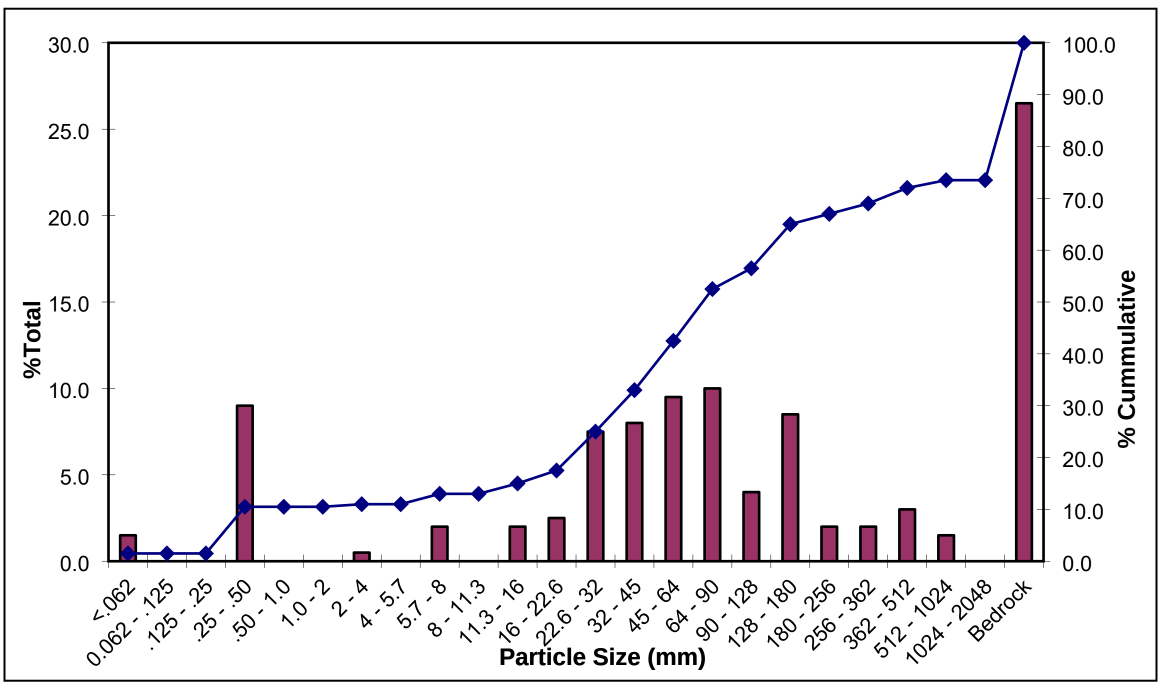


Figure 6-19. Pebble Count Particle Size Data at Middle Transect

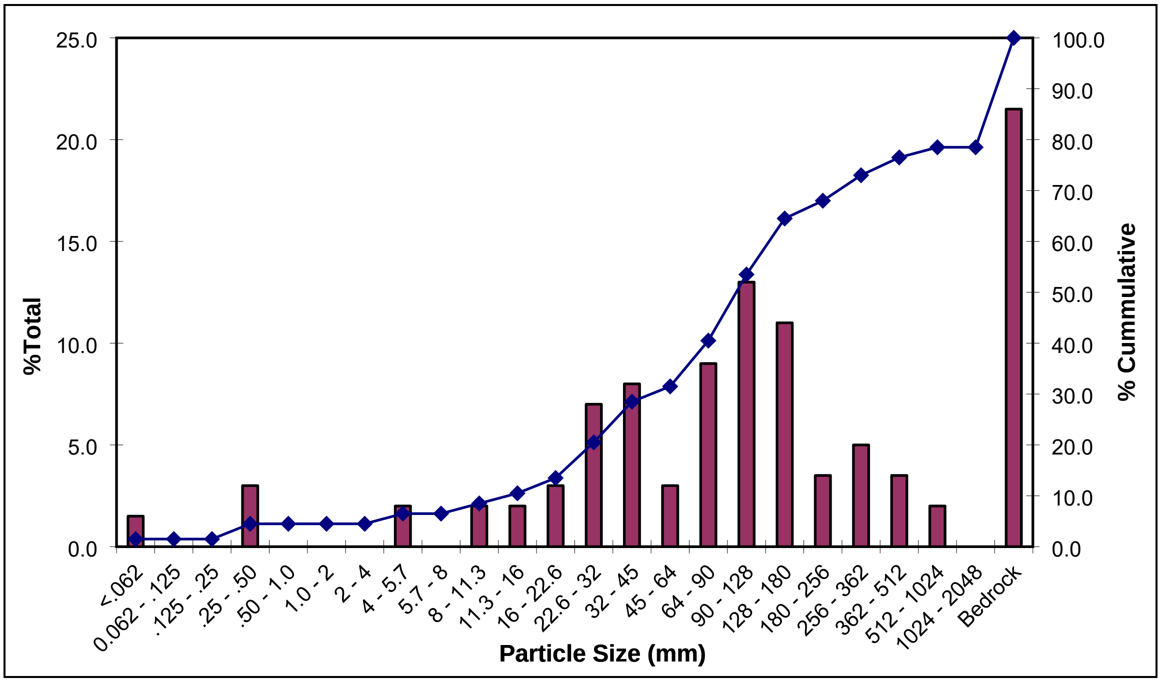


Figure 6-20. Pebble Count Particle Size Data at Lower Transect

6.5 Hydraulic Model Results

Results of the modeling effort for the Byllesby bypass study area are included in Attachment 1 (Byllesby Bypass Reach ICM Model Development); this report presents the final 2-D Byllesby Bypass Reach model developed using the ICM software, which was used to predict hydraulic regimes in the bypass reach study area under four different bypass flow scenarios.

Results of the modeling effort for the Buck bypass are included in Attachment 1 (Buck Bypass Reach ICM Model Development); this report presents the final 2-D Buck Bypass Reach model developed using the ICM software, which was used to predict hydraulic regimes in the bypass reach under varying flows and from varying spill locations.

6.6 Aquatic Habitat Evaluation Results

6.6.1 Byllesby Habitat Model Results

Habitat suitability maps under each modeled flow scenario are included in Attachment 3. Individual map series are provided for the eight species-guild representatives (i.e., two deep-fast, two deep-slow, one shallow-fast, and three shallow-slow) and Walleye (adult, fry, juvenile, and spawning lifestages). Potential available habitat under each modeled flow scenario provided in Table 6-5 is described below.

Table 6-5. Byllesby Habitat Model Flow Scenarios

Tainter Gate #6 Opening (ft)	Bypass Reach Flow (cfs)	Powerhouse Flow (cfs)
Day 1: Closed (Leakage Flow)	11	1,144
Day 2: Broken Flashboards (Low Flow)	88	1,555
Day 3: 0.5 (Mid Flow)	158	1,216
Day 4: 1.0 (High Flow)	194	1,335

Deep-Fast Guild

As expected, little to no potential habitat is available under any flow scenario in the Byllesby bypass reach for the Deep-Fast Guild. While there are deep pools in the bypass reach, it is likely that the velocities are too low and/or the substrate is limited (i.e., primarily bedrock). The two guild representatives for deep-fast are Shorthead Redhorse adult (which prefers coarse-mixed substrate) and Silver Redhorse adult (which prefers finer substrate sizes with cover).

While potential habitat is limited in the bypass reach, there is ample habitat available under all flow scenarios for the deep-fast guild in the tailrace, downstream from the tailrace, in the main channel, and the lower end of the side channel. The area downstream from the tailrace includes fines (which are preferred by Silver Redhorse adult) and the mainstem and side channel areas contain coarse-mixed substrate (preferred by Shorthead Redhorse adult).

Deep-Slow Guild

For the Generic Deep-Slow Guild (i.e., no cover), an area of preferred habitat exists along the east bank of the bypass reach (i.e., opposite the powerhouse) that is deep and slow under all four modeled flow scenarios. In addition, the margins of the tailrace and the area immediately downstream from the tailrace provide deep-slow moving water under all four modeled flow scenarios. Potential habitat in the area immediately downstream from the powerhouse increases with increasing powerhouse flow. The model results indicate zero potential habitat for the Generic Deep-Slow Guild in the main channel and side channel regardless of flow.

For the Deep-Slow Guild (with cover), the modeled bypass reach results are almost identical to the Generic Deep-Slow Guild (no cover) results for the upper pool along the east bank. However, significantly more potential habitat is available in the lower end of the bypass reach, which is fairly consistent under all four modeled flow scenarios. In addition, potential habitat is also available in the area immediately downstream from the tailrace, the main channel, and the side channel. These areas offer more cover which is preferred by the Deep-Slow Guild representative (i.e., Redbreast Sunfish adult). Little to no potential habitat exists in the tailrace under any of the modeled flow scenarios as the velocities are too high in this area.

Shallow-Fast Guild

As expected, there is little to no available habitat in the bypass reach for the Shallow-Fast Guild under any of the modeled flow scenarios as this representative prefers moderate velocities with coarse substrate. The bypass reach is likely too deep, too slow, and is mostly comprised of bedrock. Similarly, the tailrace provides zero potential habitat for this guild. However, there are several areas immediately downstream from the bypass reach/tailrace confluence and also the side channel that do provide habitat for the Shallow-Fast Guild under all four modeled flow scenarios.

Shallow-Slow Guild

The Shallow-Slow Guild includes three categories: 1) finer substrate sizes with no cover (represented by Redbreast Sunfish spawning), 2) all substrate sizes with aquatic vegetation (represented by Silver Redhorse young-of-year), and 3) coarse substrate (represented by Generic Shallow-Slow Guild). These three guild representatives exhibit widely varying potential available habitat under the four flow scenarios evaluated.

Of the three guild representatives, the Generic Shallow-Slow Guild (i.e., coarse substrate) exhibits the largest amount of potential available habitat, mostly at the lower end of the bypass reach, throughout the side channel, and along the margins of the main channel where velocities are lower. Little to no habitat is available in the tailrace and center of the main channel as depths and/or velocities are too high. Results are similar under all four modeled flow scenarios.

Model results for the fine substrate Shallow-Slow Guild representative (Redbreast Sunfish spawning) are similar to those for the Generic Shallow-Slow Guild described above. The main difference is the habitat preference is slightly lower because there is more coarse than fine substrate in these areas. The area immediately downstream from the tailrace is comprised of finer substrates (i.e., sand) and the model results do indicate there is more potential habitat in this area for Redbreast Sunfish spawning representative compared to the coarse substrate representative. Results are similar under all four modeled flow scenarios.

The Silver Redhorse young-of-year representative is not particular about substrate type but requires aquatic vegetation, which was not observed in the Byllesby study area. As a result, potential habitat for this guild representative is not available regardless of flow scenario.

Walleye

Habitat modeling results indicate preferred habitat in the bypass reach for Walleye adult in the upper deep pool along the east bank and also in the shoal area in the lower portion of the bypass reach. There is also a small area of available habitat along the stream margin downstream of the tailrace. Little to no suitable habitat exists in the main channel or side channel. Results are similar under all four modeled flow scenarios.

With the exception of a small area of potential habitat at the downstream end of the side channel, Walleye juvenile results are similar to the adult lifestage, but with a slightly lower preference compared to the adult lifestage.

The lower end of the bypass reach provides preferred habitat for the Walleye fry lifestage as the shoals in this area provide velocity shelters. Available habitat is higher under lower bypass reach flows and decreases as flows increase. Some fry habitat is present along the main channel and side channel margins where velocities are lower. Results in the main channel and side channel are similar under all four modeled flow scenarios.

The Walleye spawning lifestage prefers higher velocities (i.e., > 2.0 ft per second), a depth range of 2 – 6 ft, and larger substrate sizes. Very little potential Walleye spawning habitat is available in the bypass reach, however, suitable habitat is present in the area downstream from the tailrace and in the main channel under all four modeled flow scenarios.

6.6.2 Buck Habitat Model Results

Habitat suitability maps under each modeled flow scenario are included in Attachment 3. Individual map series are provided for the eight species-guild representatives (i.e., two deep-fast, two deep-slow, one shallow-fast, and three shallow-slow) and Walleye (adult, fry, juvenile, and spawning lifestages). Potential available habitat under each modeled flow scenario provided in Table 6-6 is described below.

Table 6-6. Buck Habitat Model Flow Scenarios

Tainter Gate #1 Opening (ft)	Bypass Reach Flow (cfs)	Powerhouse Flow (cfs)
Day 1: Closed (Leakage Flow)	17.1	1,700
Day 2: 0.5 (Low Flow)	210.7	1,700
Day 3: 1.0 (Mid Flow)	354	2,700
Day 4: 2.0 (High Flow)	714	1,925

Deep-Fast Guild

As expected, little to no potential habitat is available under leakage conditions in the Buck bypass reach for the Deep-Fast Guild. As bypass reach flows increase, potential habitat increases along the main flow pathway for both guild representatives (one that prefers finer substrate sizes with cover and the other that prefers coarse-mixed substrate). Between the two, more potential suitable habitat is available for the guild representative that prefers coarse-mixed substrate (i.e., Shorthead Redhorse adult) compared to the representative that prefers finer substrate sizes with cover (i.e., Silver Redhorse adult). The largest area of potential habitat is located at the confluence of the bypass reach and tailrace for both representatives.

Potential habitat is present in the tailrace at 1,700 cfs for Shorthead Redhorse but decreases at higher flows (i.e. 2,700 cfs). Potential habitat is available only along the tailrace margins for Silver Redhorse at the flows evaluated, which is likely the result of a preference for cover along the tailrace streambanks.

Deep-Slow Guild

Limited potential habitat is available for the Generic Deep-Slow Guild (i.e., no cover) at the flows evaluated. Small pockets of preferential habitat exist in the lower half of the Buck bypass reach on the downstream side of rock outcrops which provide a velocity shelter. Available habitat gradually increases with increasing flow and depth.

Significantly more potential habitat is available for the Deep-Slow Guild representative that prefers cover (i.e., Redbreast Sunfish adult) at all four flows evaluated. Preferred habitat is along the main flow pathway at lower flows and shifts to backwater areas as flows increase. A large area of potential habitat is present at the bottom end of the bypass reach (just upstream of the confluence with the tailrace) under all four flow scenarios.

No potential habitat exists in the tailrace for either Deep-Slow Guild representative as the velocities are too high in this area.

Shallow-Fast Guild

Minimal potential habitat is available for the Generic Shallow-Fast Guild in the bypass reach at leakage flow as this representative prefers moderate velocities with coarse substrate; however, potential habitat increases along the main flow pathway throughout the bypass reach as flows increase (including the relatively shallow shoal area near the end of the bypass reach). Preferred habitat also exists in the wide riffle/run area near the downstream end of the study area (i.e., below the confluence of the tailrace and bypass reach) under lower river flows (i.e., 1,700 cfs). Preference for habitat in this area decreases slightly as river flows increase (i.e., 1,925 cfs and 2,700 cfs)

Shallow-Slow Guild

The Shallow-Slow Guild includes three categories: 1) finer substrate sizes with no cover (represented by Redbreast Sunfish spawning), 2) all substrate sizes with aquatic vegetation (represented by Silver Redhorse young-of-year), and 3) coarse substrate (represented by Generic Shallow-Slow Guild). These three guild representatives exhibit widely varying potential available habitat under the four flow scenarios evaluated.

Of the three guild representatives, the Generic Shallow-Slow Guild (i.e., coarse substrate) exhibits the largest amount of potential available habitat, particularly at the lower end of the flow range (i.e., Leakage and Low target flows). Potential habitat is also well distributed throughout the bypass reach but shifts with increasing flow. As flow increases above 200 cfs, potential habitat shifts away from the main flow path to the stream margins, backwater areas, and behind rock outcrops that provide velocity shelters as areas in the main flow path become either too deep and/or too fast.

Potential habitat is available for the Redbreast Sunfish spawning representative (finer substrate sizes and no cover) throughout the bypass reach with a preference for the lower half. Similar to the Generic Shallow-Slow Guild, potential habitat shifts to the stream margins, backwater areas, and behind velocity shelters as flow increases.

The Silver Redhorse young-of-year representative is not particular about substrate type but requires aquatic vegetation, which was not observed in the Buck bypass reach. As a result, potential habitat for this guild representative is not available regardless of bypass flow.

Walleye

Habitat modeling results indicate little to no suitable habitat for the Walleye adult lifestage under any of the target flow scenarios. This lifestage prefers relatively deep, slow-moving water and the only potential habitat in the Buck Bypass reach is located in very small, sporadic, and isolated areas. Model results also indicate little to no potential habitat in the tailrace under any of the target flow scenarios.

Walleye juvenile results are similar to the adult lifestage, but with a few more areas in the lower half of the bypass reach providing potential available habitat (e.g. along the edges of the main flow path and backwater areas) at the higher modeled flows (i.e., 354 cfs and 714 cfs). An area of potential habitat is also present along the backside of the island area near the downstream end of the study reach at all modeled flows. Walleye fry results are similar to the juvenile lifestage with a slight preference for potential available habitat at the lower two modeled flow scenarios (i.e., leakage and 210.7 cfs) as compared to the higher two modeled flow scenarios (i.e., 354 cfs and 714 cfs).

The Walleye spawning lifestage prefers higher velocities (i.e., > 2.0 ft per second), a depth range of 2–6 ft, and larger substrate sizes. While some potential Walleye spawning habitat is available in the main bypass flow channel along the left descending bank (at higher bypass flows), the largest area of potential spawning habitat is located just downstream from the confluence of the tailrace and bypass reach during higher powerhouse generation flows (i.e., > 1,925 cfs).

7 Summary and Discussion

This section provides a summary and discussion of the results of this study, organized by study objective for each development.

7.1 Byllesby Bypass Reach

7.1.1 Delineate and Quantify Aquatic Habitats and Substrate Types

The Byllesby bypass reach primarily consists of deep and shallow pool and shoal habitat types dominated by larger substrate sizes (i.e., bedrock and large boulders). The tailrace is a relatively deep and swift man-made channel lined with bedrock and large boulders. The cross-over channel between the tailrace and main channel is primarily comprised of run-type habitat with gravel, cobble, and sand substrate. The main channel downstream from the bypass reach consists of relatively wide riffles and runs with undulating bedrock/boulder substrate which provides instream cover. The side channel is also comprised of run/riffle habitat but is much narrower than the main channel with gravel/cobble substrates. In all, the bypass reach study area contains a wide variety of aquatic habitat and substrate types.

7.1.2 Surface Water Travel Times and Water Surface Elevation Responses

Level logger data during the bypass flow field data collection period (July 26 – September 13, 2021) was used to determine surface water travel times in the bypass reach as well as water surface elevation responses throughout the bypass reach study area under the target flow releases. A summary of key findings is provided below:

- Depths increased in the bypass reach approximately 0.8 ft from Leakage Flow to Low Flow range (11 cfs to 88 cfs), approximately 0.2 ft from Low Flow to Mid Flow (88 cfs to 158 cfs), and approximately 0.5 ft from Mid Flow to High Flow (158 cfs to 194 cfs). The overall depth increase was approximately 1.5 ft from Leakage Flow to High Flow (11 cfs to 194 cfs).
- Depth increases in the main channel immediately downstream from the bypass reach were much lower than the bypass reach increasing a maximum of only 0.25 ft between Leakage Flow and High Flow.
- Bypass flow releases did not influence water surface elevations in the tailrace, cross-over channel, or side channel areas. These areas are influenced by powerhouse flow releases and not bypass flow releases.
- Because the Byllesby bypass reach is relatively short (i.e., 475 ft long), travel times of flow releases from Tainter Gate #6 to the downstream end of the bypass reach are also relatively short. For example, the Mid Flow and High Flow releases reached the downstream end of the bypass reach in 6 minutes and 2 minutes, respectively.

7.1.3 Identify and Characterize Locations of Habitat Management Interest

Habitat model results for the Byllesby bypass reach indicate suitable habitat for species and lifestages that prefer deep and/or slow-moving water (e.g., Redbreast Sunfish adult and Walleye adult, juvenile, and fry). The bypass reach is relatively wide and comprised of deep and shallow pools and shoal habitat types. Therefore, increasing flow in the bypass reach only has a marginal effect on depths and velocities. As a result, the amount of available habitat in the bypass reach is very similar over the modeled flow range (between 11–194 cfs).

The bypass reach itself is only a small portion of the overall bypass reach study area. The tailrace, cross-over channel between the tailrace and main channel, the main channel downstream from the bypass reach, and side channel areas all provide a wide range of available habitat and substrate types. Habitat model results indicate these areas provide suitable habitat for each of the guilds and Walleye lifestages under the four modeled flow scenarios. From an aquatic habitat perspective, maintaining run-of-river operations through the Byllesby powerhouse is more beneficial than increasing flows in the bypass reach because the tailrace, cross-over channel, main channel, and side channel are all fed by generation flows whereas only the main channel would be fed by increased bypass flows.

7.1.4 Efficacy of Existing Powerhouse Minimum Flow Requirement

The mean monthly average flow and 25th percentile monthly average flow for August (typically the lowest flow month of the year) at the USGS 03165500 New River at Ivanhoe flow gaging station from 1996 – 2020 are 1,497 cfs and 896 cfs, respectively (see Table 4-1). The mean monthly flow in August over the 1996 – 2020 POR is more than four times higher than the current FERC authorized mini mum downstream flow requirement of 360 cfs (or inflow, whichever is less) and the 25th percentile flow for August is more than double the minimum downstream flow requirement.

As a result, the minimum downstream flow requirement is rarely triggered, but did occur during the POR evaluated for this study (i.e., 1996 – 2020). A review of daily average flow statistics over the POR resulted in 14 days (or 0.15 percent of total days in the POR) that Project inflows were less than or equal to 360 cfs. Six of these days occurred during August 2002 and the remaining eight occurred during August 2008, corresponding to the two most severe droughts on record. The average Project inflows during the six days in August 2002 and eight days in August 2008 were 354 cfs and 328 cfs, respectively at Byllesby.

When the minimum downstream flow requirement is triggered, Project inflows at Byllesby are passed downstream to the bypass reach either via the trash sluice gate and/or one of the Tainter or Obermeyer gates. At Byllesby, the bypass reach is relatively small (compared to the Buck bypass reach) and from an aquatic habitat perspective, it likely makes no substantial difference which gate is used to release the minimum downstream flow requirement. And, based on the habitat modeling results, there is also likely no substantial difference in aquatic habitat whether the minimum downstream flow requirement is released into the bypass reach or through the powerhouse.

7.1.5 Evaluate the Impacts of Seasonal Minimum Flows

The habitat results do not show any significant differences in the amount or location of suitable habitat between the four modeled flow scenarios. As a result, seasonal minimum flows in the bypass reach would likely have little to no effect on species and lifestages that may use the bypass reach seasonally. For example, Walleye spawning habitat is minimal in the bypass reach under all four of the modeled flow scenarios. However, Walleye spawning habitat is available in the cross-over channel between the tailrace and main channel and main channel itself. Both of these areas receive flow from run-of-river powerhouse operations which do vary seasonally

7.2 Buck Bypass Reach

7.2.1 Delineate and Quantify Aquatic Habitats and Substrate Types

The Buck bypass reach consists of a complex assemblage of aquatic habitat and substrate types, dominated by angular bedrock. The key difference between the Buck upper reach versus the middle to lower reaches is that the orientation of the bedrock slabs is parallel to the flow, which facilitates scour and sediment transport, while the middle to lower reaches are dominated by bedrock slabs oriented perpendicular to streamflow, which facilitates sediment deposition (on the downstream side of the slab). As a result, the Buck upper reach is approximately 50 percent bedrock while the middle to lower reaches, while still dominated by bedrock, contain more smaller-sized particles. The middle to lower transects display zones of sediment deposition and lower-velocity shelters, which create a variety of aquatic habitat for a wider range of aquatic species and lifestages.

7.2.2 Surface Water Travel Times and Water Surface Elevation Responses

Flow releases from the right (looking downstream) side of the Buck spillway structure (via Tainter Gate #1) generally travel across the bypass reach toward the apex of the channel bend along the left descending bank. From there, the main flow path is along the left descending bank to the end of the bypass reach (see flow direction arrows on Figure 3-2). As a result, water surface elevations spanning a large area of the upper bypass reach along the toe of the spillway from the center of the channel to the left abutment were not affected by the target flow releases. This is due to a large island of higher topography in this area. Because the island area separates the right and left channels in the upper portion of the bypass reach, flow releases from Tainter Gates 1–6 and Obermeyer Gates 7–10 would likely travel a similar path.

Bypass reach flow travel time (from the spillway to the downstream end of the reach) was approximately 2 hours and 30 minutes at Low Flow (210.7 cfs), 1 hour and 40 minutes at Mid Flow (354 cfs) and 1 hour at High Flow (714 cfs). Details are provided in Attachment 1 – Buck Bypass Reach ICM Model Development, Section 4.1.4.

From the Leakage Flow to Low Flow range (17.1 cfs to 210.7 cfs), depths increased approximately 1.0 - 1.5 ft along the main flow path (i.e., right descending channel in the upper portion of the bypass reach and along the left descending bank in the lower portion of the reach). As the target flows increased to the Mid (354 cfs) to High (714 cfs) flow range, corresponding depths along the main flow path increased an additional 1.0 ft; or a total of approximately 2.5 ft deeper than at leakage flow.

7.2.3 Identify and Characterize Locations of Habitat Management Interest

The upper portion of the channel along the left descending bank is considered an area of concern from a potential fish stranding perspective. Two level loggers were placed along this channel to evaluate potential impacts to water surface elevations resulting from Tainter gate operations (see BK_LL2 and BK_LL4 locations on Figure 6-7). Water surface elevations at BK_LL2 were not affected during the High Flow release of 714 cfs (which corresponds to a 2-ft opening at Tainter Gate #1). Water surface elevations at BK_LL4 increase approximately 0.13 ft at Low Flow (201.7 cfs), approximately 0.22 ft at Mid Flow (354 cfs), and approximately 0.37 ft at High Flow (714 cfs). While the water surface elevations at BK_LL4 were impacted, this area is not in the main flow path where much higher water surface elevation changes were recorded (see Figure 6-8).

During the level logger deployment, several large rainfall runoff events occurred which resulted in Tainter gate openings greater than 2-ft (the maximum target flow opening). Figure 6-12 shows that spillway flows need to reach at least 5,000 cfs to affect water surface elevations at the BK_LL2 location. As a result, the existing ramping rate requirements have little to no effect on the upper portion of the left descending channel.

7.2.4 Efficacy of Existing Ramping Rate Requirements

Under the existing FERC operating license, ramping rates are required for the Buck bypass reach to help protect fish communities. Appalachian is required to discharge flows through a 2-ft gate opening for at least three hours following any spills released through a gate opened 2 ft or more. Appalachian is then required to reduce the opening to 1 ft for at least an additional three hours, after which Appalachian may close the gate. The gradual reduction of flow allows time for fish to respond to the receding water levels, thus avoiding stranding that can occur with sudden flow discontinuation.

During the target flow field measurements, level loggers (set to record at 5-minute increments) captured the impact that the existing ramping rate requirements have on bypass reach water surface elevations. The decrease in water surface elevation from a 2-ft gate opening (High Flow) to a 1-ft gate opening (Mid Flow) was approximately 0.5 ft in the main flow path. From a 1-ft gate opening to a closed position, the water surface decreased an additional 1.5 – 2.0 ft in the main flow path (see Figure 6-8, Day 4 High Flow event). The seemingly disproportionate change in depth from a 2-ft to 1-ft gate opening, and a 1-ft to closed position is likely the result of the dominant bypass reach substrate type which is angled bedrock. These bedrock slabs block and trap flows in the bypass channel and their effect on water surface elevations is more pronounced at lower flows.

7.2.5 Efficacy of Existing Powerhouse Minimum Flow Requirement

The mean monthly average flow and 25th percentile monthly average flow for August (typically the lowest flow month of the year) at the USGS 03165500 New River at Ivanhoe flow gaging station from 1996 – 2020 are 1,497 cfs and 896 cfs, respectively (see Table 4-1). The mean monthly flow in August over the 1996 – 2020 POR is more than four times higher than the current FERC authorized minimum downstream flow requirement of 360 cfs (or inflow, whichever is less) and the 25th percentile flow for August is more than double the minimum downstream flow requirement.

As a result, the minimum downstream flow requirement is rarely triggered, but did occur during the POR evaluated for this study (i.e., 1996 – 2020). A review of daily average flow statistics over the POR resulted in 14 days (or 0.15 percent of total days in the POR) that Project inflows were less than or equal to 360 cfs. Six of these days occurred during August 2002 and the remaining eight occurred during August 2008, corresponding to the two most severe droughts on record. The average Project inflows during the six days in August 2002 and eight days in August 2008 were 357 cfs and 331 cfs, respectively at Buck.

When the minimum downstream flow requirement is triggered at Buck, Project inflows can be passed through the trash sluice gate into the tailrace and/or through a Tainter or Obermeyer gate into the bypass reach. At Buck, the minimum downstream flow requirement is rarely triggered and typically occurs only during August for about a week at a time; therefore, the effect on aquatic habitat is likely negligible when considering whether the flow is released to the tailrace and/or bypass reach.

7.2.6 Evaluate the Impacts of Seasonal Minimum Flows

Seasonal minimum flows were evaluated using the habitat modeling results provided in Attachment 3 for the various habitat guilds and standalone Walleye species/lifestages. Spawning lifestages were of particular interest since there is a seasonal component to this lifestage.

At Buck, Redbreast Sunfish spawning lifestage was used as one of the representative species for the Shallow-Slow Guild (i.e., finer substrate sizes and no cover). The amount of potential spawning habitat available is similar under all four modeled flow scenarios. The difference between modeled scenarios is the location of the potential habitat shifts from the main flow path under Leakage Flow conditions (i.e., 17.1 cfs) to the stream margins, backwater areas, and behind velocity shelters created by rock outcrops as flows in the bypass reach increase.

Potential Walleye spawning habitat was also modeled for the four target flow scenarios at Buck. While the High target flow (714 cfs) produced a minimal amount of potential habitat along the left descending channel in the lower portion of the bypass reach, the largest area of potential habitat is located just downstream of the tailrace/bypass reach confluence. Powerhouse flows of at least 1,925 cfs created the largest amount of potential available habitat in the area immediately below the confluence.

As a result, seasonal minimum flows in the Buck bypass reach are not likely to provide a significant amount of additional available habitat for the target species/lifestages of interest.

8 Variances from FERC-Approved Study Plan

This study has been conducted in accordance with the FERC-approved RSP.

9 Germane Correspondence and Consultation

The Proposed Flow Test Scenarios technical memo was emailed by AEP to key agency stakeholders on August 18, 2020. On August 25, 2020, VDWR requested a conference call with Appalachian and key agency stakeholders, which was held on August 28, 2020. The Proposed Flow Test Scenarios technical memo, the Bypass Flow Test Scenario meeting notes, and emails with agency concurrence are included in Attachment 4.

10 References

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Attachment 1

Attachment 1 – Byllesby and Buck Bypass ICM Model Development Reports

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Byllesby Bypass Reach ICM Model Development

Byllesby-Buck Hydroelectric Project (FERC No. 2514)

November 17, 2021

Prepared by:

HDR

Prepared for:

Appalachian Power Company

APPALACHIAN POWER

An AEP Company

BOUNDLESS ENERGY

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Contents

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List of Acronyms

2-D	2-Dimensional
ADCP	Acoustic Doppler current profiler
AEP	American Electric Power
cfs	cubic feet per second
DTM	Digital Terrain Model
ESRI	Environmental Systems Research Institute
ft	feet/foot
GIS	Geographic Information Systems
GPS	Global Positioning System
ICM	Integrated Catchment Model
ICM Model	2-D Innovyze Infoworks Integrated Catchment Model
LiDAR	Light Detection and Ranging
Model	2-D ICM
R12 GPS	Trimble® R12 GPS
Project	Byllesby-Buck Hydroelectric Project
TIN	Triangulated Irregular Network
VGIN	Virginia Geographic Information Network

1 Project Background

1.1 Purpose and Scope

This report presents the final results of the 2-Dimensional (2-D) Byllesby Bypass Reach model developed using Innovyze Infoworks Integrated Catchment Model (ICM) software (Innovyze 2016). The 2-D Byllesby Bypass Reach ICM (Model) was used to predict hydraulic regimes in the bypass reach under varying flows. The results of the Model were used in conjunction with habitat analysis presented in the Byllesby-Buck Bypass Reach Flow and Aquatic Habitat Study Report to develop habitat suitability maps under the various flow scenarios. These maps are presented in Appendix A, Attachment 3 of the Byllesby-Buck Updated Study Report.

1.2 Study Area

The Byllesby-Buck Hydroelectric Project (FERC Project No. 2514-VA) (Project) is owned and operated by Appalachian Power Company, a subsidiary of American Electric Power (AEP). The Project is located on the New River in Carrol County, Virginia and consists of the Byllesby and Buck Dams. Byllesby Dam is approximately 7.8 miles downstream Fries, Virginia and Byllesby Dam is approximately 2.5 miles upstream of Buck Dam.

2 Model Development

2.1 Flow Study Field Data Collection

To aid calibration and validation of the Model, phased flow data collection was performed under varying flows. Fourteen level loggers (Onset® U-20 brand pressure transducers that measure water stage change with high precision) were deployed in the Byllesby Bypass reach and downstream prior to the flow tests. The Onset U-20 instrumentation details document measured water levels with an accuracy of ±0.01 feet (ft). Reference water elevations were collected using a staff gage at each level logger when installed. Level loggers recorded water surface elevation data at 5-minute intervals providing detail for travel time, and rates of rise estimations used in the Model calibration. Locations of the deployed level loggers are shown in Figure 2-1.

Four flow tests were performed over two separate trips. Prior to the flashboard repairs along the spillway, bypass flow of 88 cubic ft per second (cfs) was measured on July 28, 2021. The remaining three test flows (11, 168, 194 cfs) were performed on September 8-9, 2021. Each test was designed to capture a specific flow in the bypass reach. Flow was delivered to the bypass reach via leakage through the broken flashboard for the 88 cfs test flow. The reaming three flows were delivered via leakage and through Tainter Gate 6. Total flows in the bypass reach were recorded using a Teledyne Rio Grande® Acoustic Doppler Current Profiler (ADCP). Additional flows were measured in the side channel on the west side of the study area using a Swoffer meter, and in the tailrace/crossover channel between the bypass reach and side channel via ADCP. Gate settings and measured flows are given in Table 2-1. Figure 2-2 shows the various flow measurement locations in the bypass reach and tailrace.

Table 2-1. Byllesby Tainter Gate Settings and Bypass Reach Flow

Tainter Gate 1 Opening (ft)	Bypass Reach Flow (cfs)
Closed (Leakage)	11
Broken Flashboard (Low Flow)	88
0.5 (Mid Flow)	168
1.0 (High Flow)	194

A Trimble® R12 Global Positional System (R12 GPS) unit using Static Global Navigation Satellite System positioning with horizontal and vertical accuracies of 3 millimeters and 3.5 millimeters, respectively, was used to gather water surface elevation point data at various locations in the bypass reach under the various test flows. The R12 GPS data points are shown in Figure 2-3.

Steady-state conditions were verified in the field using temporary staff gages. All discharge measurements were made a minimum of three times or until there was less than 5 percent difference between measurements.

After the flow test periods, level logger data were downloaded and the loggers were redeployed to sample actual flow conditions for an additional three months. Data from this long-term deployment was used to further characterize the hydraulics of the bypass reach under a larger range of flow/spill conditions present outside of the two-day flow study test period.

The data collection plan enabled correlation of gate openings, flow, and water surface elevations at level logger locations within the bypass reach. The data was used to enhance understanding of travel times and rates of rise under conditions experienced during the collection period.

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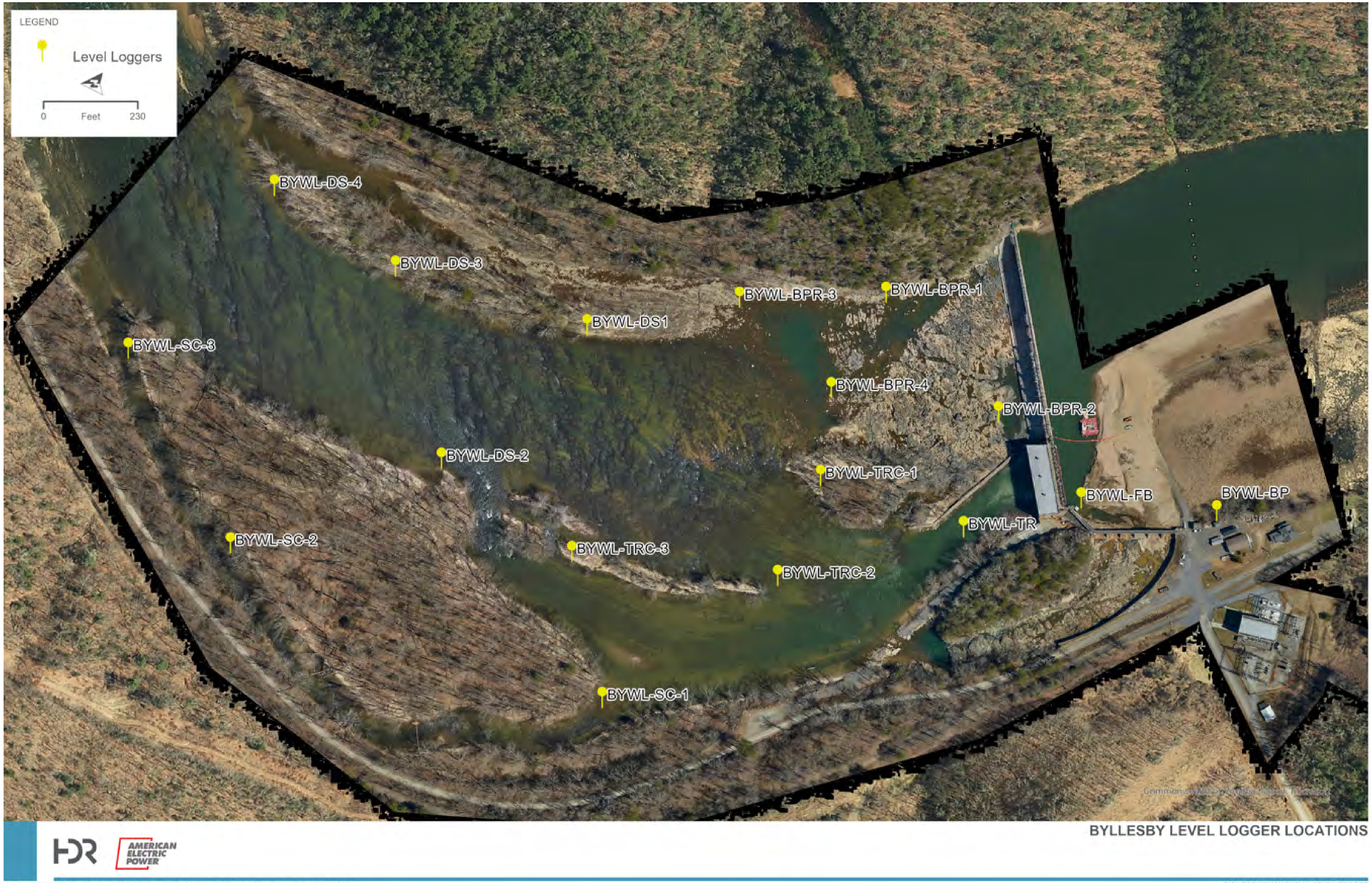

Figure 2-1. Byllesby Bypass Reach Level Logger Locations

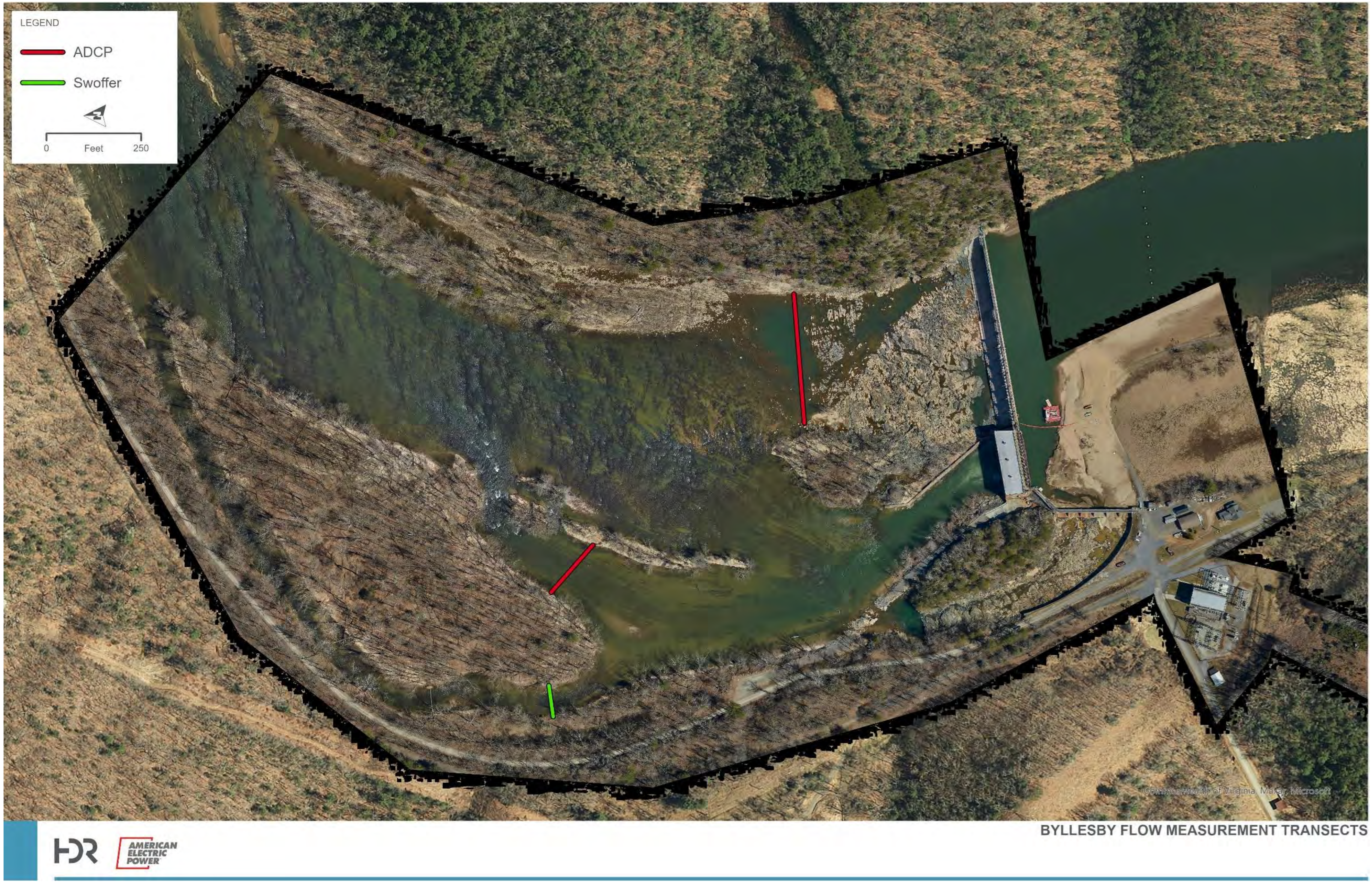

Figure 2-2. Flow Measurement Transects

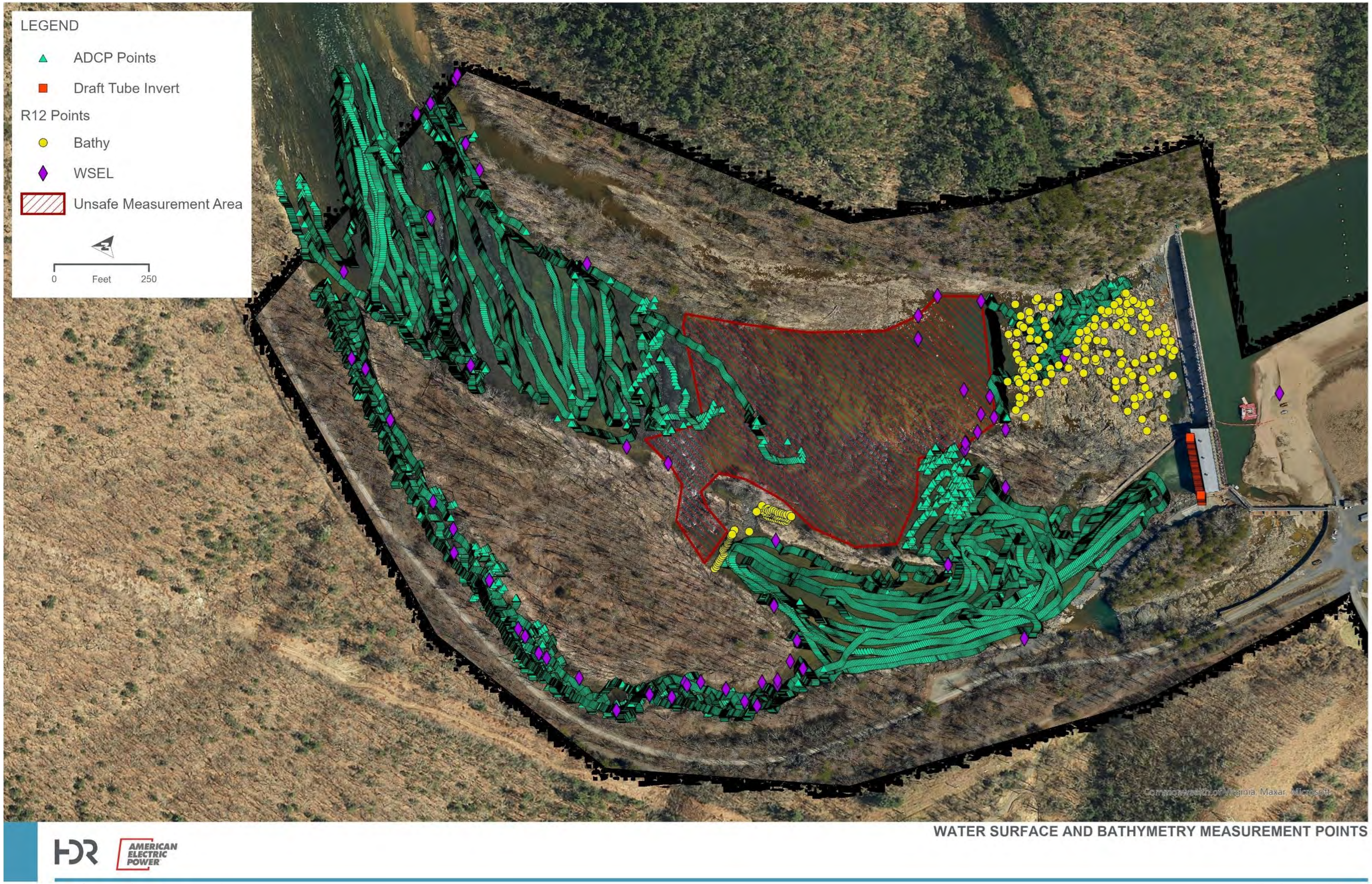

Figure 2-3. R12 Water Surface Elevation and Bathymetry Measurement Points

2.2 Terrain Data

Light Detection and Ranging (LiDAR) Data collected by the Virginia Geographic Information Network (VGIN) and available through the Virginia LiDAR web mapping application developed by VGIN was downloaded for the project site. VGIN collected the data according to the United States Geological Survey 3DEP specifications (USGS 2021) for the entire Byllesby bypass reach from the spillway extending down past the confluence with the tailrace.

Bathymetry from the flow test scenarios study was integrated into the LiDAR data in a common coordinate system and datum in areas that were underwater during the LiDAR collection. Coincident with the flow test field effort, HDR used the ADCP connected to the Global Positioning System (GPS) network to define the bathymetry downstream of Byllesby Dam. Additional bathymetry points were taken using the R12 GPS unit in the bypass reach. Measured bathymetry data is shown on Figure 2-3.

The Byllesby Powerhouse draft tube invert was defined along the edge of the powerhouse. The invert value of 2,004.5 feet above mean sea level was taken from plant drawings presented in the Byllesby Supporting Technical Information Document (STID) (Kleinschmidt 2004).

The Digital Terrain Model (DTM) used in the Byllesby Bypass Reach Hydraulic Model was developed by combining the two sources (VGIN LiDAR and ADCP) of terrain/bathymetry data using professional judgment and field observations. Detailed information on DTM development is presented in Section 3.2.

2.3 Hydraulic Model Development

2.3.1 Conventions and Assumptions

The DTM utilized in the Model was referenced to the North American Vertical Datum of 1988. The DTM was projected using the Virginia State Plane Coordinate System (i.e., U.S. Survey Foot) and horizontally referenced to the North American Datum of 1983.

The Model was developed with the following assumptions:

- In addition to LiDAR data, VGIN provides land cover data at 1-meter resolution. This dataset was used for the model Manning's *n* roughness. Detailed discussion of the Manning's roughness is provided in Section 3.
- Powerhouse outflows were provided by AEP via an operations spreadsheet.
- Leakage flow was measured in the bypass reach using the ADCP at the same transect as the other test flows locations. Using field observations as a guide, the leakage flow was distributed evenly among the Tainter gates. All scenarios used this setup as the base inflow condition.

2.3.2 Design Inputs

Additional design inputs include:

- Steady State inflow hydrographs formed from the base leakage flow discussed in Sections 2.1 and 2.3.1 adding 158, and 184 cfs inflows at Tainter Gate 6 for the Mid and High flow scenarios, and 88 cfs at flashboard 1 for the Low flow scenario, respectively.
- Roughness zones (Manning's *n*-values). Note the remaining 10 cfs for the Mid and High flow scenarios are provided by leakage through the other Tainter gates;
- Initial hydraulic conditions – the bypass reach and tailrace begin the simulation dry and are allowed to fill to steady state conditions.
- Boundary conditions (i.e., 2-D Zone boundary, inflow hydrographs, and downstream boundary conditions).

3 Methodology

3.1 ICM Development

Innovyze Infoworks ICM Version 11.0.5 (Innovyze 2020) was used to evaluate the hydraulics of the Bypass Reach. The Model is a fully integrated 2-D hydrodynamic model which facilitates accurate representation of flow paths while enabling complex hydraulics and hydrology to be incorporated into a single model. ICM uses the shallow water equations to develop depth averaged hydraulics results. The Model does not directly model turbulence, but accounts for energy losses due to turbulence due to bed resistance via the Manning's *n* roughness. The modeling domain extends approximately 0.55 miles downstream of the spillway and includes the side channel on the west side of the river. The domain is modeled with ICM's 2-D surface flooding module. This portion of the modeling extent is known as the 2-D Zone. The Model allows for detailed hydraulic results and provides a reasonable variability in average flow, depth, and velocity from one water column element to the next throughout the modeled area. The Model is considered appropriate for the evaluation of the bypass reach hydraulics. See Section 2.3.2 for design inputs.

3.2 Digital Terrain Model Development

The DTM used in the Model was constructed with data from the following sources:

- Virginia State LiDAR data collected from the VGIN Virginia GIS Clearinghouse database; and
- Additional bathymetry measurements collected by HDR in July 2021

The DTM was projected using the North Carolina State Plane Coordinate System (i.e., U.S. Survey Foot) and horizontally referenced to the North American Datum of 1983 and vertically referenced to the North American Vertical Datum of 1988.

LiDAR data points were discarded in areas under water during the LiDAR collection and bathymetry data was measured in 2021 using a Teledyne Rio Grande® ADCP and a Trimble® AG_GPS receiver equipped with an Omnistar® real-time differential GPS correction. Bathymetry points were measured with the ADCP using both a low-draft jet boat and via wading. Water depths were converted to elevations using the water surface elevations recorded with the R12 GPS unit at the time of data collection.

An area between the bypass reach and downstream extent was deemed unsafe for all forms of bathymetry collection. The flow in this location was both too deep and too fast for wading or canoe/kayak transportation. One attempt was made to gather data using the jet boat; however, it was determined to be too shallow. Because of this, an approximate bathymetry was modeled. In the field, the downstream collection area was determined to be an appropriate “representative sample” of the New River bathymetry in the vicinity of Byllesby Dam. Points from the downstream collection area were copied and moved into this unsafe area using aerial photography and best professional judgement to approximate the bathymetry.

Water surface elevations were taken on the edges of the unsafe area. These elevations were then used to convert the approximated depths to bathymetry and maintain the channel bottom slope. The unsafe measurement areas are shown on Figure 2-3.

The data sources were converted into triangulated irregular network (TIN) surface files and merged using Environmental Systems Research Institute (Esri™) ArcGIS Pro version 2.8.3 Geographic Information System (GIS) software (Esri 2021). The resulting DTM encompassed the entire study area and was used as the basis for developing the conceptual design for the Hydraulic & Hydrologic analysis and modeling discussed in this report.

Figure 3-1 shows the final DTM used in the Model.

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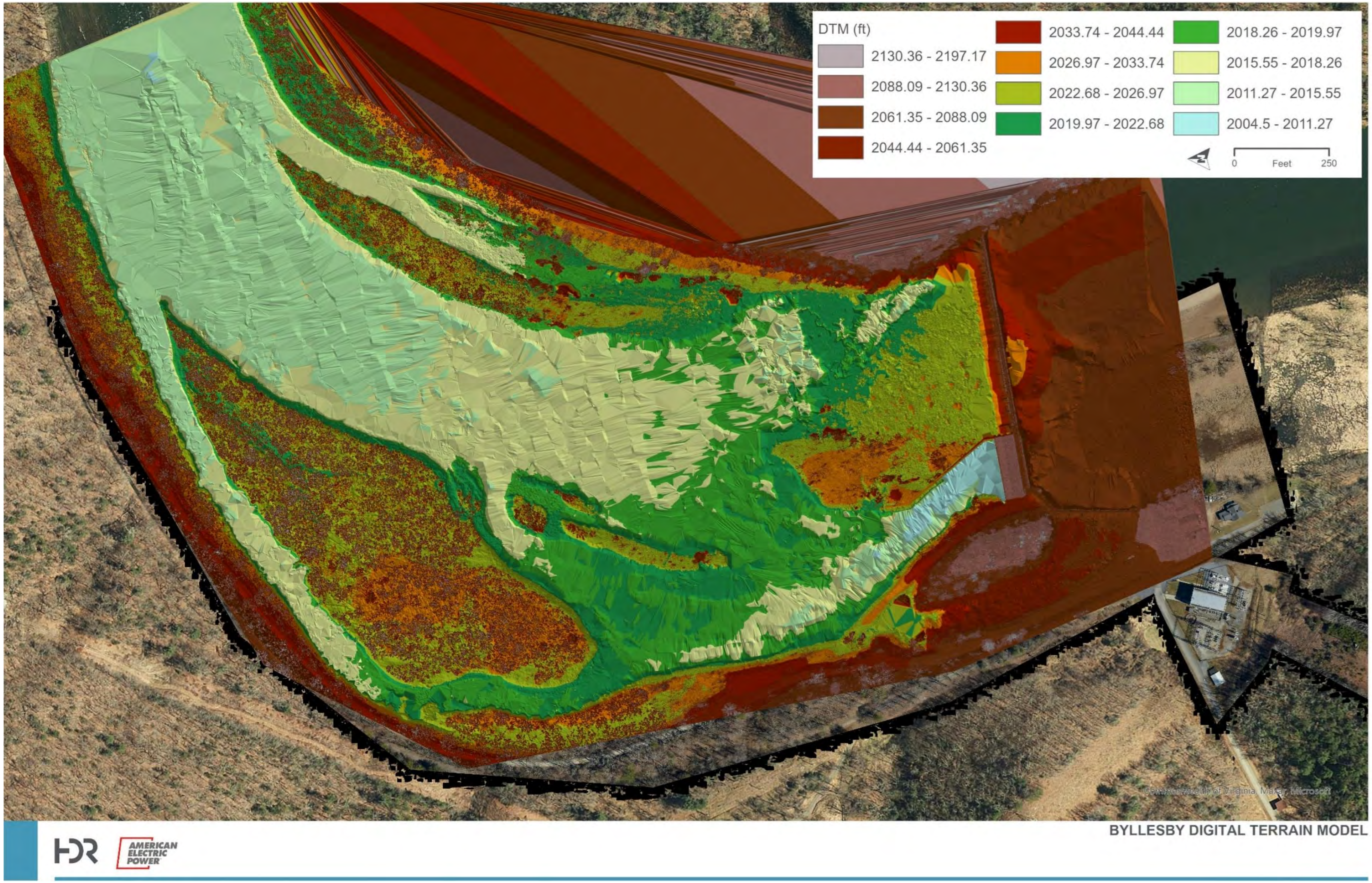

Figure 3-1. Byllesby Bypass Reach Digital Terrain Model

3.3 ICM

3.3.1 Site Topography

A TIN was created from the following topography data:

The 2-D Zone defining the Model includes approximately 0.55 miles of the New River. Figure 3-2 provides a view of the maximum extent of the 2-D Zone.

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

- Maximum triangle area – A measure of mesh resolution used when creating a 2-D mesh; maximum allowable triangle area for areas in the 2-D Zone that are not inside of a secondary mesh zone.
- Minimum element area – Minimum mesh element area used for calculating results. Mesh elements with area less than the minimum area specified are aggregated with adjoining elements until the minimum area is met. This is done for the purpose of calculating results to improve simulation stability and run time.
- Boundary points – Boundary condition for 2-D Zone.
- Terrain-sensitive meshing – Meshing is used to increase the resolution of the mesh in areas that have a large variation in height without increasing the number of elements in relatively flat areas.
- Maximum height variation – The maximum height variation that is permitted within a single triangle. Triangles with a height variation greater than the assigned value are split provided this would not result in a triangle smaller than the Minimum element area.
- Minimum triangle angle – Minimum allowable angle between triangle vertices when creating a 2-D mesh.
- Roughness – Manning's *n* roughness values, used when creating a 2-D mesh. The roughness value assigned to mesh elements in areas in the 2-D Zone that are not in a roughness zone. Roughness values were selected from published tables (Chow 1959).

Table 3-1 provides a summary of the selected user input values for the ICM meshing routine as well as the total 2-D Zone area.

A section of the resulting mesh is shown on Figure 3-3. The model mesh contains 508,943 triangles and 507,688 elements. The approximate minimum, maximum, and average element areas are 0.23 sq ft, 99 sq ft, and 0.52 sq ft, respectively.

Table 3-1. ICM Meshing User Inputs and Area Summary

2D zone Object Properties			
Polygon definition			
ID	Byllesby 2D Zone		
Area (acre)	65.26167757		#D
Maximum triangle area (ft2)	1076.391		#D
Minimum element area (ft2)	2.500		
Mesh generation			
Boundary points	Vertical Wall		#D
Terrain-sensitive meshing	☒		
Maximum height variation (ft)	0.250		
Minimum angle (degree)	25.00		#D
Roughness (Manning's n)	0.1600		
Apply rainfall etc directly to mes	☐		
Apply rainfall etc	everywhere		#D
Rainfall profile	1		#D
Infiltration surface			#D
Turbulence model			
Rainfall percentage	100.000		#D
Mesh summary	...		
Mesh data	...		
General properties			
Notes	...		
Hyperlinks	...		
User defined properties			

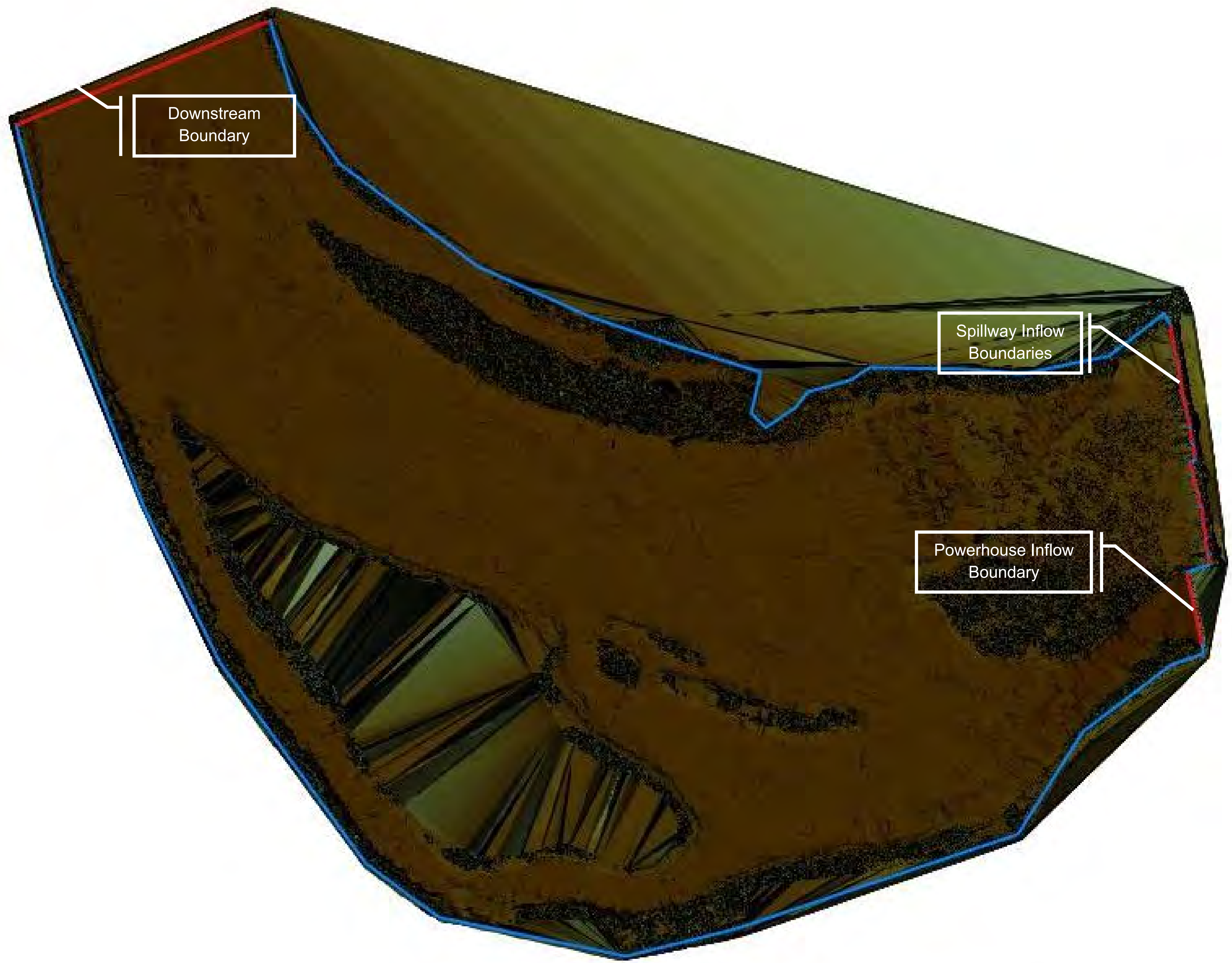

Figure 3-2. Extent of 2-D Zone and ICM Mesh (North is to the Left of the Figure)

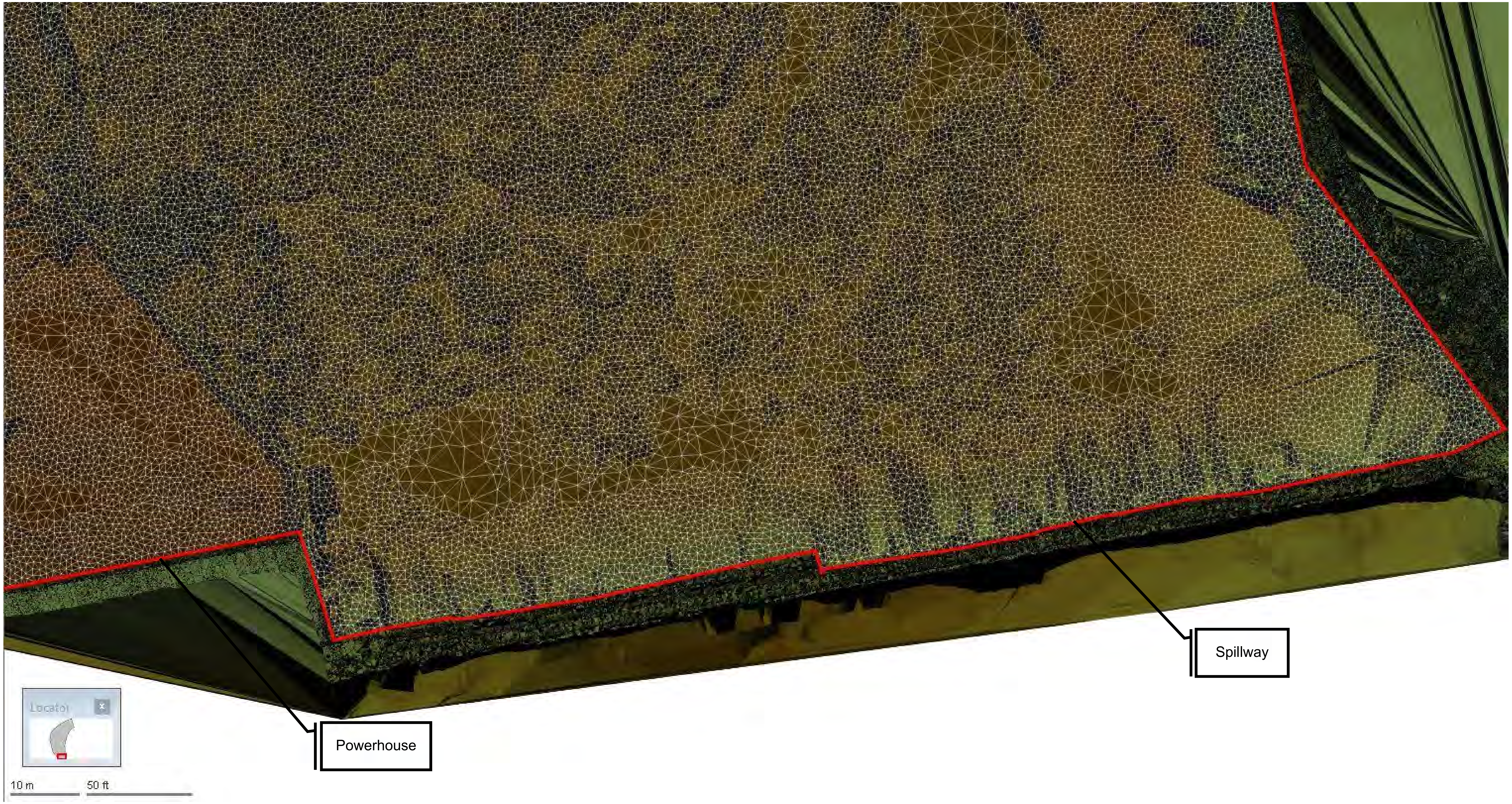

Figure 3-3. ICM Mesh Section (North is to the Top of the Figure)

3.3.2 Roughness Zones

Roughness Zones for the 2-D Zone were created in GIS using land cover data provided by VGIS. Roughness Zones were assigned a Manning's *n*-value indicated in Table 3-2 (Chow 1959). Table 3-2 presents the roughness values used in the model. The land cover is shown in Figure 3-4. Note, the open water code was separated into three separate areas to represent the main reach, side channel, and tailrace side of the domain. These three areas have distinctly different substrates that result in varied roughness values from the default open water value.

The main reach substrate is mostly bedrock, the side channel substrate is mostly cobble, and the tailrace side has mostly a sandy bottom. The roughness values for these open water areas are shown in Table 3-2.

Table 3-2. Manning's *n* Roughness Values

Description	Grid Code	Roughness
Open Water – Main Reach	11	0.025
Open Water – Side Channel	11	0.035
Open Water – Tailrace Side	11	0.050
Developed, Open Space	21	0.040
Developed, Low Intensity	22	0.100
Barren Land	31	0.025
Deciduous Forest	41	0.160
Evergreen Forest	42	0.160
Shrub/Scrub	51	0.100
Grassland/Herbaceous	71	0.035
Emergent Herbaceous Wetlands	91	0.070

The Manning's *n*-values utilized for this analysis provide a reasonable assessment of current conditions at the project site when evaluating the hydraulics of the bypass reach.

Figure 3-4. Land Cover Raster for Manning's *n* Roughness

3.3.3 Initial Hydraulic Conditions

Both the bypass reach and tailrace were allowed to start from a dry condition to allow the pools within the bypass reach to fill as they naturally would during a real-life spill event.

3.3.4 Boundary Conditions

The primary 2-D Zone boundary condition (i.e., "vertical wall" Boundary Point settings in Table 3-1) was selected based on the topography at the edge of the 2-D Zone. This boundary condition is considered to be an impermeable and infinitely high barrier that does not allow water to flow into or out of the 2-D Zone unless specified with another boundary condition.

In addition to the primary 2-D Zone boundary condition, three additional boundary conditions were incorporated into the Model. An upstream boundary condition was defined at the spillway where the leakage and Tainter Gate inflow hydrographs were applied. A second upstream boundary condition was defined at the powerhouse outlet where the powerhouse flows were introduced. See Section 2 for discussion of the model inflows. The final boundary condition was located at the downstream end of the 2-D Zone on the New River and allows water to leave to 2-D Zone assuming normal depth. Under this condition it is assumed that slope balances friction forces (normal flow) i.e., depth and velocity are kept constant when water reaches the boundary, so water can flow out of the 2-D Zone without energy losses.

4 Results

The model inputs discussed above were used to set up four scenarios which represent the four test flows. Due to the complexity of the Model and mesh representing the New River, Model outputs presented in this calculation are limited to select locations and points of interest.

4.1 Model Calibration and Verification

Field data points collected during the flow testing as well as timing of releases recorded by the level loggers in the bypass reach were used to calibrate and verify the model setup.

4.1.1 Point Water Surface Elevations

Water surface elevations collected at thirteen of the fourteen deployed level loggers were compared to water surface elevations predicted by the model. Figure 4-1 through Figure 4-4 show the water surface elevation comparisons for the four test flow scenarios. Field measurement data points are colored by magnitude of percentage difference between field and modeled water surface elevations. The ranges of percentage difference and absolute difference for the four scenarios are presented in Table 4-1.

The hydraulics downstream of Byllesby dam and resulting safety issues limit survey point data collection to the banks of the reach. A triangulation effect from the creation of the DTM occurs where the LiDAR and bathymetry data points meet; therefore, the Model must interpolate between the LiDAR and bathymetry points, which can result in overestimation of the elevations along the bank.

Because of this model limitation, accurately modeling hydraulics, including the water surface elevations along banks, is challenging.

Table 4-1. Point Water Surface Elevation Comparison

	Minimum Delta		Maximum Delta		Average Delta	
Flow	Percentage	Magnitude (ft)	Percentage	Magnitude (ft)	Percentage	Magnitude (ft)
Leakage	-0.12%	-2.5	0.13%	2.7	0.01%	0.2
Low	-0.12%	-2.4	0.08%	1.6	-0.02%	-0.3
Mid	-0.14%	-2.9	0.1%	2.1	0.01%	0.1
High	-0.16%	-3.15	0.09%	1.8	0.01%	0.2

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Figure 4-1. Field vs Modeled Water Surface Elevations – Leakage Flow

Figure 4-2. Field vs Modeled Water Surface Elevations – Low Flow

Figure 4-3. Field vs Modeled Water Surface Elevations – Mid Flow

Figure 4-4. Field vs Modeled Water Surface Elevations – High Flow

4.1.2 Wetted Area Comparison

The total wetted area in the bypass reach increases with increasing test flows. Table 4-2 presents the incremental differences predicted by the model of the total modeled reach wetted area between the various test flows. Because the volume of water released from the powerhouse during the test flows was more than 10 times the volume released at the bypass, the side channel hydraulics are not affected by bypass release flows. While providing flow from Tainter Gate 6 increased the wetted area from the leakage condition in the Bypass Reach, varying the flow releases did not greatly affect the wetted area. Table 4-2 through Table 4-4 present incremental differences of wetted area for the model domain, bypass reach, and side channel, respectively.

Table 4-2. Total Model Domain Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta from Leakage	Incremental Area Increase (Acres)
Leakage	37.2	N/A	N/A
Low	38.9	4.6%	1.7
Mid	38.9	4.4%	-0.1
High	39.2	5.2%	0.3

Table 4-3. Bypass Reach Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta from Leakage	Incremental Area Increase (Acres)
Leakage	3.6	N/A	N/A
Low	4.6	29.1%	1.0
Mid	4.9	36.4%	0.3
High	5.0	39.3%	0.1

Table 4-4. Side Channel Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta from Leakage	Incremental Area Increase (Acres)
Leakage	2.6	N/A	N/A
Low	2.7	4.0%	0.1
Mid	2.6	0.0%	0.0
High	2.7	4.0%	0.1

4.1.3 Travel Time

Travel time measures the time it takes an inflow to travel between designated points in the bypass reach. This measurement is an important data point used for verifying a number of model inputs including the Manning's *n* roughness values presented in Section 3.3.2, inflow, and overall bypass reach slope from the LiDAR data/DTM are appropriate for the analysis. Additionally, it provides insight into model hydraulics, specifically the average velocity within the bypass reach.

Because the majority of flow (over 87%) below Byllesby dam during the test flows came from the Powerhouse, travel times due to spillway releases are limited to the Bypass Reach. For this analysis, the travel time was measured between BYWL-BPR2 and BYWL-BPR4 (for reference see Figure 2-1). Table 4-5 presents travel times measured by the level loggers and predicted by the model. A s leakage is constant, travel time is not measured for that flow condition. Additionally, a broken flashboard provided a constant flow for the Low flow scenario and the travel time was not measured.

Table 4-5. Travel Times

Bypass Reach Flow	Level Logger Time (hr:min)	Model Time (hr:min)	Delta (hr:min)
Leakage	N/A	N/A	N/A
Low	N/A	N/A	N/A
Mid	0:06	0:05	0:01
High	0:02	0:01	0:01

The model predicts slightly faster travel times than seen in the field. The small deltas between field and model data confirm the modeling inputs are appropriate and average velocities calculated are representative of field conditions.

5 References

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Buck Bypass Reach ICM Model Development

Byllesby-Buck Hydroelectric Project
(FERC No. 2514)

November 17, 2021

Prepared by:

HDR

Prepared for:

Appalachian Power Company

APPALACHIAN POWER
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ft	feet/foot
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GIS	Geographic Information Systems
GPS	Global Positioning System
ICM	Integrated Catchment Model
ICM Model	2-D Innovyze Infoworks Integrated Catchment Model
LiDAR	Light Detection and Ranging
Model	2-D ICM Model
QSI	Quantum Spatial, Inc.
Project	Byllesby-Buck Hydroelectric Project
R10 GPS	Trimble® R10 GPS
TIN	Triangulated Irregular Network
VGIN	Virginia Geographic Information Network
WSEL	Water Surface Elevation

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1 Project Background

1.1 Purpose and Scope

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2.1 Flow Study Field Data Collection

To aid calibration and validation of the Model phased flow data collection was performed under varying flows. Eleven level loggers (Onset® U-20 brand pressure transducers that measure water stage change with high precision) were deployed in the Buck Bypass reach prior to the target flow releases. The Onset® U-20 instrumentation documents a measured water level with an accuracy of ±0.01 feet (ft). Reference water elevations were collected using a staff gage at each level logger when installed. Level loggers recorded water surface elevation data at 5-minute intervals providing detail for travel time, and rates of rise estimations used in the Model calibration. Locations of the deployed level loggers are shown in Figure 2-1.

Four target flow releases were performed over four days and two separate trips, September 8th through 10th and September 15th through 17th. Each target flow was designed to capture a specific/stable flow in the bypass reach. Flows were delivered to the bypass reach via leakage through the closed spillway gates and flashboard bays and/or Tainter Gate 1. Total flows in the bypass reach were recorded using a handheld manual Swoffer flow meter for the Day 1 (leakage) and Day 2 (0.5 ft gate opening) target flows and using an Acoustic Doppler current profiler (ADCP) for the Day 3 and Day 4 (1 ft and 2 ft gate opening, respectively) target flows. Gate settings and resulting flows (cubic ft per second [cfs]) are provided in Table 2-1. Figure 2-2 shows the various flow measurement locations in the bypass reach and tailrace.

Table 2-1. Buck Tainter Gate 1 Settings and Bypass Reach Flow

Tainter Gate 1 Opening (ft)	Bypass Reach Flow (cfs)
Day 1: Closed (Leakage Flow)	17.1
Day 2: 0.5 (Low Flow)	210.7
Day 3: 1.0 (Mid Flow)	354
Day 4: 2.0 (High Flow)	714

In addition to the field data collected during the target flows, an Inspire 2 drone equipped with a Zenmuse X5S camera using a ground sample distance of 1-inch per pixel was used to capture an aerial imagery orthomosaic of the steady-state flow conditions for each target flow in the immediate vicinity of the bypass reach and tailrace.

A Trimble® R10 Global Positioning System (R10 GPS) using Static Global Navigation Satellite System positioning with horizontal and vertical accuracies of 3 millimeters and 3.5 millimeters, respectively, was used to gather water surface elevation point data at various locations in the bypass reach during each target flow event. Due to time constraints and satellite coverage effects, a limited number of R10 data points were gathered during the Low target flow event on September 10th. The R10 data points are colored by target flow scenario and shown in Figure 2-3.

In conjunction with the level logger and R10 data recording, point velocity and depth measurements were collected using a Swoffer flow meter at various locations during the Day 1 (Leakage) and Day 2 (Low) target flows after steady-state river conditions were reached. Due to safety concerns, depth and velocity data was not captured for the Day 3 (Mid) and 4 (High) target flow scenarios. Figure 2-4 shows point velocity and depth measurement locations.

Steady-state conditions were verified in the field using temporary staff gages. All discharge measurements were made a minimum of three times or until there was less than 5 percent difference between measurements.

Upon completion of the target flow events, the level logger data were downloaded and the loggers were redeployed to collect depth data for an additional three weeks. Data from this long-term deployment was used to further characterize the hydraulics of the bypass reach under a larger range of flow/spill conditions present outside of the two-week target flow measurement period.

The data collection plan enabled correlation of gate openings, flow, and water surface elevations at select locations within the bypass reach. The data was used to enhance understanding of travel times and rates of rise under conditions experienced during the collection period.

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Figure 2-1. Buck Bypass Reach Level Logger Locations

Figure 2-2. Flow Measurement Transects

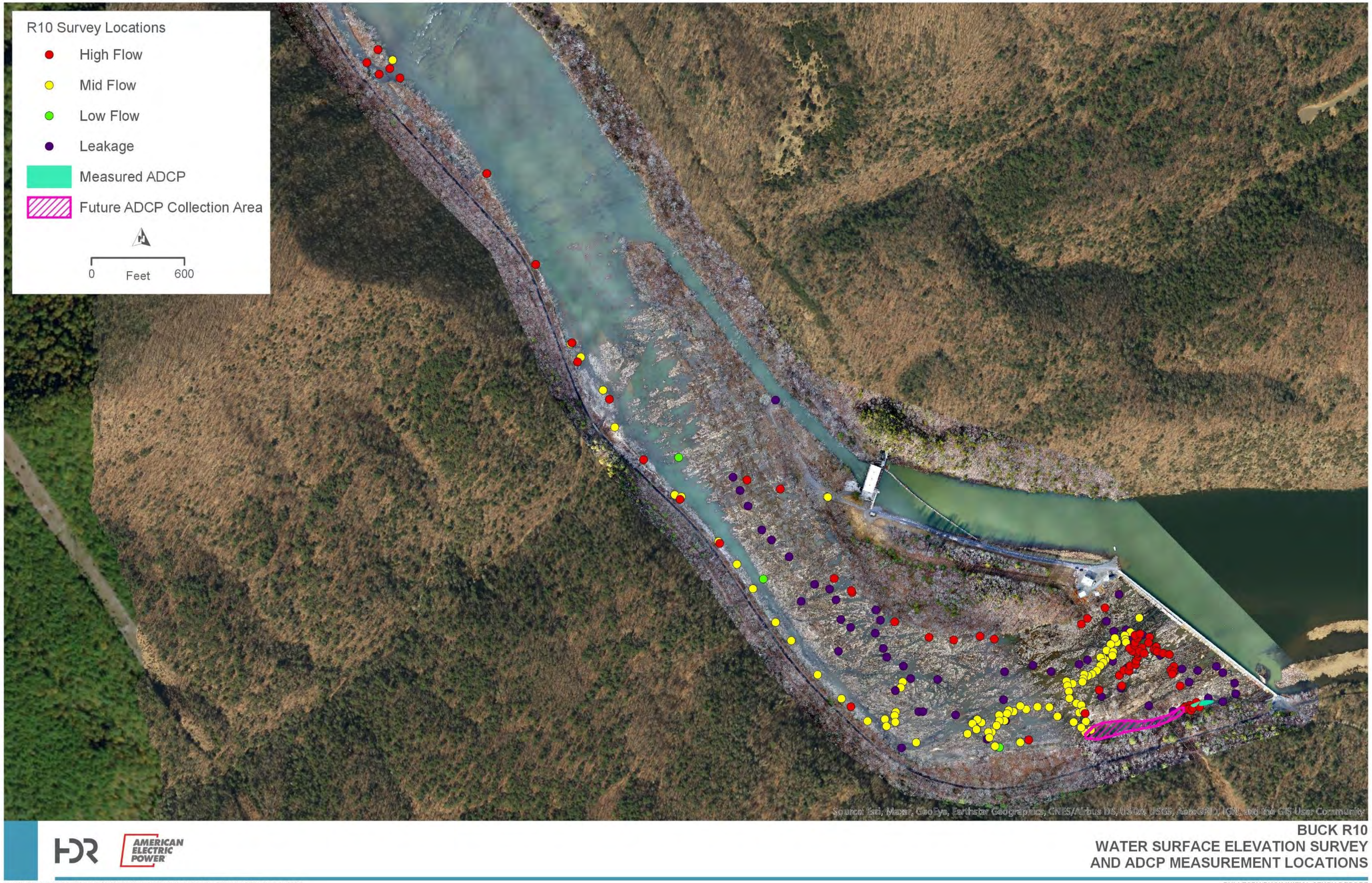

Figure 2-3. R10 Water Surface Elevation Points and ADCP Data Collection Areas

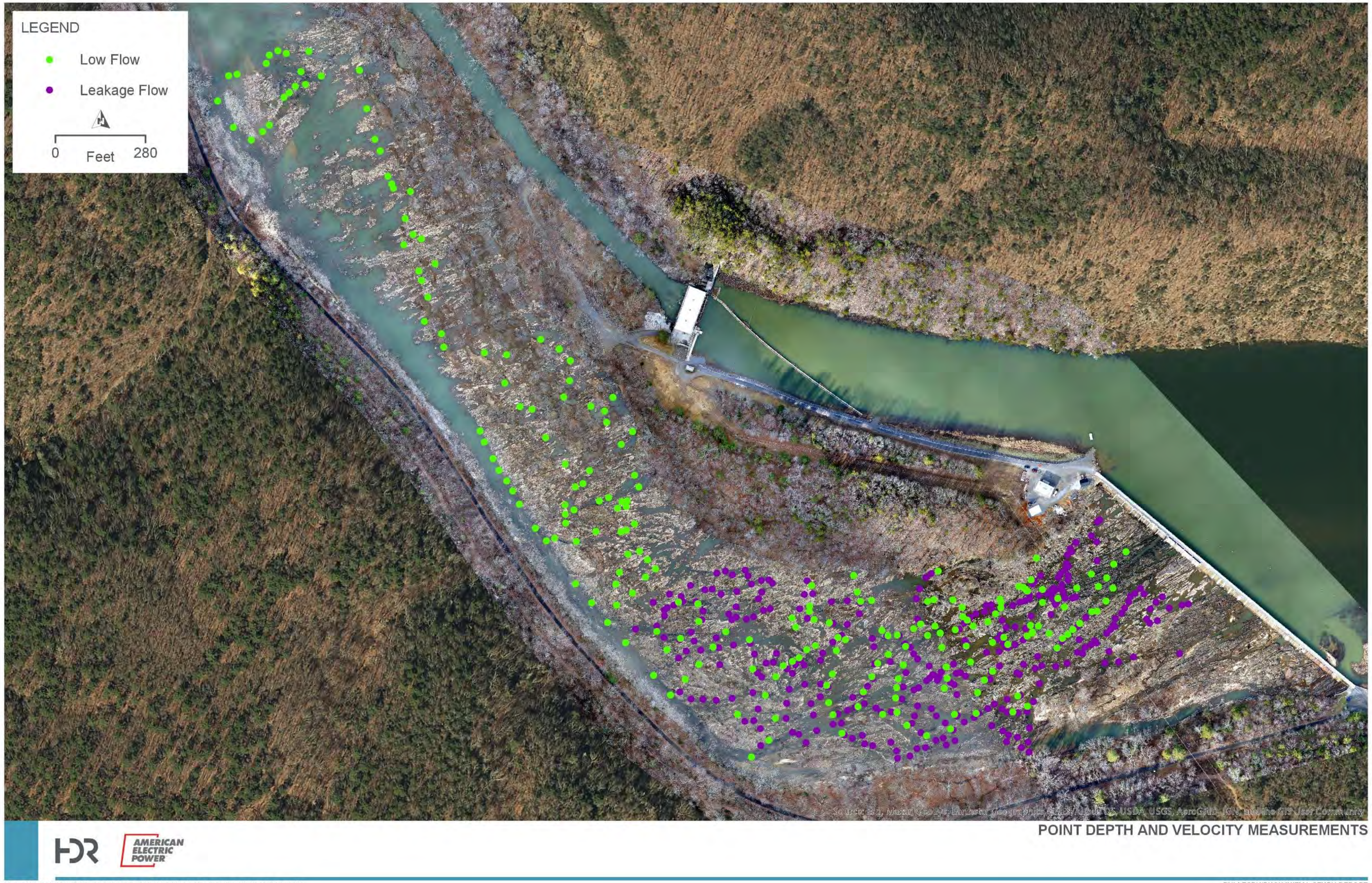

Figure 2-4. Manual Swoffer Flow Meter Depth and Velocity Point Measurements

2.2 Terrain Data

Light Detection and Ranging (LiDAR) data were collected for the entire Buck bypass reach from the spillway extending down past the confluence with the tailrace. HDR contracted with Quantum Spatial, Inc. (QSI) to collect and process LiDAR data at the lowest possible bypass channel flow (QSI 2020). Additionally, LiDAR data collected by the Virginia Geographic Information Network (VGIN) and available through the Virginia LiDAR web mapping application were downloaded. VGIN collected the data according to the United States Geological Survey 3DEP specifications (USGS 2021).

Bathymetry data collected during the target flow measurements were integrated into the LiDAR data in a common coordinate system and datum. Coincident with the target flow field effort, HDR used the ADCP connected to the Global Positioning System (GPS) network to define the bathymetry of two pools on the southwest side of the bypass reach. It is anticipated that additional bathymetry data in this area may need to be collected and incorporated into the model. Measured and anticipated ADCP bathymetry data is shown in Figure 2-3.

The additional bathymetric data was used to describe the channel below the water surface level present when the LiDAR was flown. The bathymetry was supplemented in pools by interpolating areas within the pools using professional judgment and field observed depths and elevations.

The Digital Terrain Model (DTM) used in the Buck Bypass Reach Hydraulic Model was developed by combining the three sources (QSI and VGIN LiDAR plus ADCP) of terrain/bathymetry data using professional judgment and field observations. Detailed information on DTM development is presented in Section 3.2.

2.3 Hydraulic Model Development

2.3.1 Conventions and Assumptions

The DTM utilized in the Model was referenced to the North American Vertical Datum of 1988. The DTM was projected using the Virginia State Plane Coordinate System (i.e., U.S. Survey Foot) and horizontally referenced to the North American Datum of 1983.

The Model was developed with the following assumptions:

- In addition to LiDAR data, VGIN provides land cover data at 1-meter resolution. This dataset was used for the model Manning's *n* roughness. Detailed discussion of the Manning's roughness is provided in Section 3.
- Powerhouse outflows were measured in the tailrace using the ADCP for the Day 1 (Leakage) and Day 2 (Low) target flow events. An approximate flow of 1,700 cfs was used for the Leakage and Low flow scenarios. Due to safety concerns, tailrace flows were not measured for the Day 3 (Mid) and Day 4 (High) target flow scenarios. To determine the powerhouse outflow for these cases, the measured bypass reach flow was subtracted from the reported flow measured at the USGS New River at Ivanhoe, Virginia gage approximately 1.75 miles downstream of the Buck development.

On September 15th and 16th, the USGS gage reported mean flows of 3,060 cfs and 2,640 cfs in the New River, respectively. Flows of 2,700 and 1,925 cfs were then used as powerhouse outflows for the Day 3 (Mid) and Day 4 (High) target flow scenarios, respectively. Due to the close proximity of the USGS gage, accretion flow between the Buck development and gage was considered negligible. Additionally, due to the geometry of the bypass reach and tailrace, tailrace flows are expected to have negligible impact on bypass reach hydraulics thus an approximate powerhouse outflow is appropriate for this analysis.

- Day 1 (Leakage) flow was measured in the bypass reach using the Swoffer flow meter at three locations, one downstream location to capture the total bypass reach leakage flow, and two upstream locations. Using field observations and these flow measurements, the leakage flow was distributed among the various Tainter gates, Obermeyer gates, and flashboards according to Table 2-2. All scenarios used this setup as the base inflow condition.

Table 2-2. Gate Leakage Flows

Gate	Leakage Flow (cfs)
T2	1.0
T3	1.0
T4	1.0
T5	1.0
T6	1.0
FB6	1.0
FB7	1.0
FB8	2.0
FB9	2.0
FB10	2.0
FB12	0.75
FB15	0.75
FB17	2.15
FB18	2.15

2.3.2 Design Inputs

Additional design inputs include:

- Steady-state inflow hydrographs formed from the base Leakage flow presented in Section 2.3.1 adding 210.7, 354, and 714 cfs inflows at Tainter Gate 1 for the Low, Mid, and High flow scenarios, respectively.
- Roughness zones (Manning's *n*-values);
- Initial hydraulic conditions – the bypass reach and tailrace begin the simulation dry and are allowed to fill to steady state conditions.
- Boundary conditions (i.e., 2-D Zone boundary, inflow hydrographs, and downstream boundary conditions).

3 Methodology

3.1 ICM Model Development

Innovyze Infoworks ICM Version 7.5 (Innovyze 2016) was used to evaluate the hydraulics of the Bypass Reach. The Model is a fully integrated 2-D hydrodynamic model which facilitates accurate representation of flow paths while enabling complex hydraulics and hydrology to be incorporated into a single model. ICM uses the shallow water equations to develop depth averaged hydraulics results. The Model does not directly model turbulence, but accounts for energy losses due to turbulence due to bed resistance via the Manning's *n* roughness. The modeling domain extends approximately 1.25 miles downstream of the Buck spillway and includes Buck tailrace. The domain is modeled with ICM's 2-D surface flooding module. This portion of the modeling extent is known as the 2-D Zone. The Model allows for detailed hydraulic results and provides a reasonable variability in average flow, depth, and velocity from one water column element to the next throughout the modeled area. The Model is considered appropriate for the evaluation of the bypass reach hydraulics. See Section 2.3.2 for design inputs.

3.2 Digital Terrain Model Development

The DTM used in the Model was constructed with data from several sources:

- Virginia State LiDAR data collected from the VGIN database;
- Supplemental site LiDAR data collected by QSI (QSI 2020); and
- Additional bathymetry measurements collected by HDR in September 2020.

The DTM was projected using the North Carolina State Plane Coordinate System (i.e., U.S. Survey Foot) and horizontally referenced to the North American Datum of 1983 and vertically referenced to the North American Vertical Datum of 1988.

LiDAR data points at two pools of concern on the south western edge of the bypass reach were discarded and bathymetry data in the pools was measured in 2020 using a Teledyne® Rio Grande Acoustic Doppler Current Profiler and a Trimble® AG_GPS receiver equipped with an Omnistar® real-time differential GPS correction. Water depths were converted to elevations using the water surface elevations recorded with the R10 unit at the time of data collection.

The three data sources were converted into triangulated irregular network (TIN) surface files and merged using Environmental Systems Research Institute (Esri™) ArcGIS version 10.3 Geographic Information System (GIS) software (ESRI 2017). The resulting DTM encompassed the entire study area and was used as the basis for developing the conceptual design for the Hydraulic & Hydrologic analysis and modeling discussed in this report.

Figure 3-1 shows the final DTM used in the model and the allocation of terrain data. Blue zones indicate contractor LiDAR data. Red zones indicate ADCP data. The reminder of the data is sourced from the VGIN LiDAR data.

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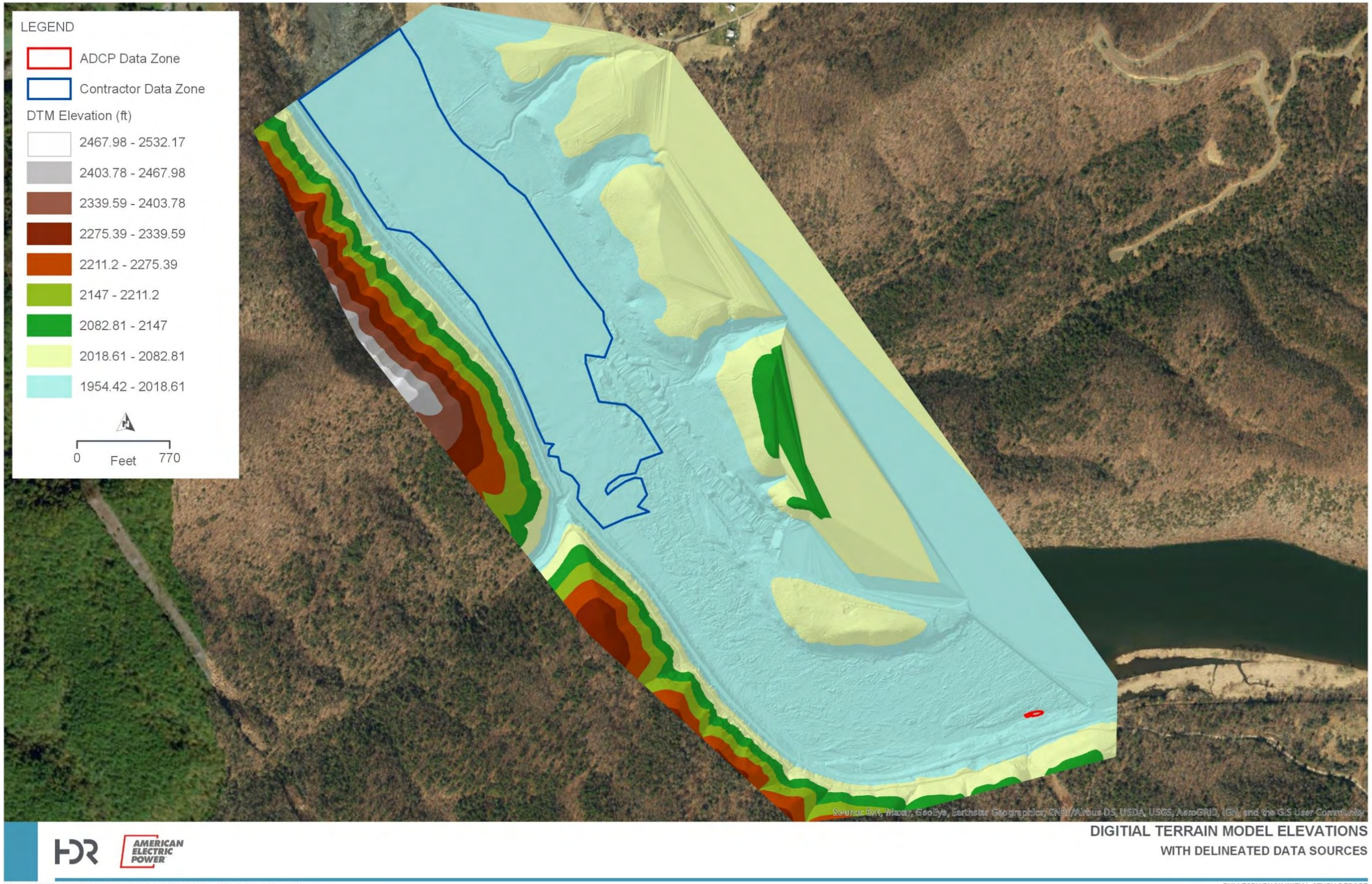

Figure 3-1. Buck Bypass Reach Digital Terrain Model and Data Sources

3.3 ICM

3.3.1 Site Topography

A TIN was created from the following topography data:

The 2-D Zone defining the Model includes approximately 1.25 miles of the New River. Figure 3-2 provides a view of the maximum extent of the 2-D Zone.

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

- Maximum triangle area – A measure of mesh resolution used when creating a 2-D mesh; maximum allowable triangle area for areas in the 2-D Zone that are not inside of a secondary mesh zone.
- Minimum element area – Minimum mesh element area used for calculating results. Mesh elements with area less than the minimum area specified are aggregated with adjoining elements until the minimum area is met. This is done for the purpose of calculating results to improve simulation stability and run time.
- Boundary points – Boundary condition for 2-D Zone.
- Terrain-sensitive meshing – Meshing is used to increase the resolution of the mesh in areas that have a large variation in height without increasing the number of elements in relatively flat areas.
- Maximum height variation – The maximum height variation that is permitted within a single triangle. Triangles with a height variation greater than the assigned value are split provided this would not result in a triangle smaller than the Minimum element area.
- Minimum triangle angle – Minimum allowable angle between triangle vertices when creating a 2-D mesh.
- Roughness – Manning's *n* roughness values, used when creating a 2-D mesh. The roughness value assigned to mesh elements in areas in the 2-D Zone that are not in a roughness zone. Roughness values were selected from published tables (Chow 1959).

Table 3-1 provides a summary of the selected user input values for the ICM meshing routine as well as the total 2-D Zone area.

Table 3-1. ICM Meshing User Inputs and Area Summary

2D zone Object Properties

Polygon definition		
ID	Buck 2D Zone	
Area (acre)	131.698	#D
Maximum triangle area (ft2)	750.000	
Minimum element area (ft2)	2.500	
Boundary points	Vertical Wall	#D
Terrain-sensitive meshing	☒	
Maximum height variation (ft)	0.125	
Minimum angle (degree)	25.00	#D
Roughness (Manning's n)	0.0230	
Apply rainfall etc directly to mesh	☐	
Apply rainfall etc	everywhere	#D
Rainfall profile	1	#D
Infiltration surface ID		#D
Rainfall percentage	100.000	#D
Mesh summary	---->	
Mesh data	---->	
General properties		
Notes		
Hyperlinks		
User defined properties		

A section of the resulting mesh is shown in Figure 3-3. The model mesh contains 927,926 triangles and 926,440 elements. The approximate minimum, maximum, and average element areas are 0.23 square ft, 70 square ft, and 0.57 square ft, respectively

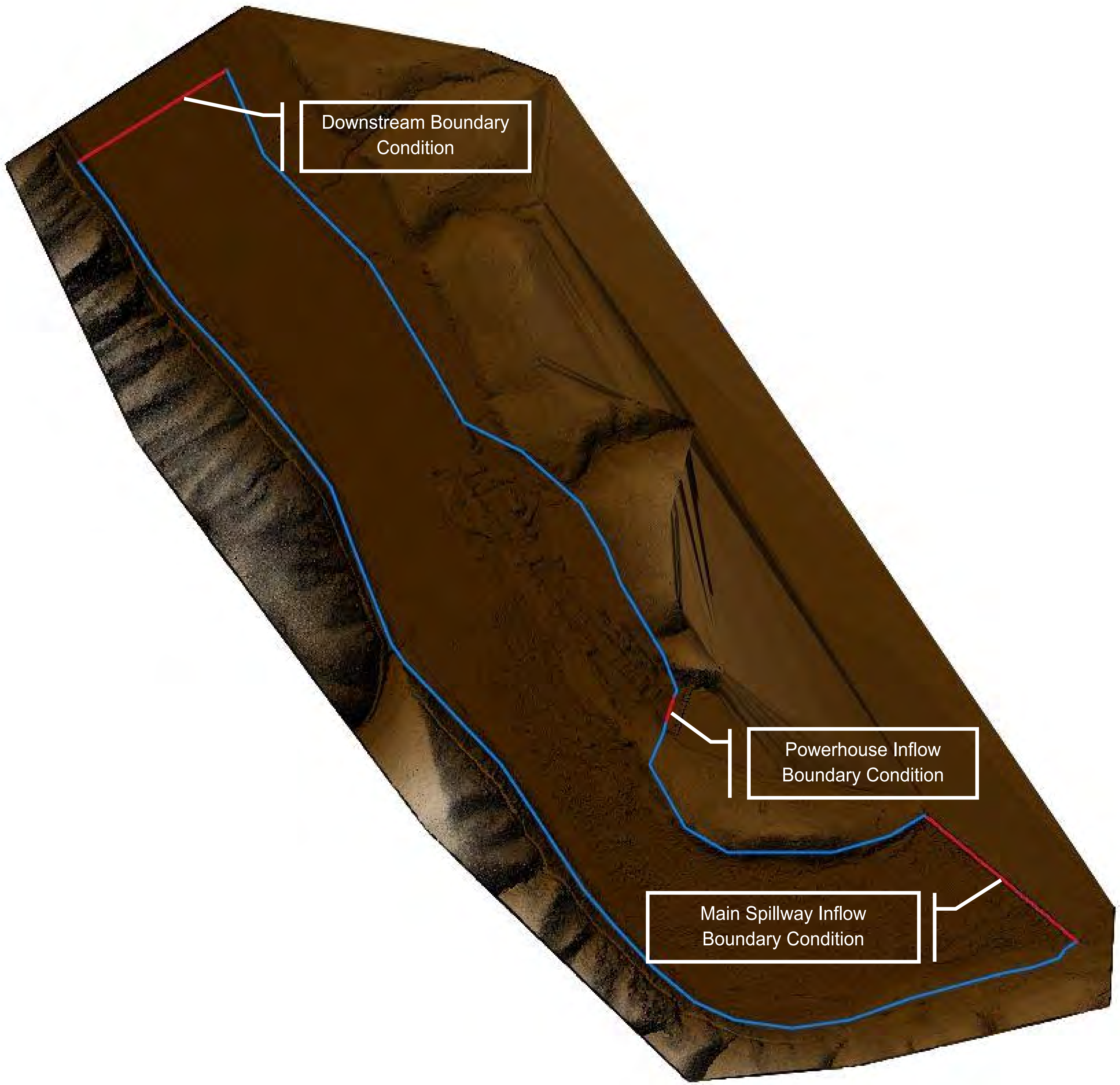

Figure 3-2. Extent of 2-D Zone and ICM Mesh (North is to the Top of the Figure)

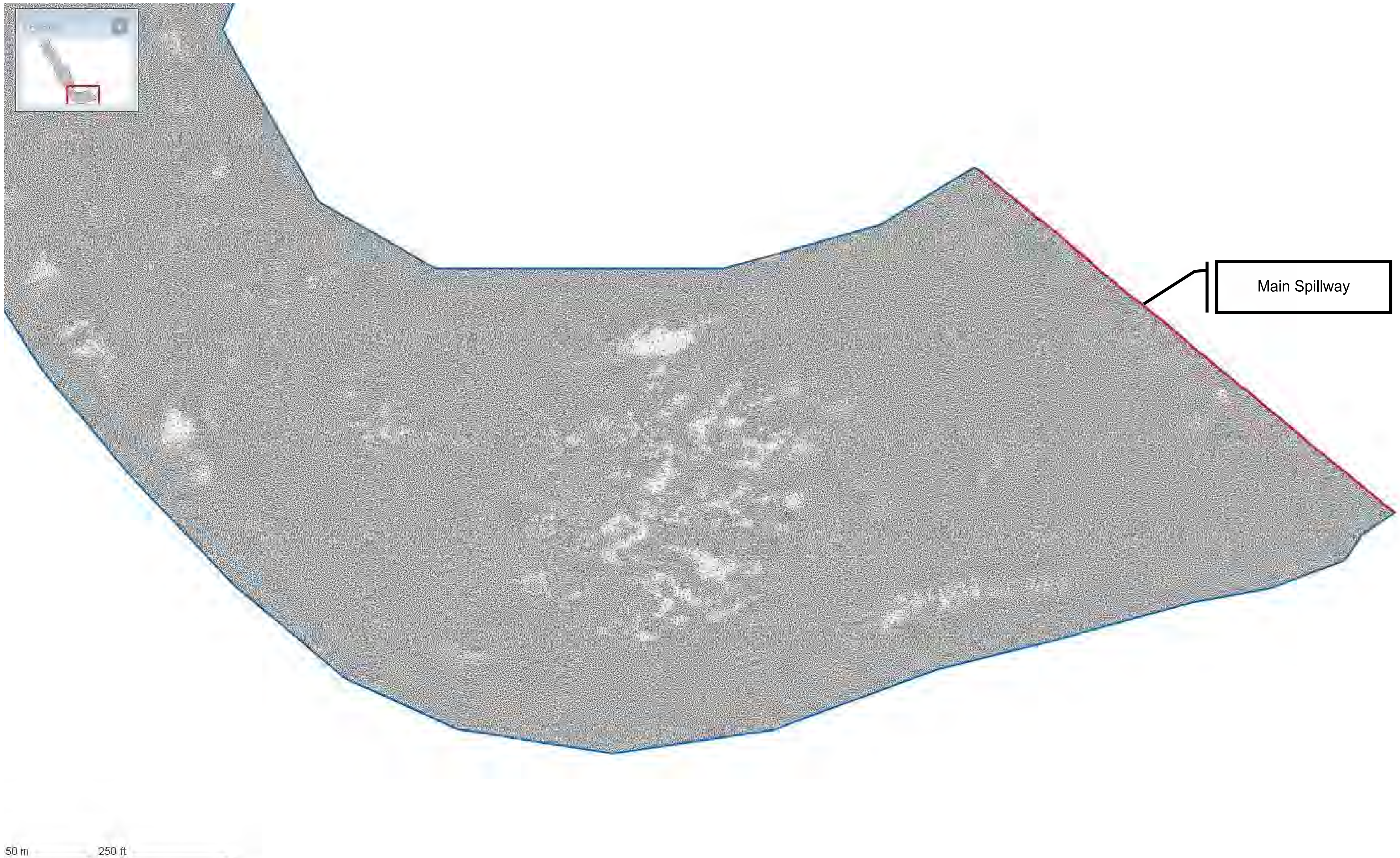

Figure 3-3. ICM Mesh Section (North is to the Top of the Figure)

3.3.2 Roughness Zones

Roughness Zones for the 2-D Zone were created in GIS using land cover data provided by VGIN. Roughness Zones were assigned a Manning's *n*-value indicated in Table 3-2 (Reference 1). Table 3-2 presents the roughness values used in the model. The land cover is shown in Figure 3-4.

Table 3-2. Manning's *n* Roughness Values

Description	Grid Code	Roughness
Open Water	11	0.040
Developed, Open Space	21	0.040
Developed, Low Intensity	22	0.100
Deciduous Forest	41	0.160
Evergreen Forest	42	0.160
Shrub/Scrub	52	0.100
Grassland/Herbaceous	71	0.035
Pasture/Hay	81	0.030

The Manning's n-values utilized for this analysis provide a reasonable assessment of current conditions at the site when evaluating the hydraulics of the bypass reach.

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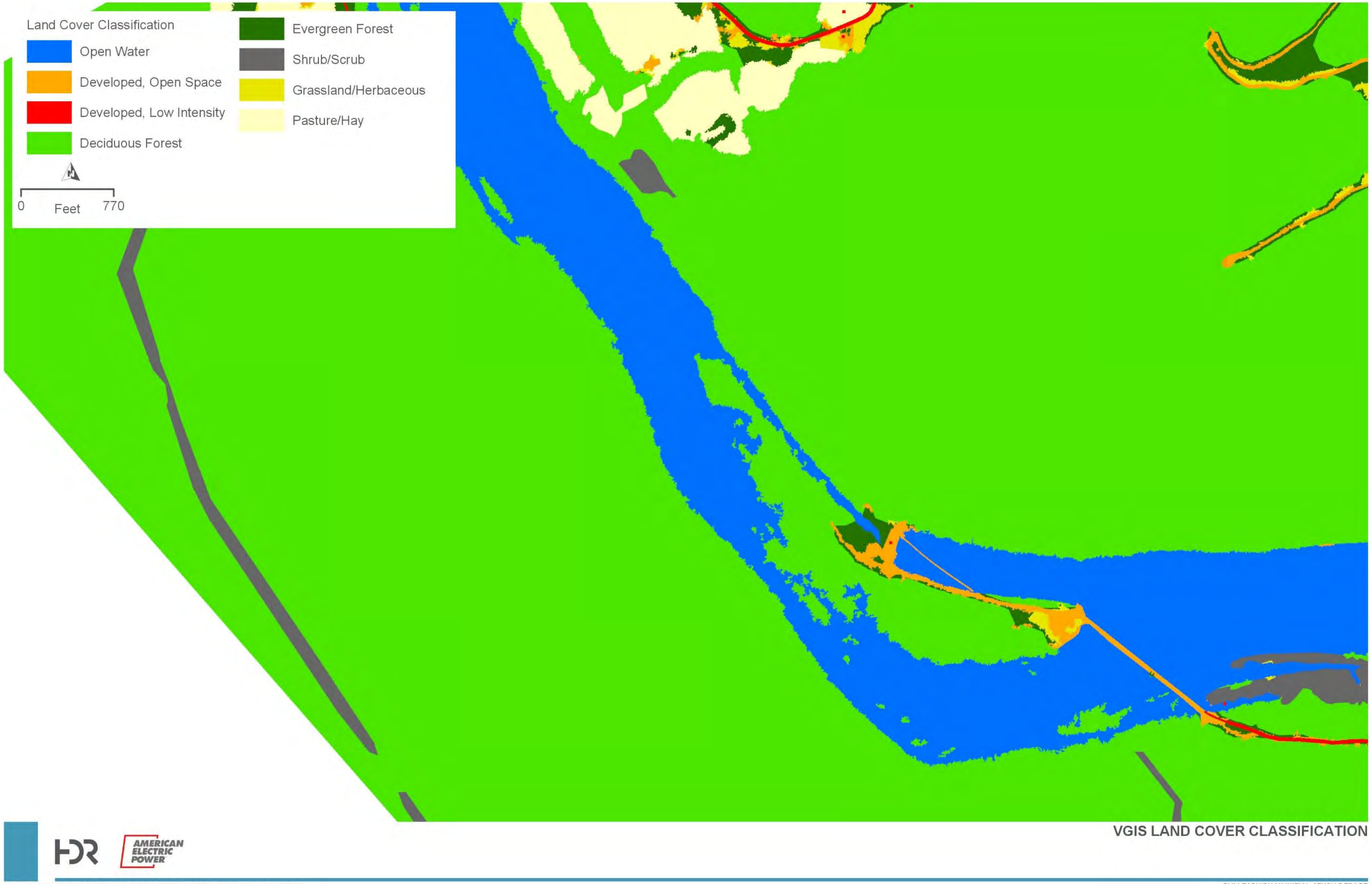

Figure 3-4. Land Cover Raster for Manning's *n* Roughness

3.3.3 Mesh Zone

A single mesh zone representing the Buck tailrace was included in the Model to represent the approximate slope of the tailrace as the tailrace water surface was not captured by the LiDAR survey. The mesh zone polygon was digitized in GIS from an aerial photograph which signifies the typical riverbank location.

3.3.4 Initial Hydraulic Conditions

Both the bypass reach and tailrace were allowed to start from a dry condition to allow the pools within the bypass reach to fill as they naturally would during a real-life spill event.

3.3.5 Boundary Conditions

The primary 2-D Zone boundary condition (i.e., “vertical wall” Boundary Point settings in Table 3-1) was selected based on the topography at the edge of the 2-D Zone. This boundary condition is considered to be an impermeable and infinitely high barrier that does not allow water to flow into or out of the 2-D Zone unless specified with another boundary condition.

In addition to the primary 2-D Zone boundary condition, three additional boundary conditions were incorporated into the Model. An upstream boundary condition was defined at the spillway where the leakage and Tainter Gate inflow hydrographs were applied. A second upstream boundary condition was defined at the powerhouse outlet where the powerhouse flows were introduced. See Section 2 for discussion of the model inflows. The final boundary condition was located at the downstream end of the 2-D Zone on the New River and allows water to leave to 2-D Zone assuming normal depth. Under this condition it is assumed that slope balances friction forces (normal flow) i.e., depth and velocity are kept constant when water reaches the boundary, so water can flow out of the 2-D Zone without energy losses.

4 Results

The model inputs discussed above were used to set up four scenarios which represent the four target flows. Due to the complexity of the Model and mesh representing the New River, Model outputs presented are limited to select locations and points of interest.

4.1 Model Calibration and Verification

Field data points collected during the target flow events, as well as timing of releases recorded by the level loggers in the bypass reach, were used to calibrate and verify the model setup.

4.1.1 Point Water Surface Elevations

Water surface elevations collected by the R10 GPS unit were compared to water surface elevations predicted by the model. Figure 4-1 through Figure 4-4 show the water surface elevation comparisons for the four target flow scenarios. Field measurement data points are colored by magnitude of percentage difference between field and modeled water surface elevations. Figure 4-5 shows the correlation between field and model water surface elevation data for all points collected with the R10 GPS unit dur ing the four target flow days. The ranges of percentage difference and absolute difference for the four target flow scenarios are presented in Table 4-1.

Table 4-1. Point Water Surface Elevation Comparison

	Minimum Delta		Maximum Delta		Average Delta	
Flow	Percentage (%)	Magnitude (ft)	Percentage (%)	Magnitude (ft)	Percentage (%)	Magnitude (ft)
Day 1 (Leakage)	0.00	0.00	0.06	1.17	0.02	0.33
Day 2 (Low)	0.00	0.01	0.07	1.37	0.04	0.75
Day 3 (Mid)	0.00	0.00	0.12	2.30	0.02	0.38
Day 4 (High)	0.00	0.01	0.13	2.53	0.023	0.46

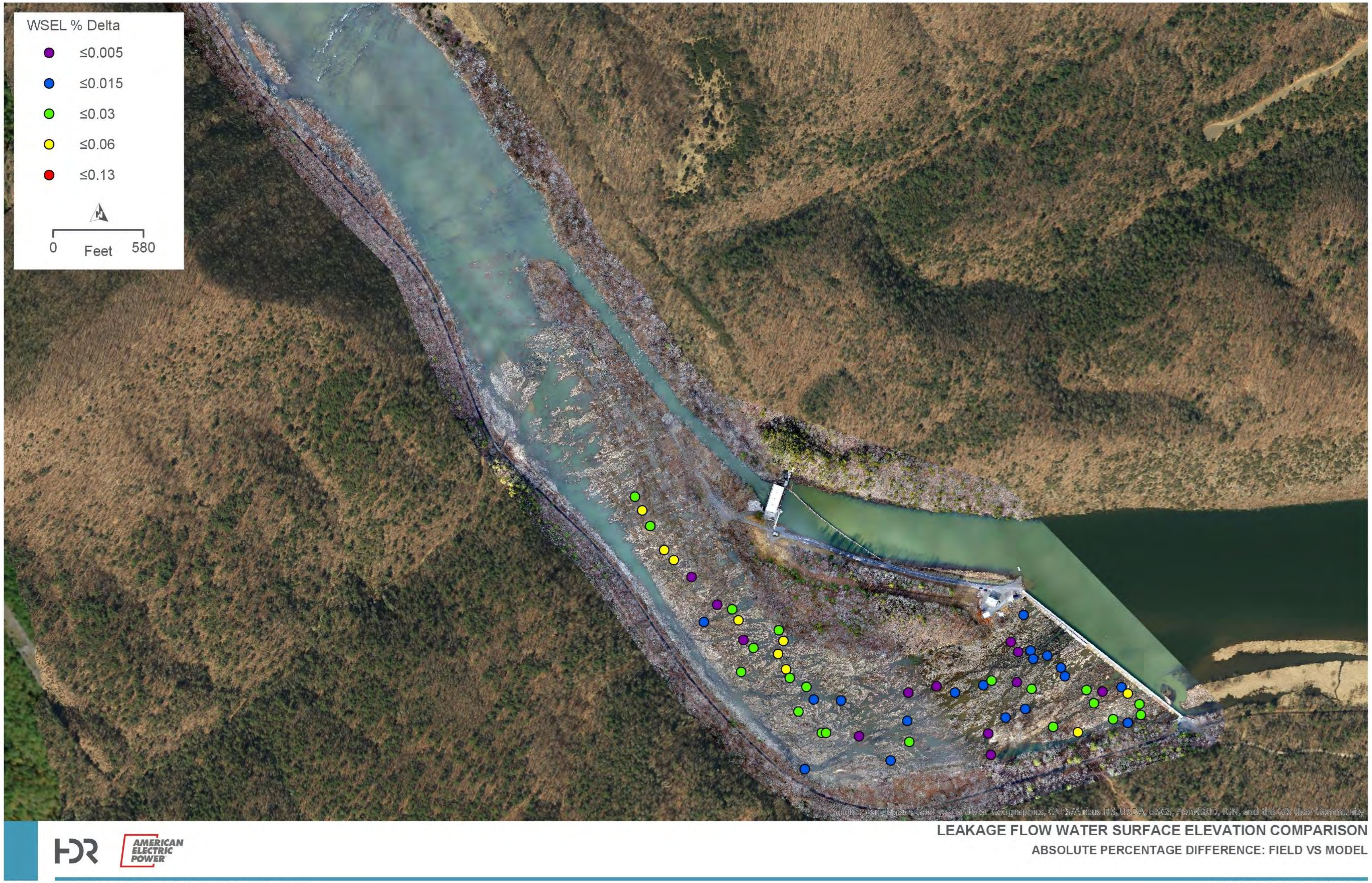

Figure 4-1. Field vs Modeled Water Surface Elevations – Day 1 (Leakage) Target Flow

Figure 4-2. Field vs Modeled Water Surface Elevations – Day 2 (Low) Target Flow

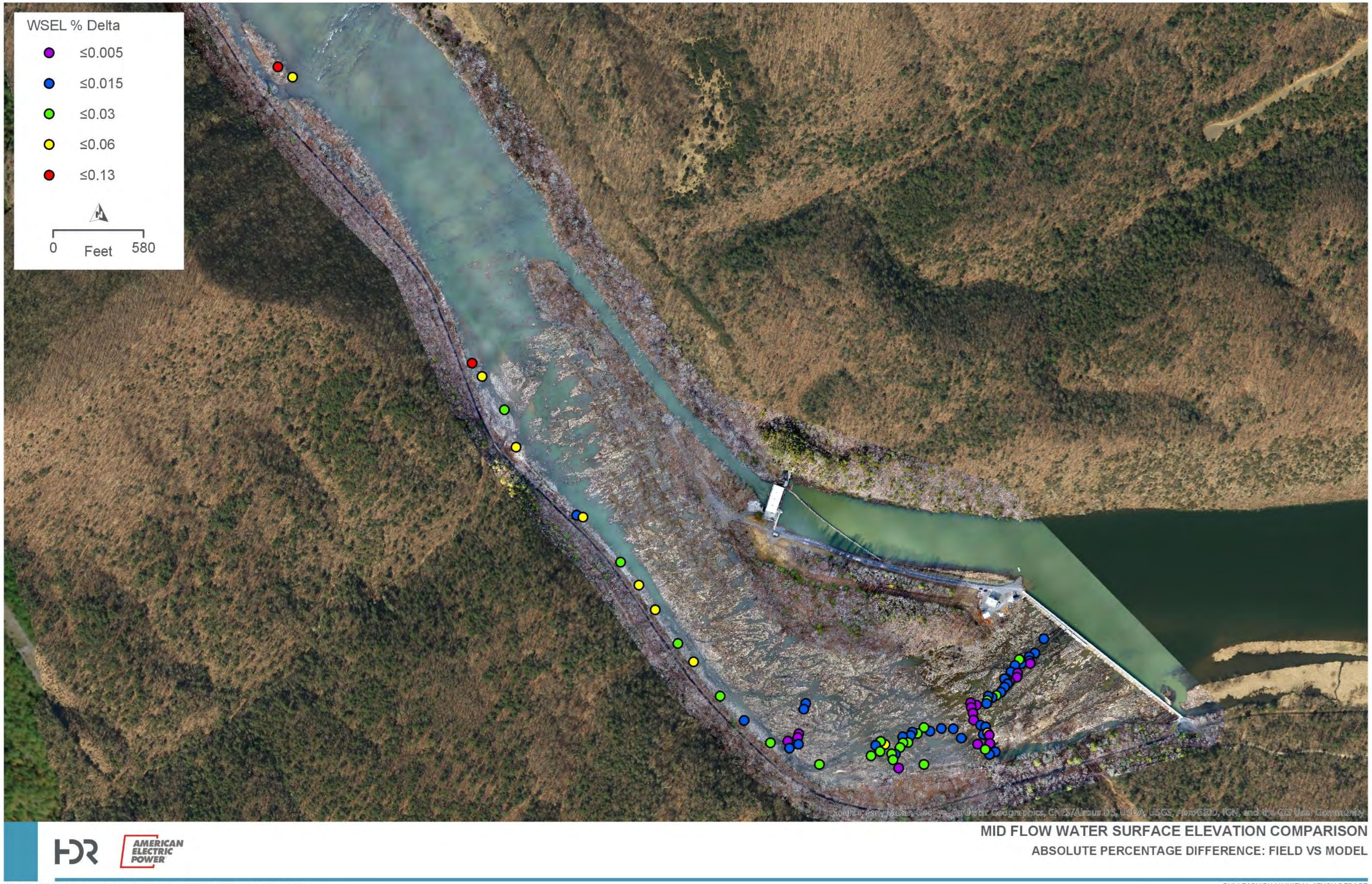

Figure 4-3. Field vs Modeled Water Surface Elevations – Day 3 (Mid) Target Flow

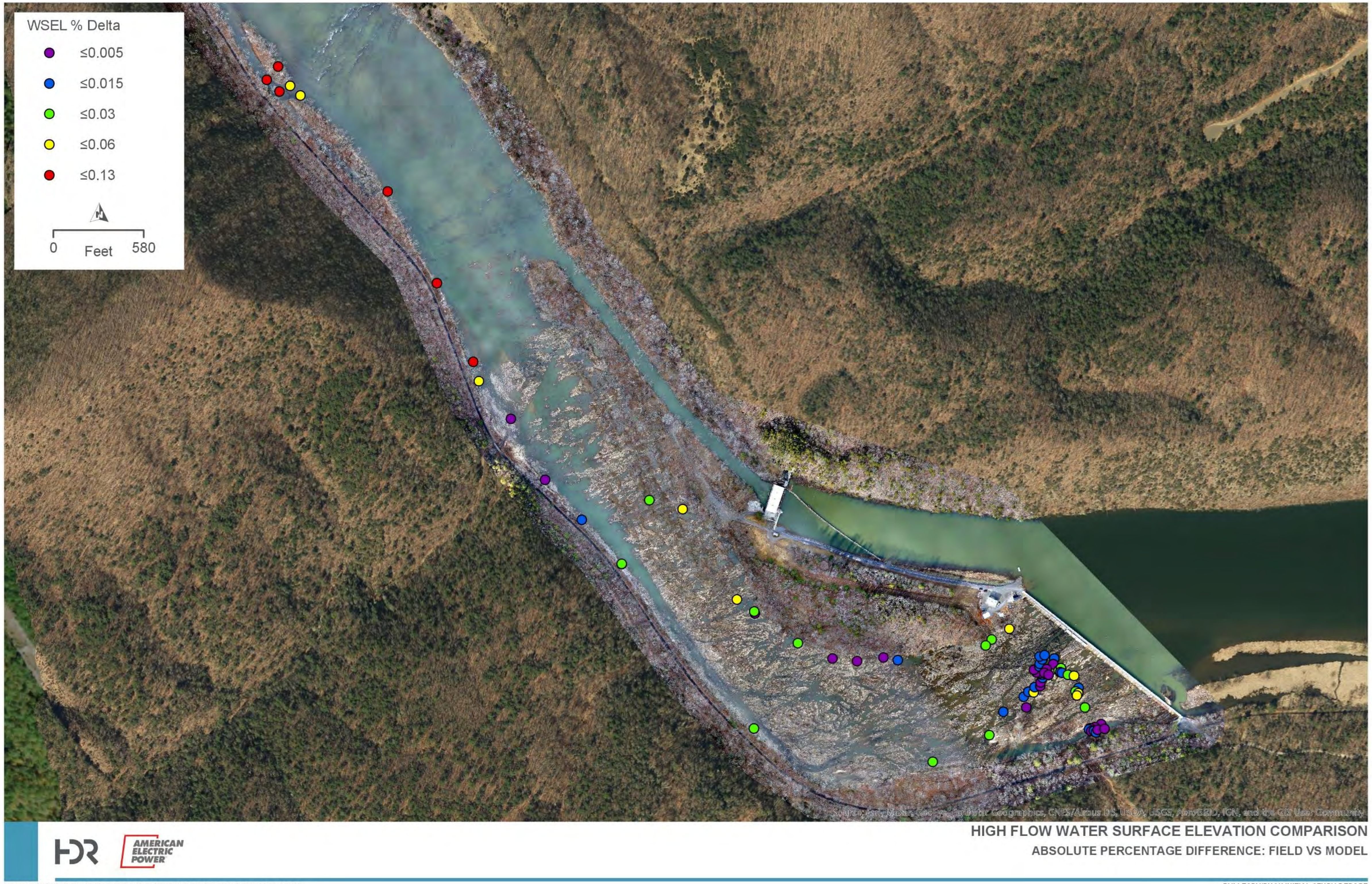

Figure 4-4. Field vs Modeled Water Surface Elevations – Day 4 (High) Target Flow

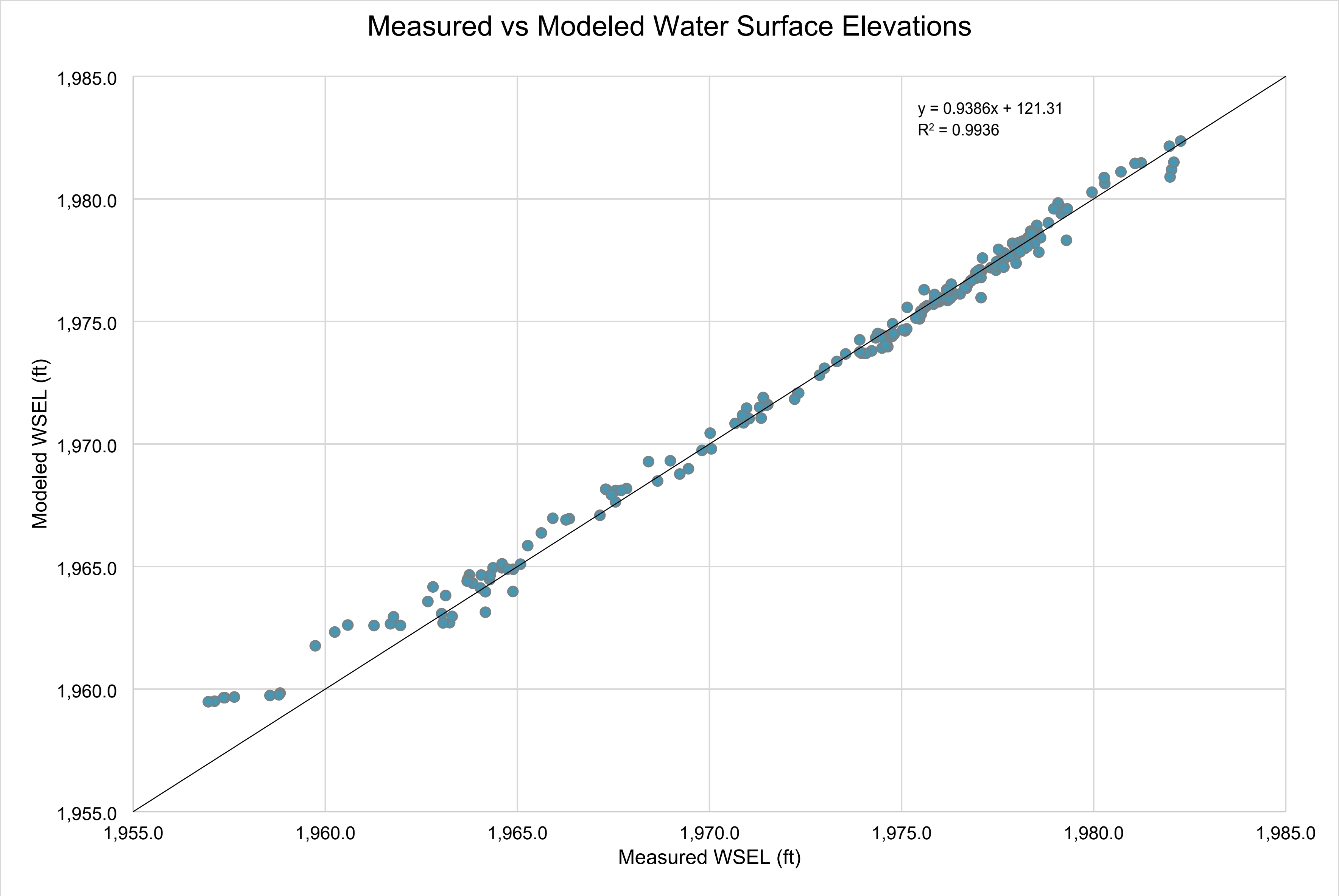

Figure 4-5. Field and Model Water Surface Elevation Correlation – All Flows

4.1.2 Point Velocity and Depth Measurements

Velocity point data collected for the Day 1 and 2 target flow scenarios were compared against velocities predicted by the model for those two scenarios. The comparison between measured field velocity data and modeled velocity for the Day 1 and 2 flow scenarios is presented in Table 4-2 and Figure 4-6 and Figure 4-7, respectively. Field velocity measurement points are colored by absolute difference from modeled velocities.

Due to the nature of a depth-averaged 2D model, matching point velocities measured within the water column is difficult as flow in the field rarely has a uniform velocity. Additional model limitations, including, but not limited to, mesh, Manning's *n* roughness polygon, and DTM resolutions reduce model accuracy near the edge of water. Section 4.1.4 discusses how average velocities across the bypass reach are modeled.

Table 4-2. Point Velocity Comparison

Flow	Field Range (ft/s)	Model Range (ft/s)	Minimum Delta (ft/s)	Maximum Delta (ft/s)	Average Delta (ft/s)
Day 1 (Leakage)	0.0 – 2.04	0.0 – 1.4	0.00	1.6	0.25
Day 2 (Low)	0.0 – 3.59	0.0 – 3.75	0.00	2.8	0.52

Due to the complex nature of the Buck Bypass reach, pool bathymetry was incorporated into the model only at the select locations shown in Figure 3-1. While LiDAR data was collected at leakage conditions, there is still significant standing water throughout the bypass reach that LiDAR cannot penetrate. Because of this, point depths were not compared between the model and data collected in the field.

Because the target flow and model scenarios were set up as steady-state analyses, these pools have very little effect on the overall model hydraulics. Velocities within pools will be slightly higher on average. The potential loss of storage volume within these pools is negligible, as they are filled under leakage flow.

Figure 4-6. Field versus Modeled Velocities – Day 1 (Leakage) Target Flow

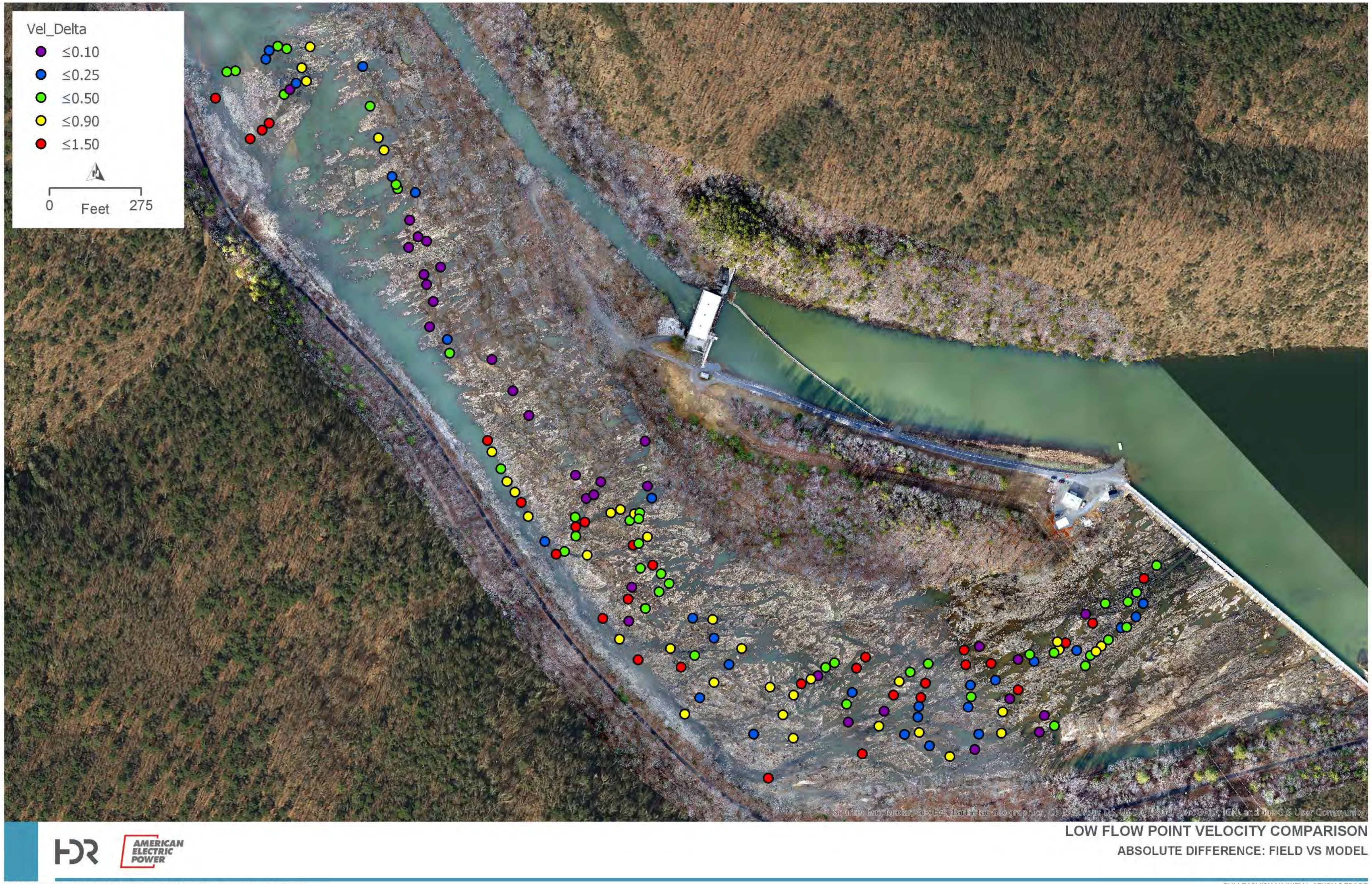

Figure 4-7. Field versus Modeled Velocities – Day 2 (Low) Target Flow

4.1.3 Wetted Area Comparison

The total wetted area in the bypass reach increases as flow increases. Table 4-3 presents the incremental differences predicted by the model of the total bypass reach wetted area between the various target flows. Table 4-4 and Table 4-5 present incremental differences of wetted area for the upper and lower sections of the bypass reach, respectively. The geology of the bypass reach bedrock can be broadly categorized as angular bedrock. This angular bedrock runs in a southeast to northwest direction and creates flow channels or pools depending on orientation. The layout of the bypass reach is such that at approximately 1/4 of the length of the bypass reach, the bedrock orientation transitions from parallel to perpendicular to the direction of flow. For this analysis, this transition area was used as the dividing line between the upper and lower sections of the bypass reach.

Table 4-3. Total Bypass Reach Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta From Leakage	Incremental Area Increase (Acres)
Day 1 (Leakage)	69.6	N/A	N/A
Day 2 (Low)	78.7	113%	9.1
Day 3 (Mid)	83.4	120%	4.7
Day 4 (High)	86.5	124%	3.1

Table 4-4. Upper Bypass Reach Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta From Leakage	Incremental Area Increase (Acres)
Day 1 (Leakage)	8.9	N/A	N/A
Day 2 (Low)	11.5	129%	2.6
Day 3 (Mid)	12.3	138%	0.8
Day 4 (High)	13.4	151%	0.9

Table 4-5. Lower Bypass Reach Wetted Area Comparison

Bypass Reach Flow	Total Wetted Area (Acres)	Percent Delta From Leakage	Incremental Area Increase (Acres)
Day 1 (Leakage)	60.7	N/A	N/A
Day 2 (Low)	67.2	111%	6.5
Day 3 (Mid)	71.1	117%	3.9
Day 4 (High)	73.1	120%	2.0

Figure 4-8 through Figure 4-11 present model results overlaid onto their respective target flow orthomosaic imagery. These figures provide a view of the model results that can be used as a qualitative check of the model's overall agreement with field conditions. For increased detail, only a portion of the upper section of the bypass reach is presented in these figures.

Results of the entire modeling domain are shown on Figure 4-12 through Figure 4-19. Figure 4-12 through Figure 4-15 are colored by velocity magnitude and Figure 4-16 through Figure 4-19 are colored by depth.

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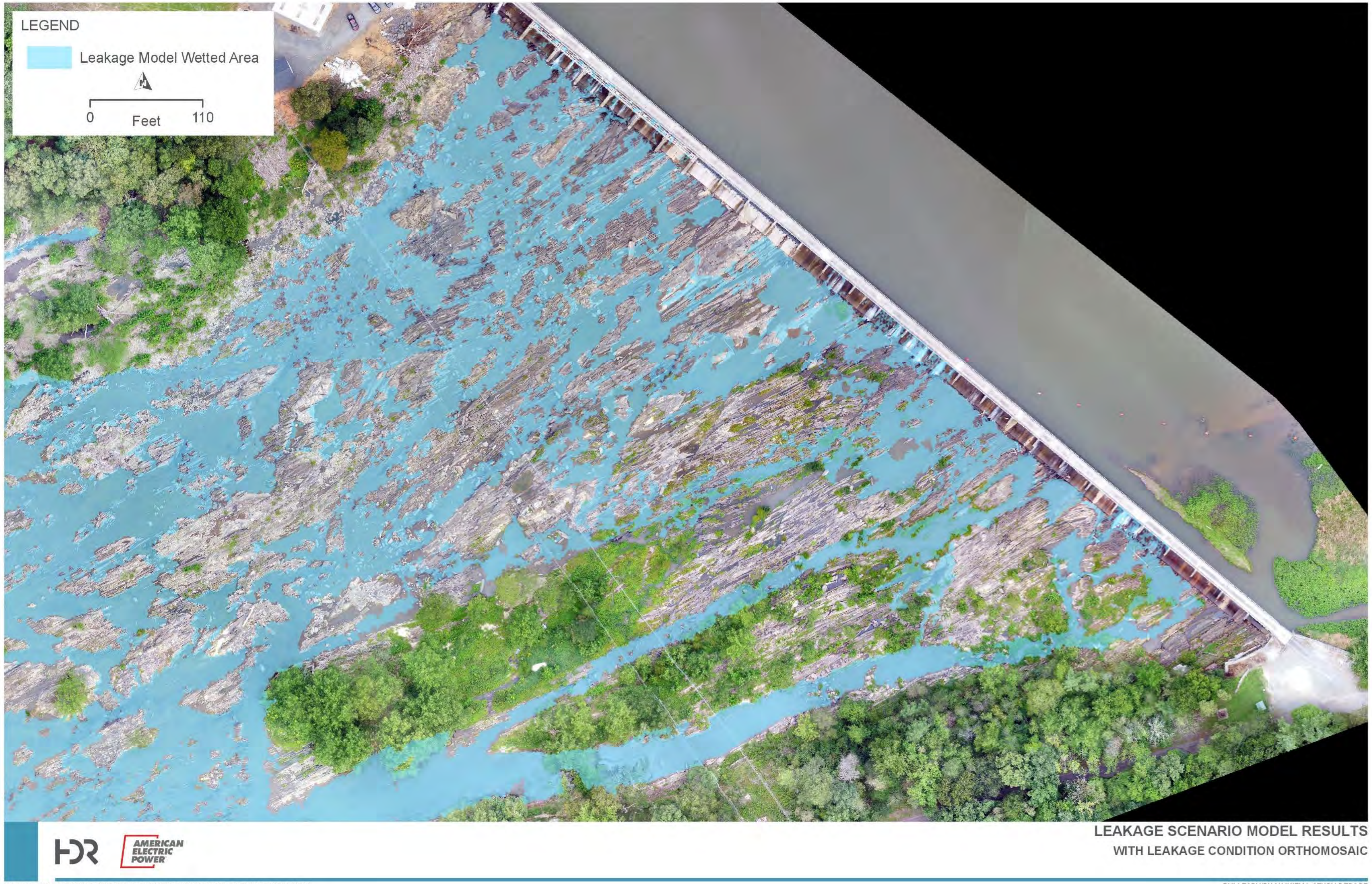

Figure 4-8. Model Results with Orthomosaic Imagery – Day 1 (Leakage) Target Flow

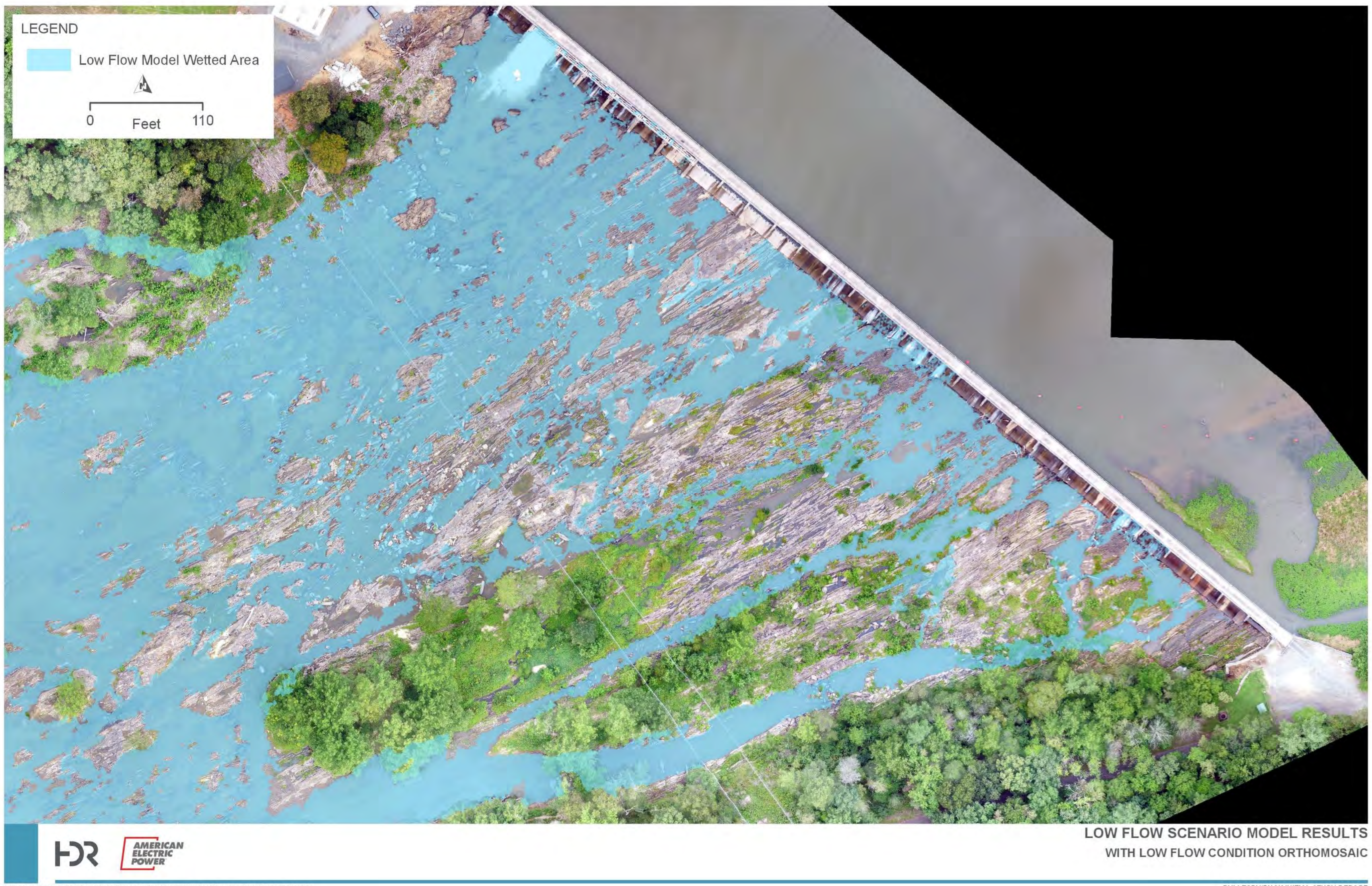

Figure 4-9. Model Results with Orthomosaic Imagery – Day 2 (Low) Target Flow

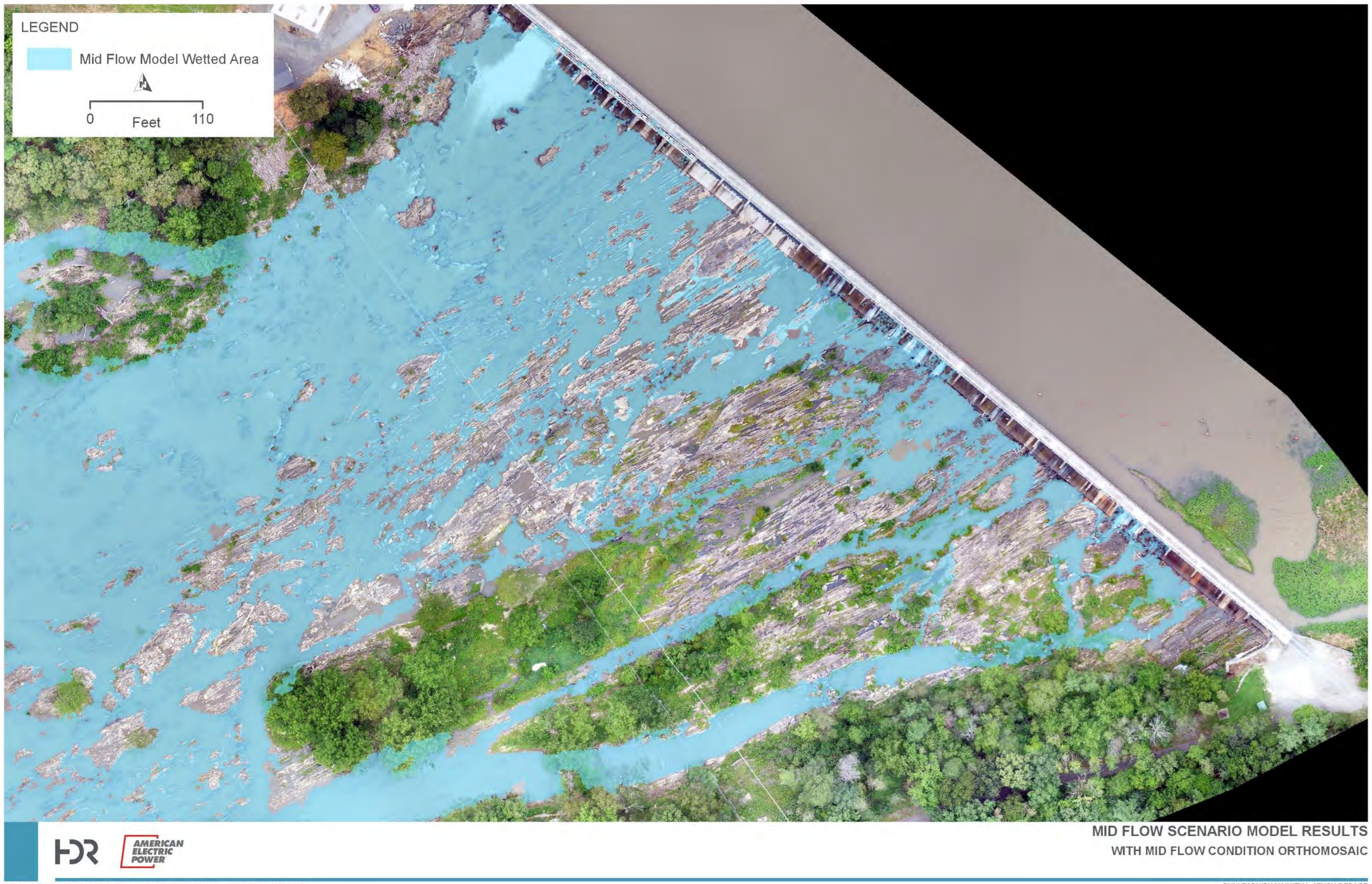

Figure 4-10. Model Results with Orthomosaic Imagery – Day 3 (Mid) Target Flow

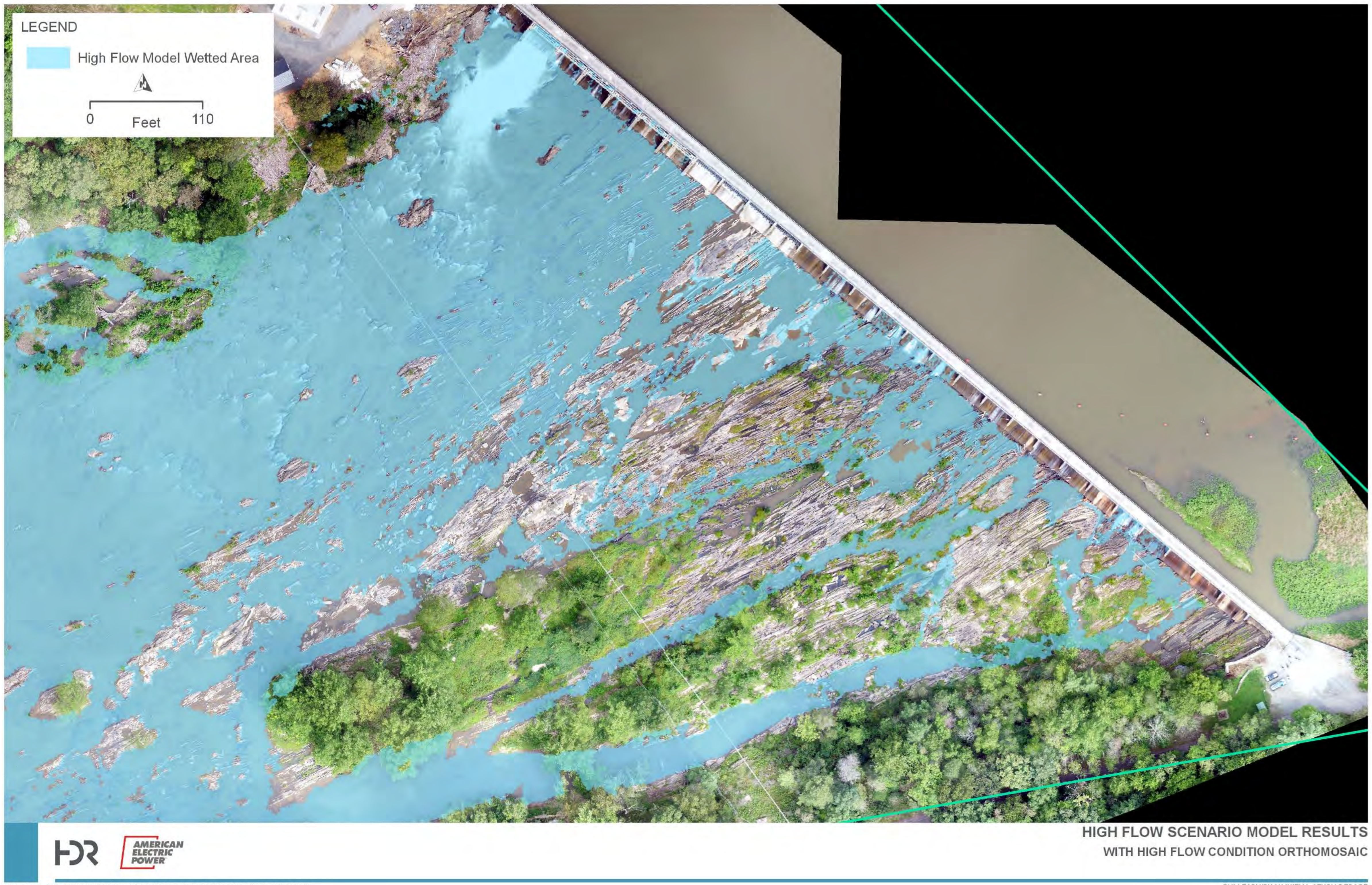

Figure 4-11. Model Results with Orthomosaic Imagery – Day 4 (High) Target Flow

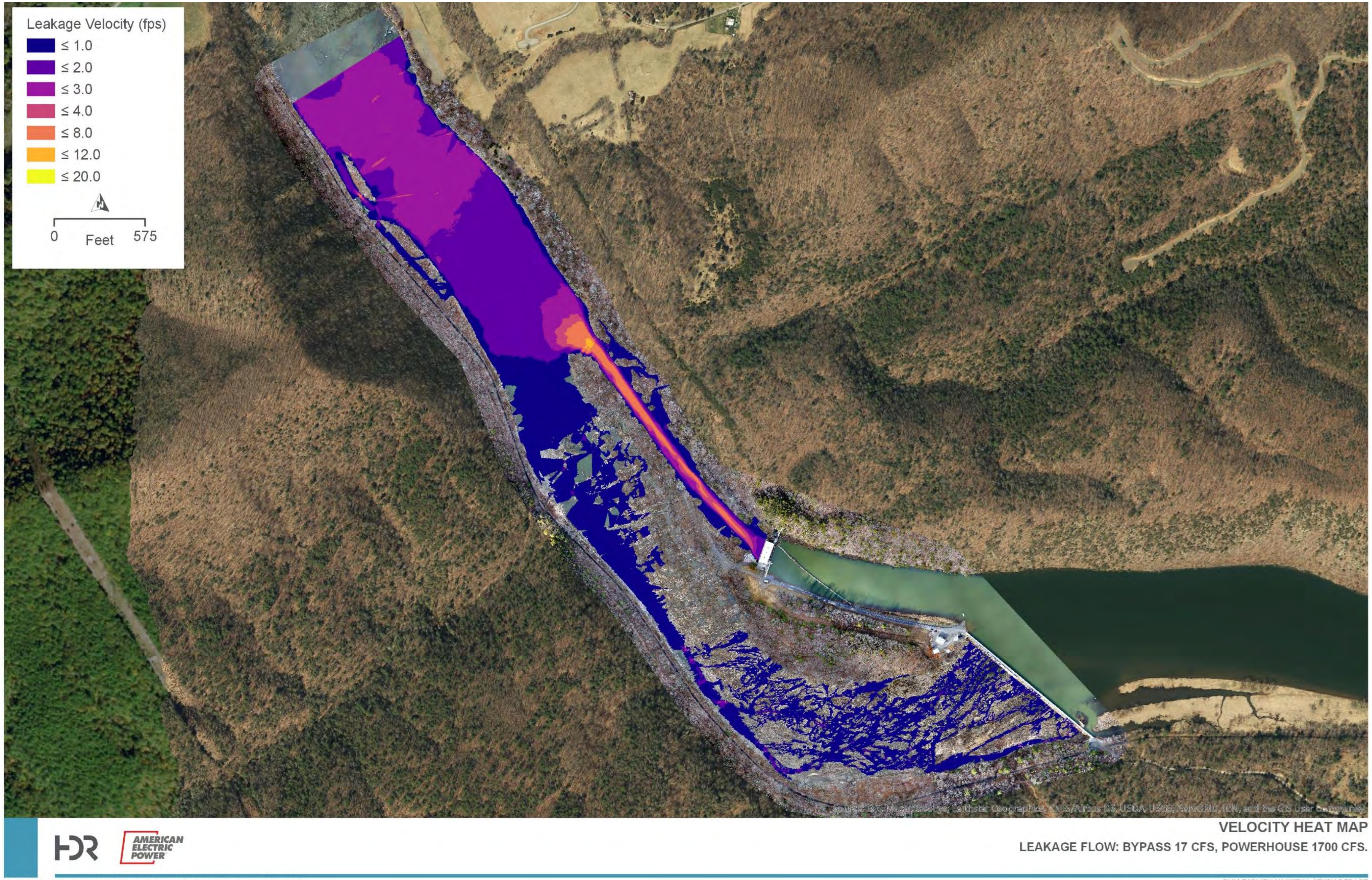

Figure 4-12. Velocity Heat Map – Day 1 (Leakage) Target Flow

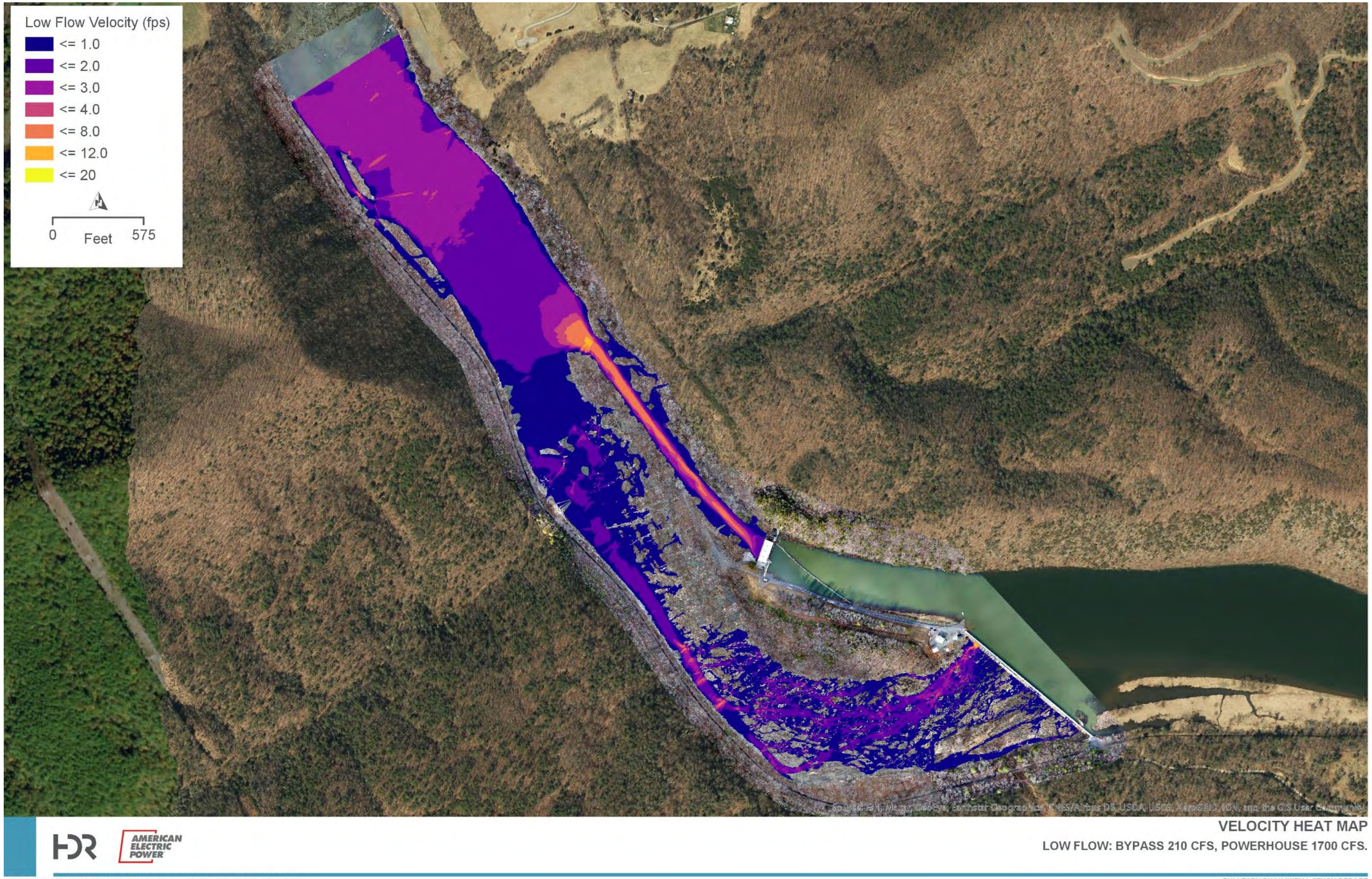

Figure 4-13. Velocity Heat Map – Day 2 (Low) Target Flow

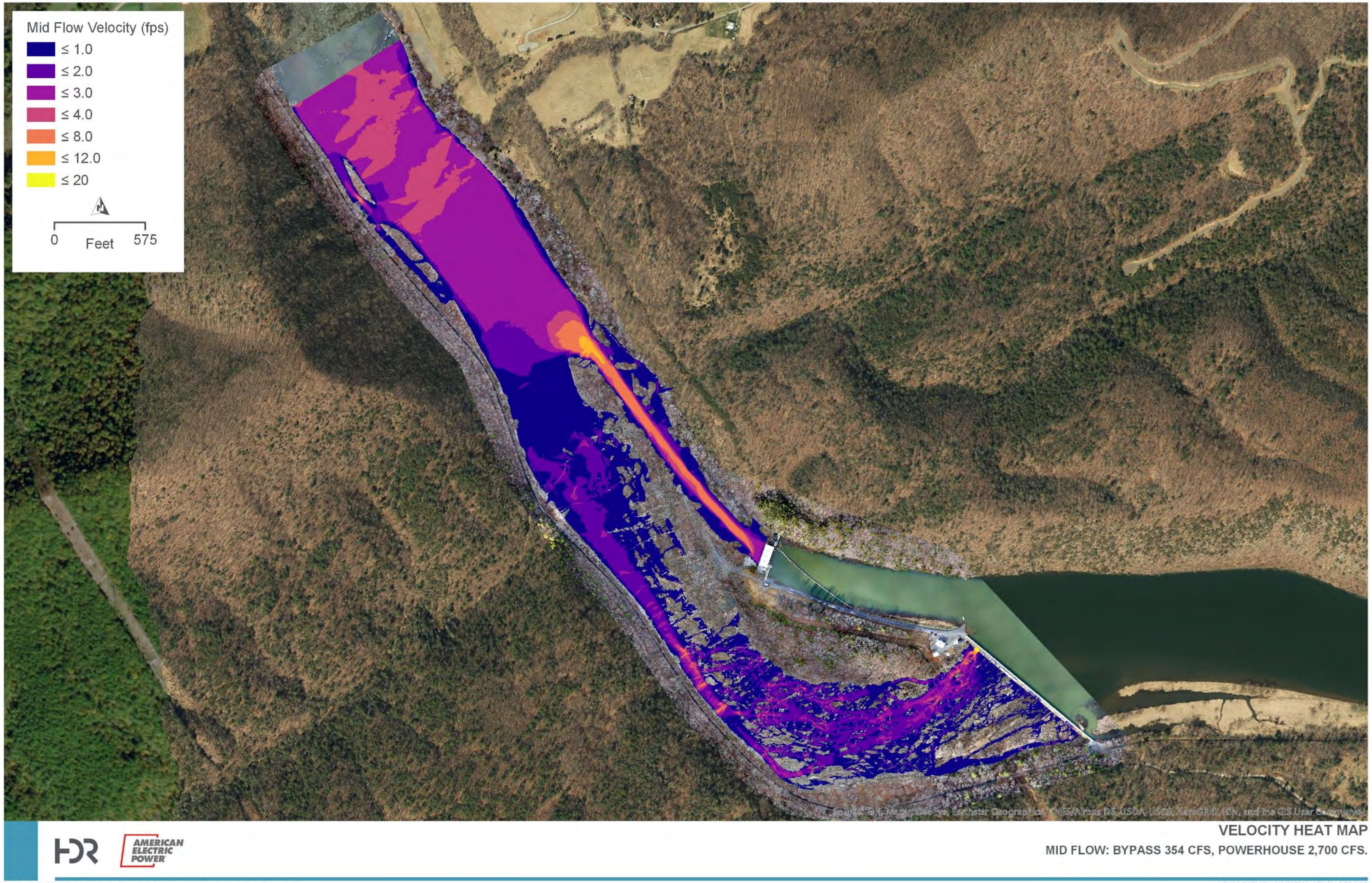

Figure 4-14. Velocity Heat Map – Day 3 (Mid) Target Flow

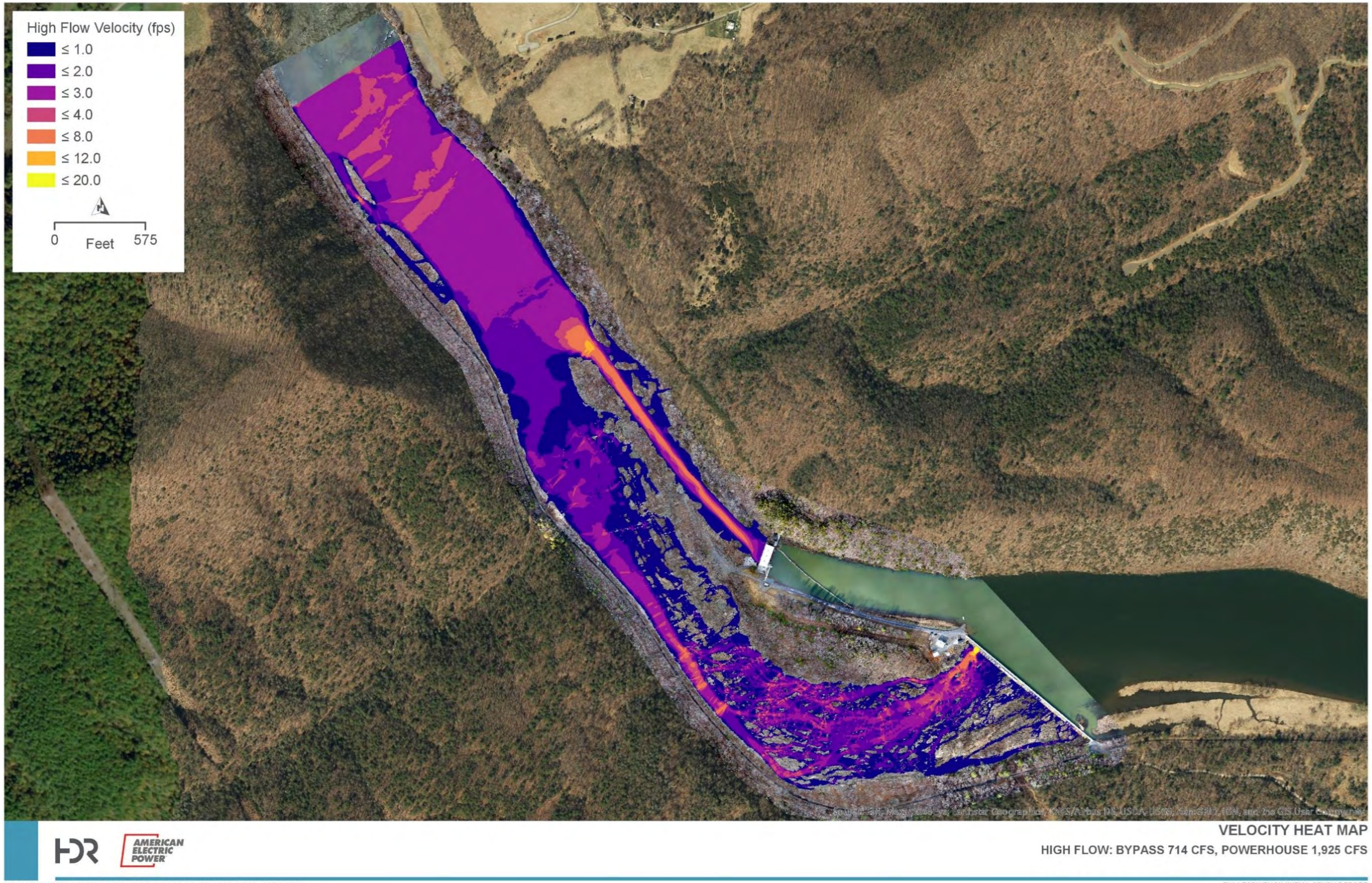

Figure 4-15. Velocity Heat Map – Day 4 (High) Target Flow

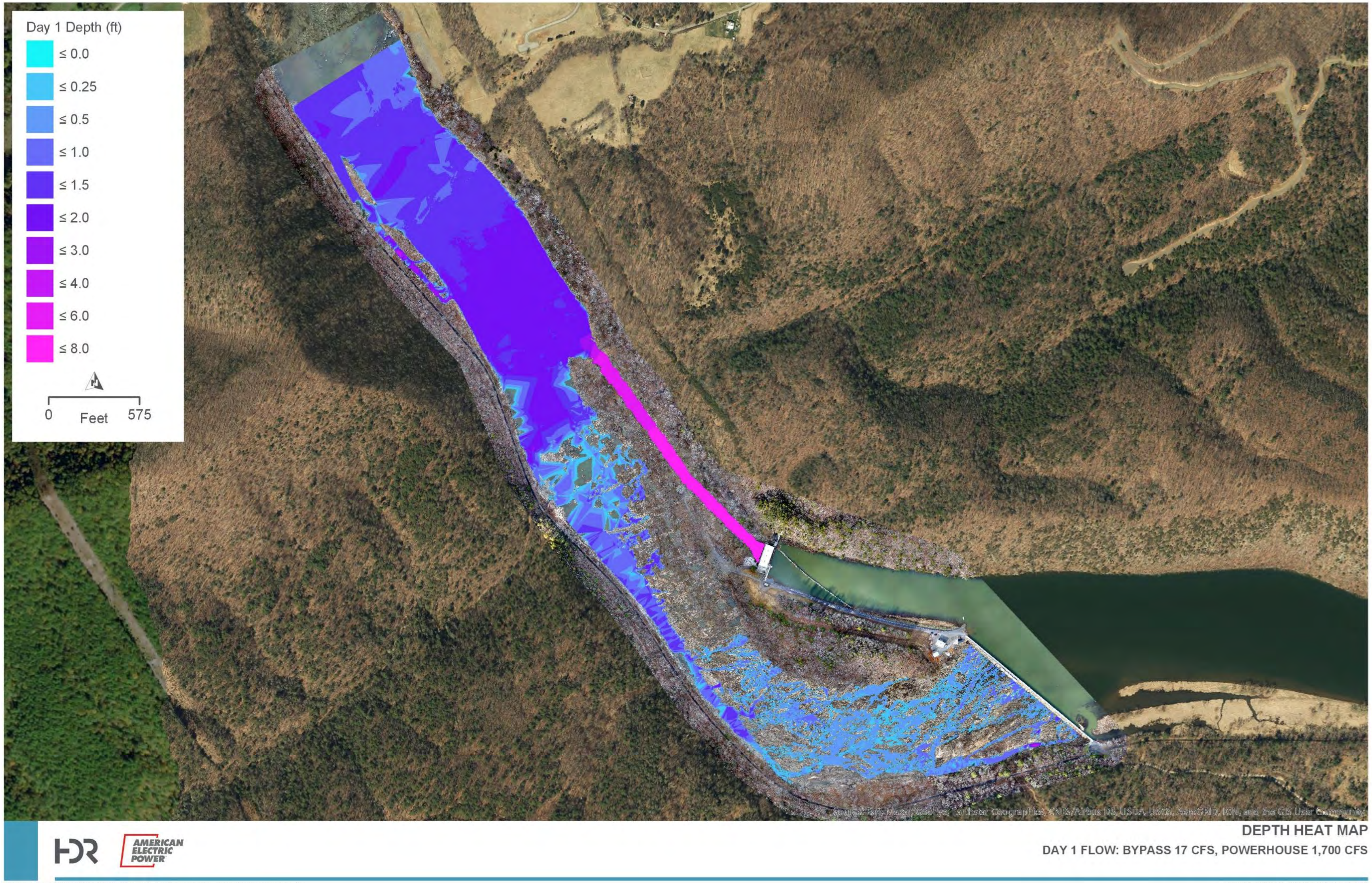

Figure 4-16. Depth Heat Map – Day 1 (Leakage) Target Flow

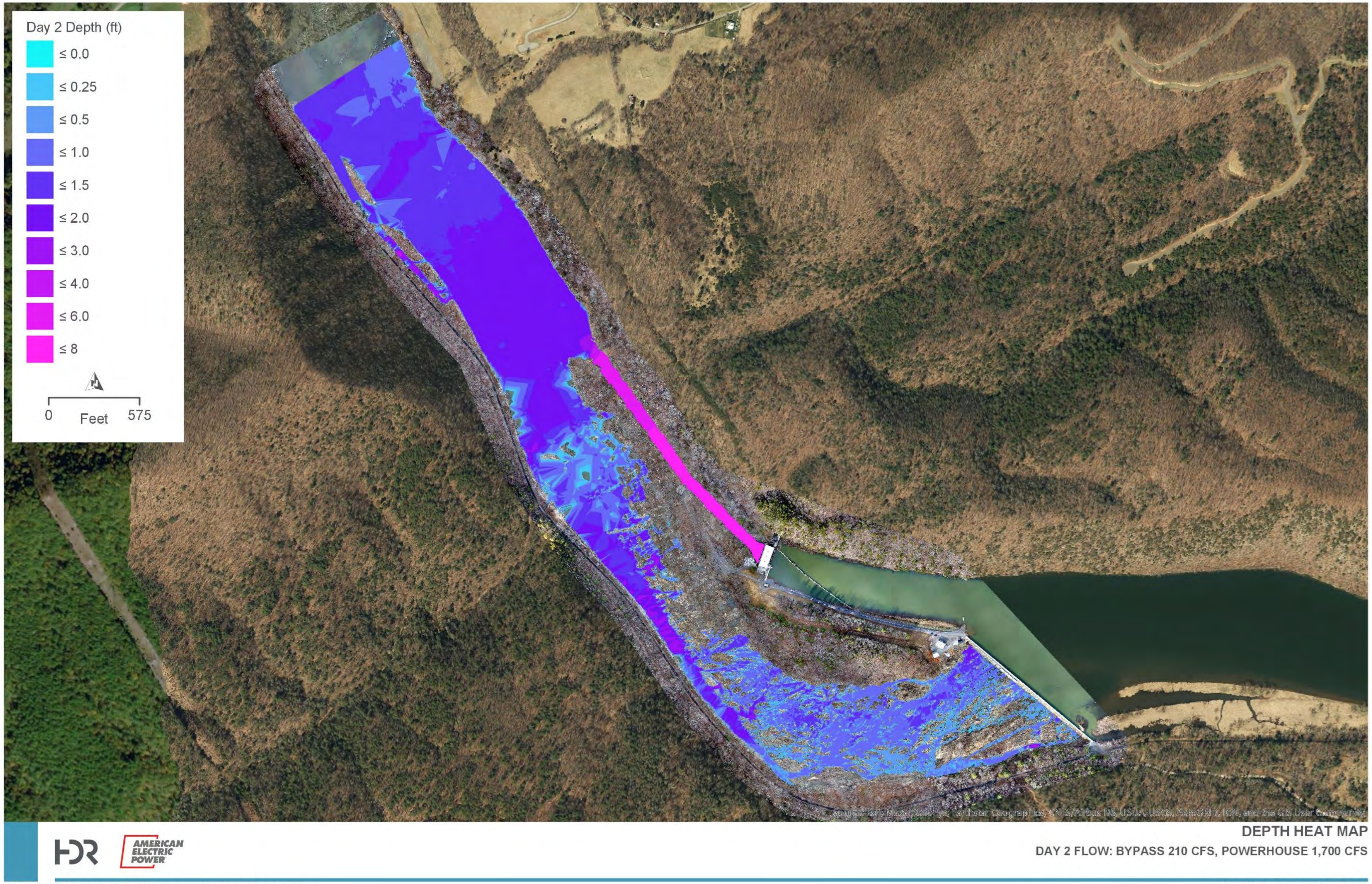

Figure 4-17. Depth Heat Map – Day 2 (Low) Target Flow

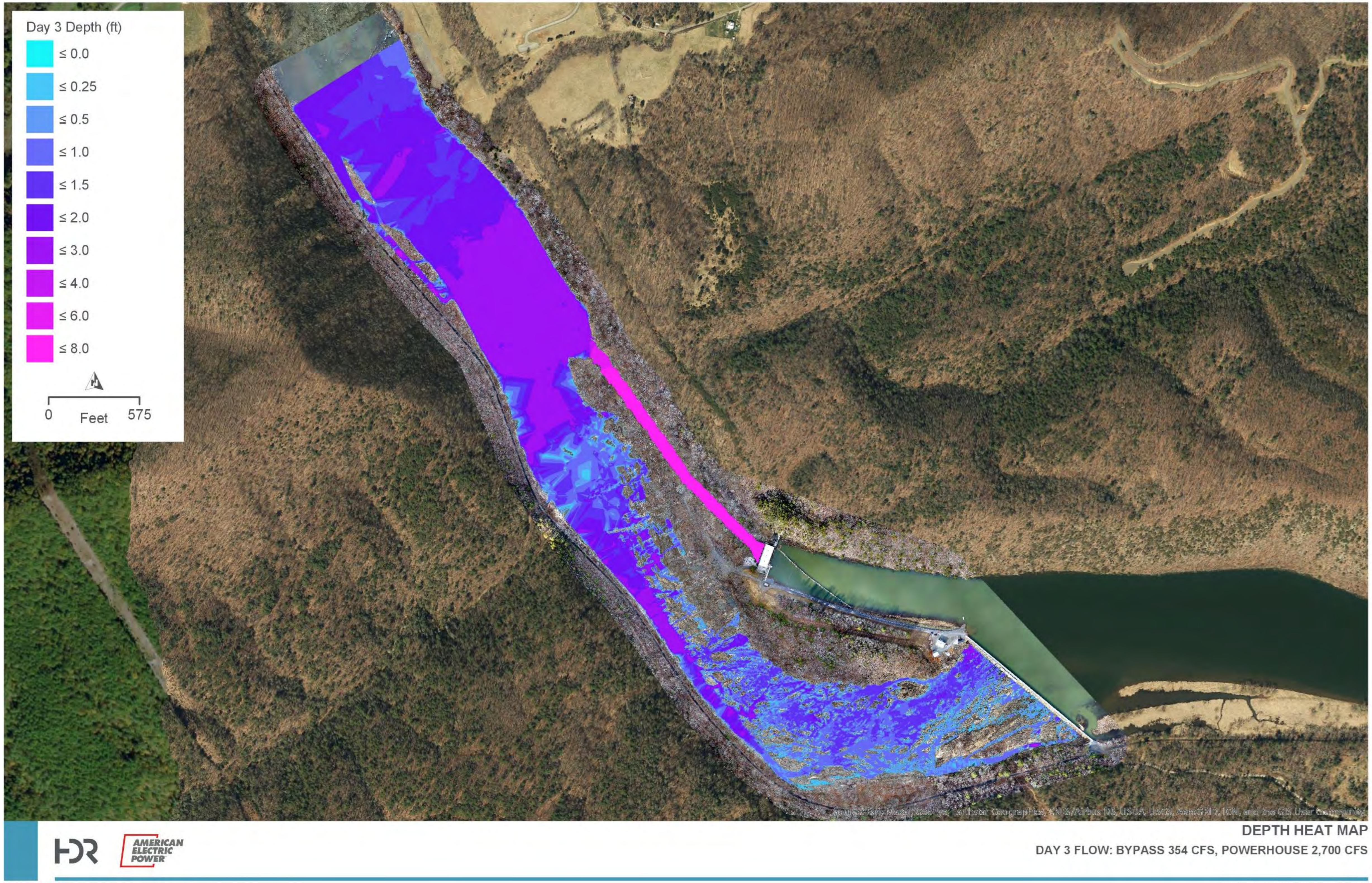

Figure 4-18. Depth Heat Map – Day 3 (Mid) Target Flow

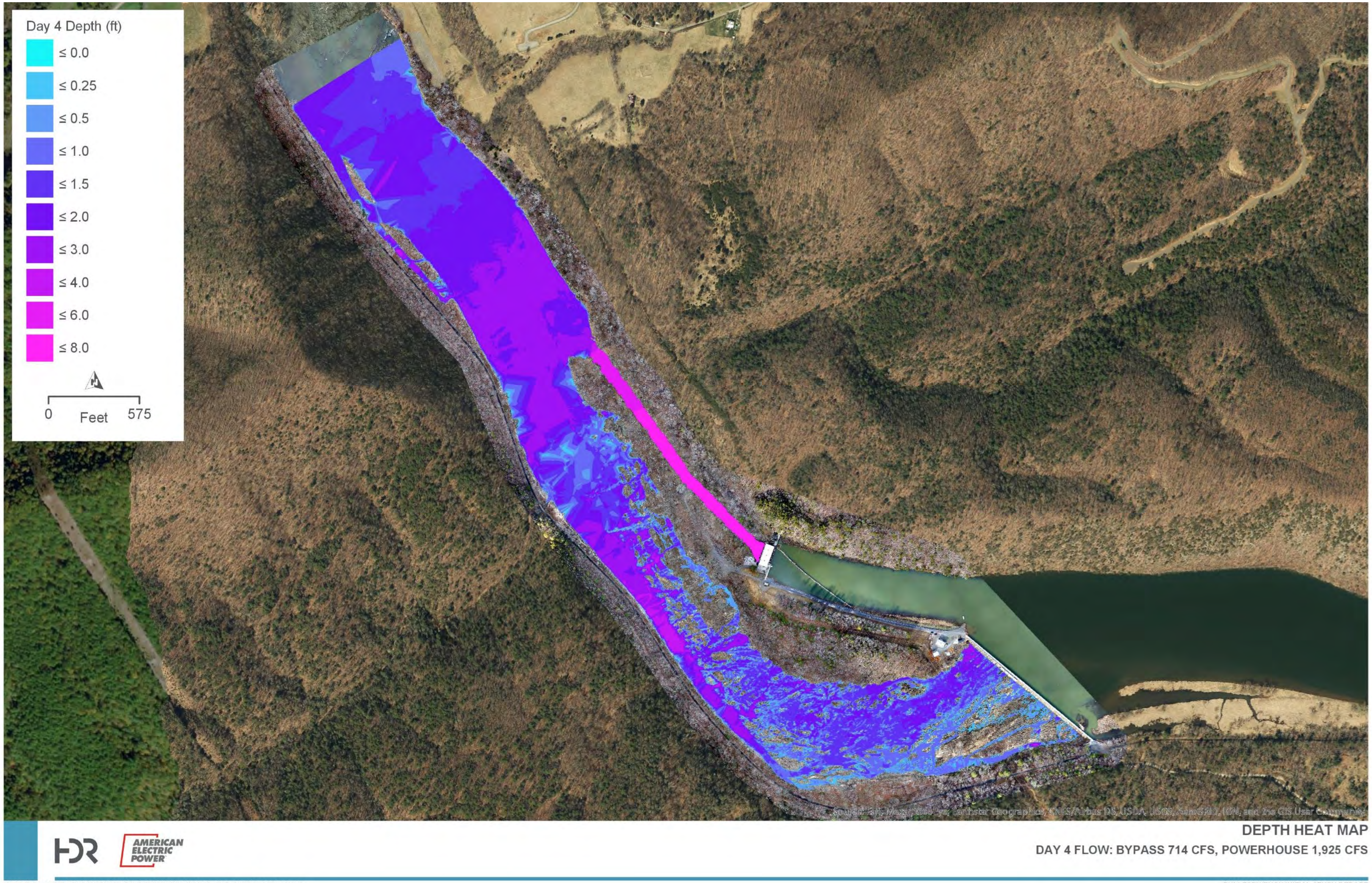

Figure 4-19. Depth Heat Map – Day 4 (High) Target Flow

4.1.4 Travel Time

Travel time measures the time it takes an inflow to travel between designated points in the bypass reach. This measurement is an important data point used for verifying a number of model inputs including the Manning's *n* roughness values presented in Section 3.3.2, inflow, and overall bypass reach slope from the LiDAR data/DTM are appropriate for the analysis. Additionally, it provides insight into model hydraulics, specifically the average velocity within the bypass reach. For this analysis, the travel time was measured between BK_LL1 and BK_LL10. For reference see Figure 2-1. Table 4-6 presents travel times measured by the level loggers and predicted by the model. As leakage is constant, travel times are not measured for that flow condition.

Table 4-6. Bypass Reach Travel Times

Bypass Reach Flow	Level Logger Time (hr:min)	Model Time (hr:min)	Delta (hr:min)
Day 1 (Leakage)	N/A	N/A	N/A
Day 2 (Low)	2:30	2:25	-0:05
Day 3 (Mid)	1:40	1:50	+0:10
Day 4 (High)	1:00	1:15	+0:15

At low flows, the model predicts slightly faster travel times than seen in the field while the opposite is true at higher flows. The small deltas between field and model data confirm the modeling inputs are appropriate and average velocities calculated are representative of field conditions.

5 References

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Attachment 2

Attachment 2 – Habitat Suitability Criteria Tables

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Table 1. Walleye HSC Table

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
Fry	0	0.00	1	0	0.00	0	1	0.07
	0.08	0.02	1	1	0.30	0	2	0.15
	0.11	0.03	0.98	1.1	0.34	0.14	3	1
	0.15	0.05	0.9	1.16	0.35	0.4	4	1
	0.2	0.06	0.74	1.2	0.37	0.64	5	0.2
	0.23	0.07	0.56	1.25	0.38	0.76	6	0
	0.25	0.08	0	1.4	0.43	0.92	7	0
	--	--	--	1.45	0.44	0.96	8	1
	--	--	--	1.5	0.46	0.98	9	1
	--	--	--	1.6	0.49	1	10	1
	--	--	--	4.9	1.49	1	11	1
	--	--	--	5.1	1.55	0.98	12	1
Fry	--	--	--	5.44	1.66	0.9	13	1
	--	--	--	5.8	1.77	0.78	14	1
	--	--	--	6.2	1.89	0.58	15	0.6
	--	--	--	6.6	2.01	0.3	16	0.55
	--	--	--	7	2.13	0	17	0.5
	--	--	--	--	--	--	18	0
Juvenile	0	0.00	1	0	0.00	0	1	0.5
	0.11	0.03	1	2	0.61	0	2	1
	0.13	0.04	0.97	2.2	0.67	0.46	3	0.8
	0.18	0.05	0.88	2.4	0.73	0.66	4	0.6
	0.23	0.07	0.74	2.6	0.79	0.76	5	0.25
	0.3	0.09	0.46	2.85	0.87	0.84	6	0.1
	0.39	0.12	0.28	3.2	0.98	0.92	7	0
	0.46	0.14	0.22	3.6	1.10	0.98	8	0.8
	0.58	0.18	0.12	4	1.22	1	9	0.9
	0.73	0.22	0.08	6	1.83	1	10	0.8
	0.88	0.27	0.06	6.5	1.98	0.96	11	0.7
	1.85	0.56	0.04	7	2.13	0.9	12	0.8
	1.95	0.59	0.04	7.4	2.26	0.82	13	0.7
	2.1	0.64	0.02	7.8	2.38	0.72	14	0.8
	2.25	0.69	0	8	2.44	0.6	15	0.7
	--	--	--	8.35	2.55	0.52	16	0.9
	--	--	--	8.9	2.71	0.46	17	0.65
	--	--	--	9.4	2.87	0.44	18	0
	--	--	--	10.6	3.23	0.42	--	--
	--	--	--	18	5.49	0.4	--	--
Adult	0.00	0.00	1.00	0.00	0.00	0.00	1	0.2
	0.20	0.06	1.00	3.10	0.94	0.00	2	1
	0.25	0.08	0.98	3.40	1.04	0.20	3	1
	0.30	0.09	0.84	3.60	1.10	0.44	4	1
	0.37	0.11	0.40	3.70	1.13	0.82	5	1
	0.45	0.14	0.26	3.80	1.16	0.92	6	1
	0.6	0.18288	0.18	3.95	1.20	0.98	7	0
	1	0.3048	0.06	4	1.2192	1	8	0.6
	1.5	0.4572	0.04	10	3.048	1	9	1
	2.5	0.762	0.04	--	--	--	10	1
	2.85	0.86868	0.02	--	--	--	11	1
	3	0.9144	0	--	--	--	12	1
	--	--	--	--	--	--	13	1
	--	--	--	--	--	--	14	1
	--	--	--	--	--	--	15	1
	--	--	--	--	--	--	16	1

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	--	--	--	--	--	--	17	0.6
	--	--	--	--	--	--	18	0
Spawning	0	0.00	0.06	0	0.00	0	1	0
	0.4	0.12	0.08	1	0.30	0	2	0
	0.85	0.26	0.12	1.5	0.46	0.22	3	0.35
	1	0.30	0.14	1.8	0.55	0.42	4	1
	1.17	0.36	0.18	2.06	0.63	0.62	5	1
	1.5	0.46	0.28	2.3	0.70	0.88	6	1
	1.78	0.54	0.38	2.4	0.73	0.94	7	0
	1.97	0.60	0.46	2.5	0.76	0.99	8	0.8
	2.07	0.63	0.54	2.6	0.79	1	9	0.8
	2.15	0.66	0.62	4.97	1.51	1	10	0.8
	2.3	0.70	0.84	5.05	1.54	0.98	11	0.8
	2.4	0.73	0.94	5.8	1.77	0.6	12	0.8
	2.47	0.75	0.98	6.1	1.86	0.44	13	0.8
	2.52	0.77	1	6.25	1.91	0.3	14	0.8
	2.97	0.91	1	6.5	1.98	0	15	0.8
	3.03	0.92	0.99	--	--	--	16	0.8
	3.05	0.93	0.98	--	--	--	17	0.11
	3.2	0.98	0.86	--	--	--	18	0
	3.35	1.02	0.68	--	--	--	--	--
	3.5	1.07	0.46	--	--	--	--	--
	3.55	1.08	0.32	--	--	--	--	--
	3.58	1.09	0	--	--	--	--	--

Table 2. Shallow Guild HSC Table

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
RBSFS	0.0	0.00	1.00	0.0	0.00	0.00	1	0.1
	0.4	0.12	1.00	0.5	0.15	0.00	2	0.7
	0.5	0.15	0.90	0.8	0.23	0.80	3	0.8
	1.0	0.31	0.15	1.0	0.31	1.00	4	0.5
	1.3	0.41	0.00	2.5	0.76	1.00	5	0.21
	--	--	--	3.1	0.95	0.60	6	0
	--	--	--	7.0	2.13	0.00	7	0
	--	--	--	--	--	--	8	0.2
	--	--	--	--	--	--	9	0.8
	--	--	--	--	--	--	10	0.4
	--	--	--	--	--	--	11	0.8
	--	--	--	--	--	--	12	0.8
	--	--	--	--	--	--	13	0.7
	--	--	--	--	--	--	14	0.9
	--	--	--	--	--	--	15	0.6
	--	--	--	--	--	--	16	0.9
	--	--	--	--	--	--	17	0.85
	--	--	--	--	--	--	18	0
SRHAV	0.0	0.00	0.92	0.0	0.00	0.00	1	1
	0.0	0.01	0.95	0.0	0.01	0.08	2	0
	0.1	0.02	0.97	0.1	0.02	0.10	3	0
	0.1	0.03	0.98	0.1	0.03	0.13	4	0
	0.1	0.04	0.99	0.1	0.04	0.17	5	0
	0.2	0.05	1.00	0.2	0.05	0.21	6	0
	0.2	0.06	1	0.2	0.06	0.25	7	0
	0.2	0.07	1	0.2	0.07	0.29	8	1
	0.3	0.08	0.99	0.3	0.08	0.34	9	0
	0.3	0.09	0.98	0.3	0.09	0.39	10	0
SRHAV	0.3	0.10	0.97	0.3	0.10	0.44	11	0
	0.4	0.11	0.95	0.4	0.11	0.5	12	0
	0.4	0.12	0.94	0.4	0.12	0.55	13	0
	0.4	0.13	0.92	0.4	0.13	0.6	14	0
	0.5	0.14	0.9	0.5	0.14	0.65	15	0
	0.5	0.15	0.88	0.5	0.15	0.7	16	0
	0.5	0.16	0.86	0.5	0.16	0.75	17	0
	0.6	0.17	0.83	0.6	0.17	0.79	18	1
	0.6	0.18	0.81	0.6	0.18	0.83	--	--
	0.6	0.19	0.79	0.6	0.19	0.87	--	--
	0.7	0.20	0.76	0.7	0.20	0.90	--	--
	0.7	0.21	0.74	0.7	0.21	0.92	--	--
	0.7	0.22	0.71	0.7	0.22	0.95	--	--
	0.8	0.23	0.69	0.8	0.23	0.96	--	--
	0.8	0.24	0.67	0.8	0.24	0.98	--	--
	0.8	0.25	0.64	0.8	0.25	0.99	--	--
	0.8	0.26	0.62	0.8	0.26	1	--	--
	0.9	0.27	0.6	0.9	0.27	1	--	--
	0.9	0.28	0.58	0.9	0.28	1	--	--
	1.0	0.29	0.55	1.0	0.29	1	--	--
	1.0	0.30	0.53	1.0	0.30	0.99	--	--
	1.0	0.31	0.51	1.0	0.31	0.98	--	--
	1.0	0.32	0.49	1.0	0.32	0.97	--	--
	1.1	0.33	0.47	1.1	0.33	0.96	--	--
	1.1	0.34	0.46	1.1	0.34	0.94	--	--
	1.2	0.35	0.44	1.2	0.35	0.93	--	--

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	1.2	0.36	0.42	1.2	0.36	0.91	--	--
	1.2	0.37	0.4	1.2	0.37	0.89	--	--
	1.3	0.38	0.39	1.3	0.38	0.87	--	--
	1.3	0.39	0.37	1.3	0.39	0.85	--	--
	1.3	0.40	0.35	1.3	0.40	0.83	--	--
	1.3	0.41	0.34	1.3	0.41	0.81	--	--
	1.4	0.42	0.33	1.4	0.42	0.79	--	--
	1.4	0.43	0.31	1.4	0.43	0.77	--	--
	1.4	0.44	0.3	1.4	0.44	0.75	--	--
	1.5	0.45	0.29	1.5	0.45	0.72	--	--
	1.5	0.46	0.27	1.5	0.46	0.7	--	--
	1.5	0.47	0.26	1.5	0.47	0.68	--	--
	1.6	0.48	0.25	1.6	0.48	0.66	--	--
	1.6	0.49	0.24	1.6	0.49	0.64	--	--
	1.6	0.50	0.23	1.6	0.50	0.62	--	--
	1.7	0.51	0.22	1.7	0.51	0.6	--	--
	1.7	0.52	0.21	1.7	0.52	0.58	--	--
	1.7	0.53	0.2	1.7	0.53	0.56	--	--
	1.8	0.54	0.19	1.8	0.54	0.54	--	--
	1.8	0.55	0.18	1.8	0.55	0.52	--	--
	1.8	0.56	0.17	1.8	0.56	0.5	--	--
	1.9	0.57	0.17	1.9	0.57	0.48	--	--
	1.9	0.58	0.16	1.9	0.58	0.46	--	--
	1.9	0.59	0.15	1.9	0.59	0.45	--	--
	2.0	0.60	0.14	2.0	0.60	0.43	--	--
	2.0	0.61	0.14	2.0	0.61	0.41	--	--
	2.0	0.62	0.13	2.0	0.62	0.4	--	--
	2.1	0.63	0.13	2.1	0.63	0.38	--	--
SRHAV	2.1	0.64	0.12	2.1	0.64	0.37	--	--
	2.1	0.65	0.11	2.1	0.65	0.35	--	--
	2.2	0.66	0.11	2.2	0.66	0.34	--	--
	2.2	0.67	0.1	2.2	0.67	0.33	--	--
	2.2	0.68	0.1	2.2	0.68	0.31	--	--
	2.3	0.69	0.09	2.3	0.69	0.3	--	--
	2.3	0.70	0.09	2.3	0.70	0.29	--	--
	2.3	0.71	0.09	2.3	0.71	0.28	--	--
	2.4	0.72	0.08	2.4	0.72	0.27	--	--
	2.4	0.73	0.08	2.4	0.73	0.25	--	--
	2.4	0.74	0.07	2.4	0.74	0.24	--	--
	2.5	0.75	0.07	2.5	0.75	0.23	--	--
	2.5	0.76	0.07	2.5	0.76	0.22	--	--
	2.5	0.77	0.06	2.5	0.77	0.22	--	--
	2.6	0.78	0.06	2.6	0.78	0.21	--	--
	2.6	0.79	0.06	2.6	0.79	0.2	--	--
	2.6	0.80	0.05	2.6	0.80	0.19	--	--
	2.7	0.81	0.05	2.7	0.81	0.18	--	--
	2.7	0.82	0.05	2.7	0.82	0.17	--	--
	2.7	0.83	0.05	2.7	0.83	0.17	--	--
	2.7	0.84	0.04	2.7	0.84	0.16	--	--
	2.8	0.85	0.04	2.8	0.85	0.15	--	--
	2.8	0.86	0.04	2.8	0.86	0.15	--	--
	2.9	0.87	0.04	2.9	0.87	0.14	--	--
	2.9	0.88	0.04	2.9	0.88	0.13	--	--
	2.9	0.89	0.03	2.9	0.89	0.13	--	--
	2.9	0.90	0.03	2.9	0.90	0.12	--	--
	3.0	0.91	0.03	3.0	0.91	0.12	--	--

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	3.0	0.92	0.03	3.0	0.92	0.11	--	--
	3.1	0.93	0.03	3.1	0.93	0.11	--	--
	3.1	0.94	0.03	3.1	0.94	0.1	--	--
	3.1	0.95	0.03	3.1	0.95	0.1	--	--
	3.1	0.96	0.02	3.1	0.96	0.09	--	--
	3.2	0.97	0.02	3.2	0.97	0.09	--	--
	3.2	0.98	0.02	3.2	0.98	0.08	--	--
	3.3	0.99	0.02	3.3	0.99	0.08	--	--
	3.3	1.00	0.02	3.3	1.00	0.08	--	--
	3.3	1.01	0.02	3.3	1.01	0.07	--	--
	3.3	1.02	0.02	3.3	1.02	0.07	--	--
	3.4	1.03	0.02	3.4	1.03	0.07	--	--
	3.4	1.04	0.02	3.4	1.04	0.06	--	--
	3.4	1.05	0.01	3.4	1.05	0.06	--	--
	3.5	1.06	0.01	3.5	1.06	0.06	--	--
	3.5	1.07	0.01	3.5	1.07	0.05	--	--
	3.5	1.08	0.01	3.5	1.08	0.05	--	--
	3.6	1.09	0.01	3.6	1.09	0.05	--	--
	3.6	1.10	0.01	3.6	1.10	0.05	--	--
	3.6	1.11	0.01	3.6	1.11	0.04	--	--
	3.7	1.12	0.01	3.7	1.12	0.04	--	--
	3.7	1.13	0.01	3.7	1.13	0.04	--	--
	3.7	1.14	0.01	3.7	1.14	0.04	--	--
	3.8	1.15	0.01	3.8	1.15	0.04	--	--
	3.8	1.16	0.01	3.8	1.16	0.03	--	--
	3.8	1.17	0.01	3.8	1.17	0.03	--	--
Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	3.9	1.18	0.01	3.9	1.18	0.03	--	--
	3.9	1.19	0.01	3.9	1.19	0.03	--	--
	3.9	1.20	0.01	3.9	1.20	0.03	--	--
	4.0	1.21	0.01	4.0	1.21	0.03	--	--
	4.0	1.22	0.01	4.0	1.22	0.02	--	--
	4.0	1.23	0.01	4.0	1.23	0.02	--	--
	4.1	1.24	0	4.1	1.24	0.02	--	--
	--	--	--	4.1	1.25	0.02	--	--
	--	--	--	4.1	1.26	0.02	--	--
	--	--	--	4.2	1.27	0.02	--	--
	--	--	--	4.2	1.28	0.02	--	--
	--	--	--	4.2	1.29	0.02	--	--
	--	--	--	4.3	1.30	0.02	--	--
SRHAV	--	--	--	4.3	1.31	0.02	--	--
	--	--	--	4.3	1.32	0.01	--	--
	--	--	--	4.4	1.33	0.01	--	--
	--	--	--	4.4	1.34	0.01	--	--
	--	--	--	4.4	1.34	0.01	--	--
	--	--	--	4.5	1.36	0.01	--	--
	--	--	--	4.5	1.37	0.01	--	--
	--	--	--	4.5	1.38	0.01	--	--
	--	--	--	4.6	1.39	0.01	--	--
	--	--	--	4.6	1.40	0.01	--	--
	--	--	--	4.6	1.41	0.01	--	--
	--	--	--	4.7	1.42	0.01	--	--
	--	--	--	4.7	1.43	0.01	--	--
	--	--	--	4.7	1.44	0.01	--	--
	--	--	--	4.8	1.45	0.01	--	--

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	--	--	--	4.8	1.46	0.01	--	--
	--	--	--	4.8	1.47	0.01	--	--
	--	--	--	4.8	1.48	0.01	--	--
	--	--	--	4.9	1.49	0.01	--	--
	--	--	--	4.9	1.50	0	--	--
	--	--	--	5.3	1.63	0	--	--
SHSLO	0.00	0.00	0	0.00	0.00	0	1	0
	0.33	0.10	1	0.10	0.03	1	2	0
	1.00	0.31	1	2.00	0.61	1	3	1
	1.00	0.31	0	2.03	0.62	0	4	1
	--	--	--	--	--	--	5	1
	--	--	--	--	--	--	6	1
	--	--	--	--	--	--	7	0
	--	--	--	--	--	--	8	0
	--	--	--	--	--	--	9	1
	--	--	--	--	--	--	10	1
	--	--	--	--	--	--	11	1
	--	--	--	--	--	--	12	1
	--	--	--	--	--	--	13	1
	--	--	--	--	--	--	14	1
	--	--	--	--	--	--	15	1
	--	--	--	--	--	--	16	1
	--	--	--	--	--	--	17	0
	--	--	--	--	--	--	18	0
SHFST	0.00	0.00	0	0.00	0.00	0	1	0
	0.76	0.23	0.3	0.15	0.05	0.1	2	0
	1.50	0.46	1	0.25	0.08	0.8	3	0.75
	2.50	0.76	1	0.35	0.11	1	4	1
	3.50	1.07	0.4	1.20	0.37	1	5	0
	3.80	1.16	0.2	1.50	0.46	0.75	6	0
	4.00	1.22	0	2.00	0.61	0.3	7	0
	--	--	--	2.50	0.76	0.1	8	0.5
	--	--	--	6.00	1.83	0	9	0.75
	--	--	--	--	--	--	10	1
	--	--	--	--	--	--	11	0
	--	--	--	--	--	--	12	1
	--	--	--	--	--	--	13	0
	--	--	--	--	--	--	14	1
	--	--	--	--	--	--	15	0
	--	--	--	--	--	--	16	0.75
	--	--	--	--	--	--	17	0
	--	--	--	--	--	--	18	0

Table 3. Deep Guild HSC Table

Lifestage	Velocity (ft/s)	Velocit y (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
RBSFA	0.0	0.00	1.00	0.0	0.00	0.00	1	0.1
	0.8	0.23	1.00	0.2	0.06	0.00	2	0.3
	1.5	0.46	0.30	1.2	0.37	0.80	3	0.7
	3.0	0.91	0.00	2.0	0.61	1.00	4	0.8
	--	--	--	6.0	1.83	1.00	5	0.7
	--	--	--	7.5	2.29	0.60	6	0.3
	--	--	--	8.2	2.50	0.00	7	0.1
	--	--	--	--	--	--	8	0.8
	--	--	--	--	--	--	9	1
	--	--	--	--	--	--	10	0.8
	--	--	--	--	--	--	11	1
	--	--	--	--	--	--	12	0.8
	--	--	--	--	--	--	13	1
	--	--	--	--	--	--	14	0.9
	--	--	--	--	--	--	15	1
	--	--	--	--	--	--	16	0.85
	--	--	--	--	--	--	17	0.65
	--	--	--	--	--	--	18	0
DSLON	0.0	0.00	1.00	0.0	0.00	0.00	1	1
	1.0	0.31	1.00	2.0	0.61	0.00	2	1
	1.0	0.31	0.00	2.0	0.61	1.00	3	1
	2.0	0.61	0.00	10.0	3.05	1.00	4	1
	--	--	--	--	--	--	5	1
	--	--	--	--	--	--	6	1
	--	--	--	--	--	--	7	1
	--	--	--	--	--	--	8	0
	--	--	--	--	--	--	9	0
	--	--	--	--	--	--	10	0
	--	--	--	--	--	--	11	0
	--	--	--	--	--	--	12	0
DSLON	--	--	--	--	--	--	13	0
	--	--	--	--	--	--	14	0.5
	--	--	--	--	--	--	15	0.5
	--	--	--	--	--	--	16	0
	--	--	--	--	--	--	17	0
	--	--	--	--	--	--	18	0
SRHAD	0.0	0.00	0.00	0.0	0.00	0.00	1	0.1
	0.1	0.04	0.51	1.5	0.46	0.00	2	0.45
	0.4	0.12	0.62	2.4	0.73	0.57	3	0.65
	0.6	0.20	0.82	3.3	1.02	0.91	4	0.475
	0.8	0.24	1.00	3.8	1.16	1.00	5	0.35
	1.0	0.32	1.00	4.8	1.45	1.00	6	0.48
	1.2	0.36	0.91	5.2	1.59	1.00	7	0.34
	1.4	0.44	0.6	6.2	1.88	1	8	0.55
	1.7	0.52	0.27	7.1	2.18	1	9	0.82
	2.0	0.60	0.08	8.1	2.47	1	10	0.75
	2.2	0.68	0.02	9.0	2.76	1	11	0.75
	2.4	0.719	0	9.5	2.90	1	12	0.75
	--	--	--	15.0	4.56	1	13	0.75
	--	--	--	--	--	--	14	0.75
	--	--	--	--	--	--	15	0.75
	--	--	--	--	--	--	16	0.82
	--	--	--	--	--	--	17	0.75
	--	--	--	--	--	--	18	0
SHRHA	0.0	0.00	0.37	0.0	0.00	0.00	1	0.2
	0.4	0.12	0.48	0.4	0.12	0.00	2	0.38

Lifestage	Velocity (ft/s)	Velocity (m/s)	Suitability Index	Depth (ft)	Depth (m)	Suitability Index	Channel Index	Suitability Index
	0.8	0.24	0.59	0.8	0.24	0.06	3	0.7
	1.2	0.37	0.70	1.0	0.31	0.14	4	0.75
	1.6	0.49	0.80	1.2	0.37	0.26	5	0.5
	2.0	0.61	0.89	1.4	0.43	0.41	6	0.55
	2.4	0.73	0.95	1.6	0.49	0.56	7	0.3
	2.8	0.85	0.99	1.8	0.55	0.7	8	0.45
	3.2	0.98	1	2.0	0.61	0.81	9	0.7
	3.6	1.10	0.97	2.2	0.67	0.9	10	0.75
	4.0	1.22	0.91	2.4	0.73	0.96	11	0.62
	4.2	1.28	0.86	2.6	0.79	0.99	12	0.75
	4.4	1.34	0.8	2.8	0.85	1	13	0.78
	4.6	1.40	0.71	5	1.52	1	14	0.75
	4.8	1.46	0.58	12	3.66	1	15	0.78
	4.9	1.49	0.47	13	3.96	0.11	16	0.85
	5.0	1.51	0.36	14	4.27	0.09	17	0.7
	5.0	1.52	0.16	15	4.57	0.07	18	0
	5.0	1.52	0	17	5.18	0.05	--	--
	--	--	--	19	5.79	0.03	--	--
	--	--	--	24	7.32	0.01	--	--
	--	--	--	28	8.53	0	--	--

Table 4. Target Species Habitat and Suitability Criteria Source and Code Table

Species	Lifestage/ Category	Representative	Source Study	HSC Code
Walleye	Fry	--	Sutton Hydroelectric Project, Elk River, WV	WLEF
	Juvenile	--	Sutton Hydroelectric Project, Elk River, WV	WLEJ
	Adult	--	Sutton Hydroelectric Project, Elk River, WV	WLEA
	Spawning	--	Sutton Hydroelectric Project, Elk River, WV	WLES
Shallow-Slow Guild	Fine substrate, no cover	Redbreast Sunfish spawning	Smith Mountain Hydroelectric Project, Roanoke River, VA	RBSFS
	All substrate with aquatic vegetation	Silver Redhorse young-of-year	Sutton Hydroelectric Project, Elk River, WV	SRHAV
	Coarse substrate	Generic Shallow-Slow Guild	Sutton Hydroelectric Project, Elk River, WV	SHSLO
Shallow-Fast Guild	Moderate velocity with coarse substrate	Generic Shallow-Fast Guild	Claytor Hydroelectric Project New River, VA	SHFST
Deep-Slow Guild	Cover	Redbreast Sunfish adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	RBSFA
	No cover	Generic Deep-Slow Guild	Sutton Hydroelectric Project, Elk River, WV	DSLON
Deep-Fast Guild	Slightly weighted for fine substrate, Cover	Silver Redhorse adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	SRHAD
	Coarse-mixed substrate	Shorthead Redhorse adult	Smith Mountain Hydroelectric Project, Roanoke River, VA	SHRHA

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Attachment 3

Attachment 3 – Combined Habitat Suitability Maps

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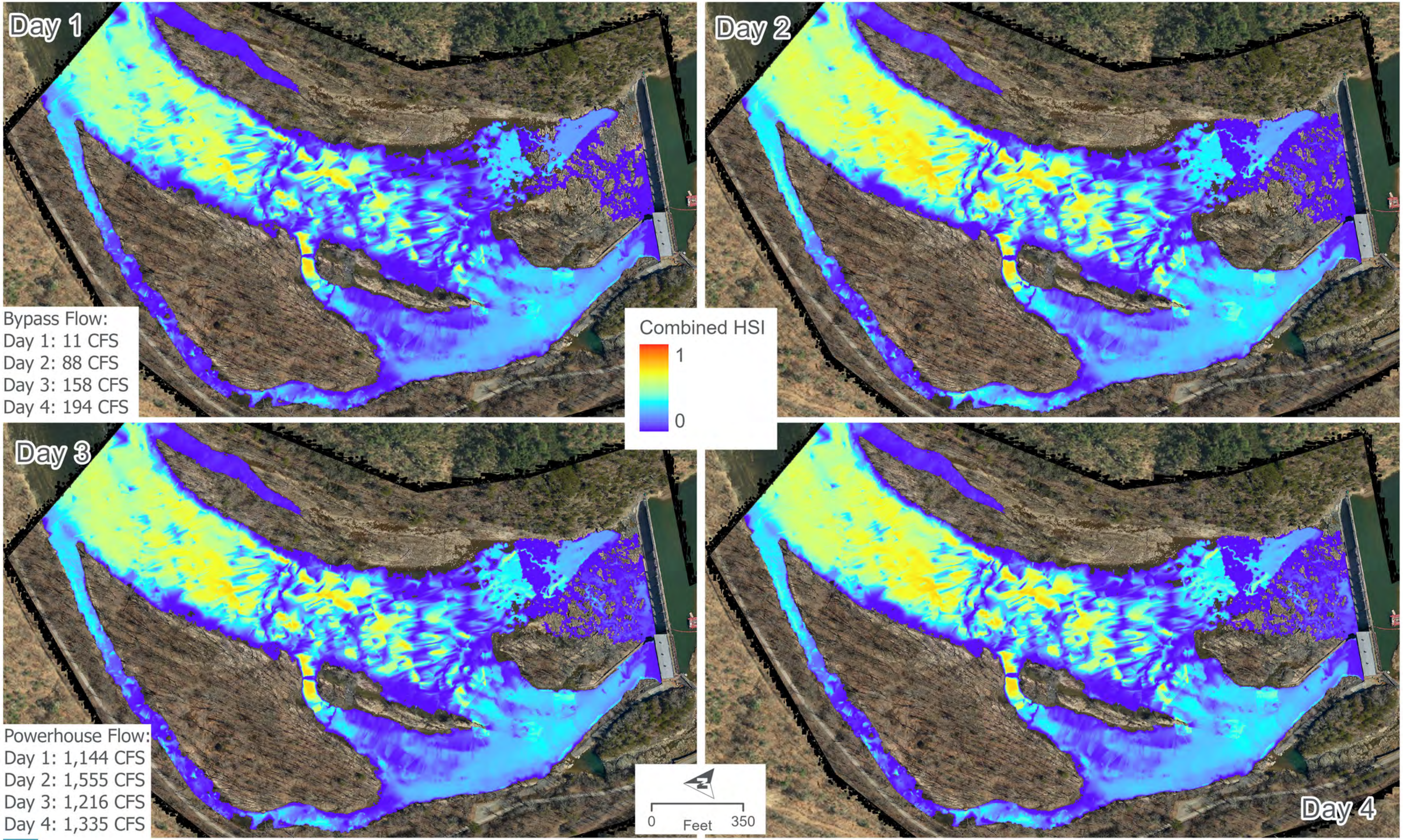
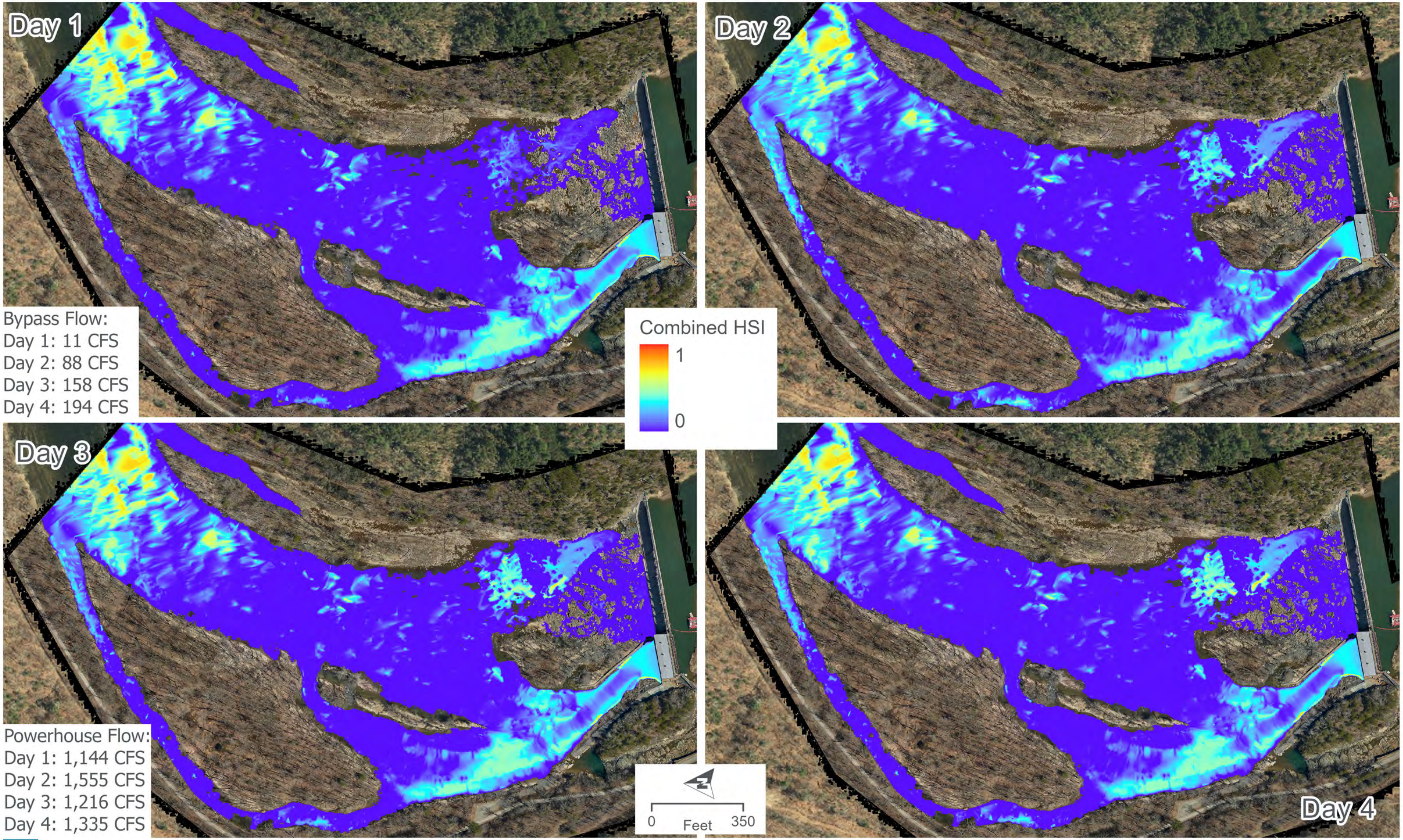


DEEP-FAST GUILD HABITAT SUITABILITY MAP

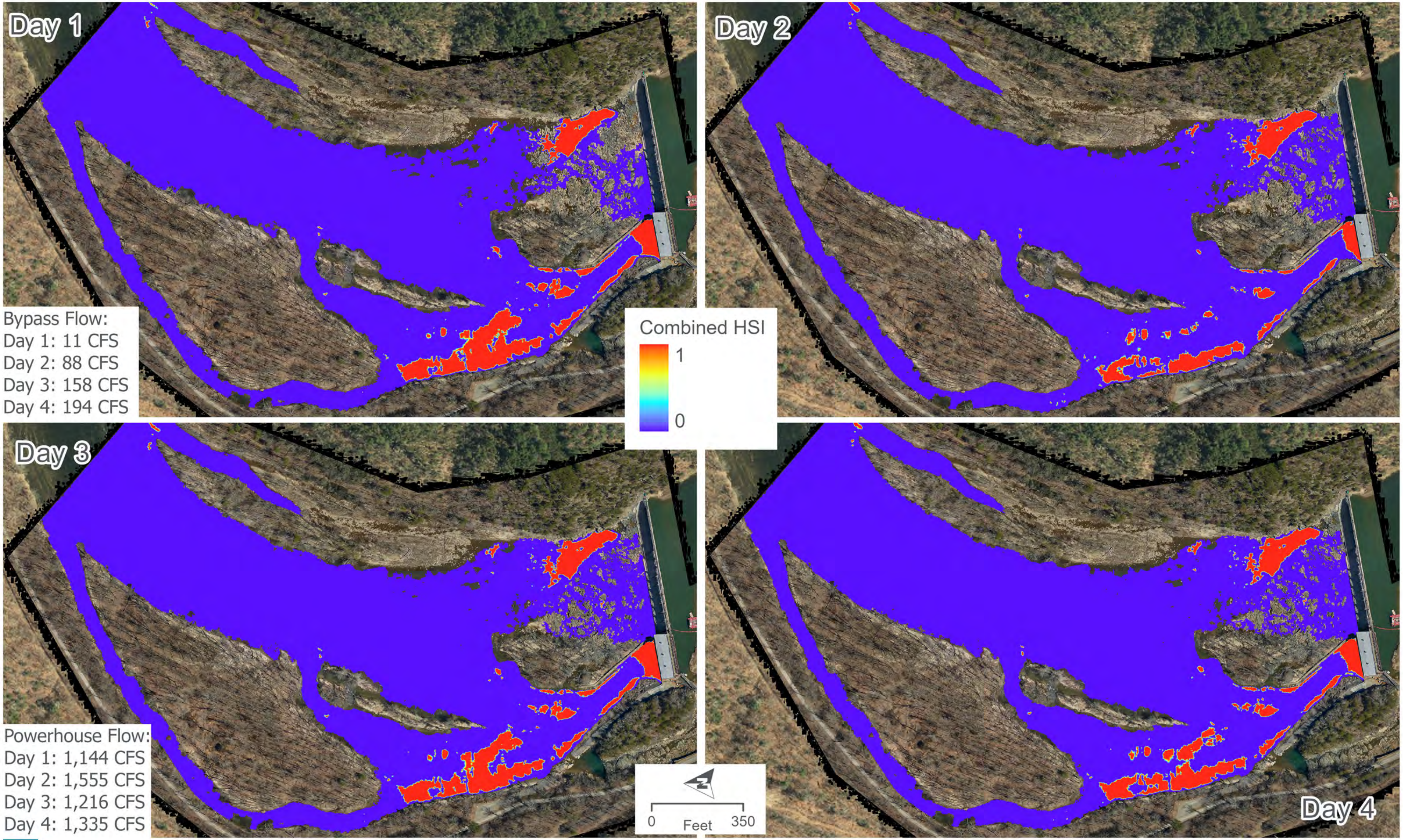
CATEGORY: COARSE-MIXED SUBSTRATE



DEEP-FAST GUILD HABITAT SUITABILITY MAP

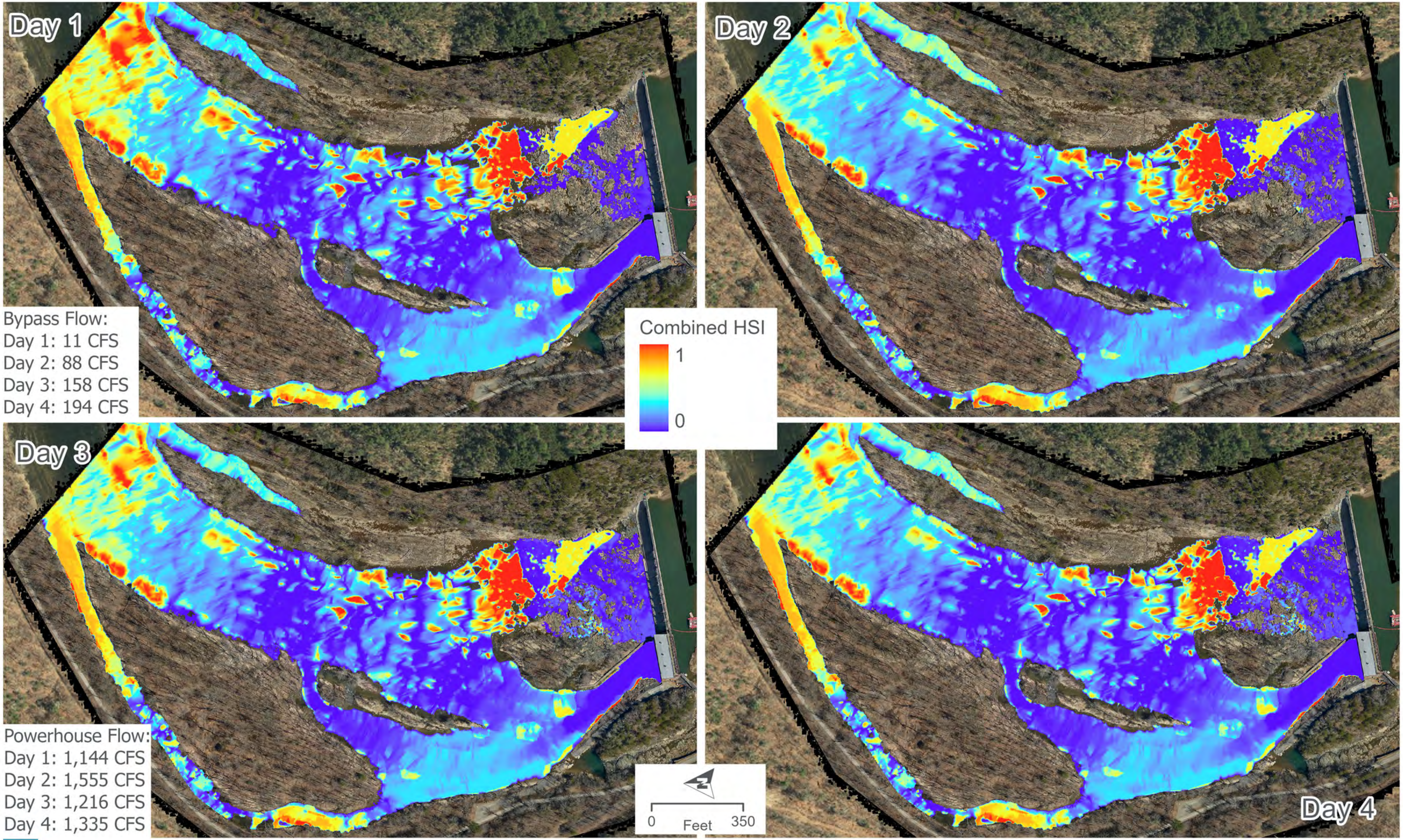
CATEGORY: SLIGHTLY WEIGHTED FOR FINE SUBSTRATE, COVER

PATH: F:\AEP\RELICENSING_2D_MODELS\BYLLESBY\HABITAT\MAPS\BYLL_HABITAT_MAPS.APRX - USER: JDVORAK - DATE: 11/12/2021



GENERIC DEEP-SLOW GUILD HABITAT SUITABILITY MAP

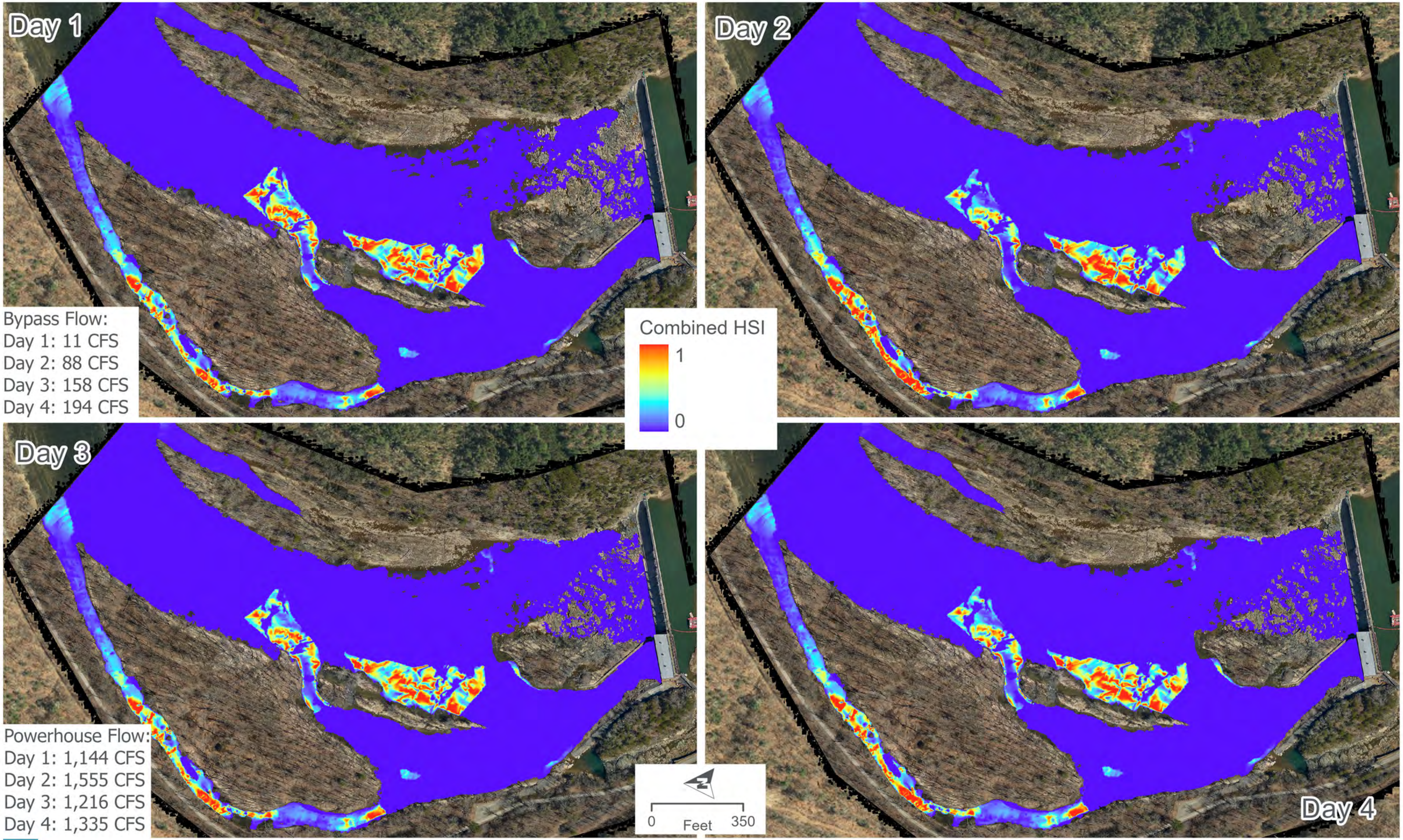
CATEGORY: NO COVER



DEEP-SLOW GUILD HABITAT SUITABILITY MAP

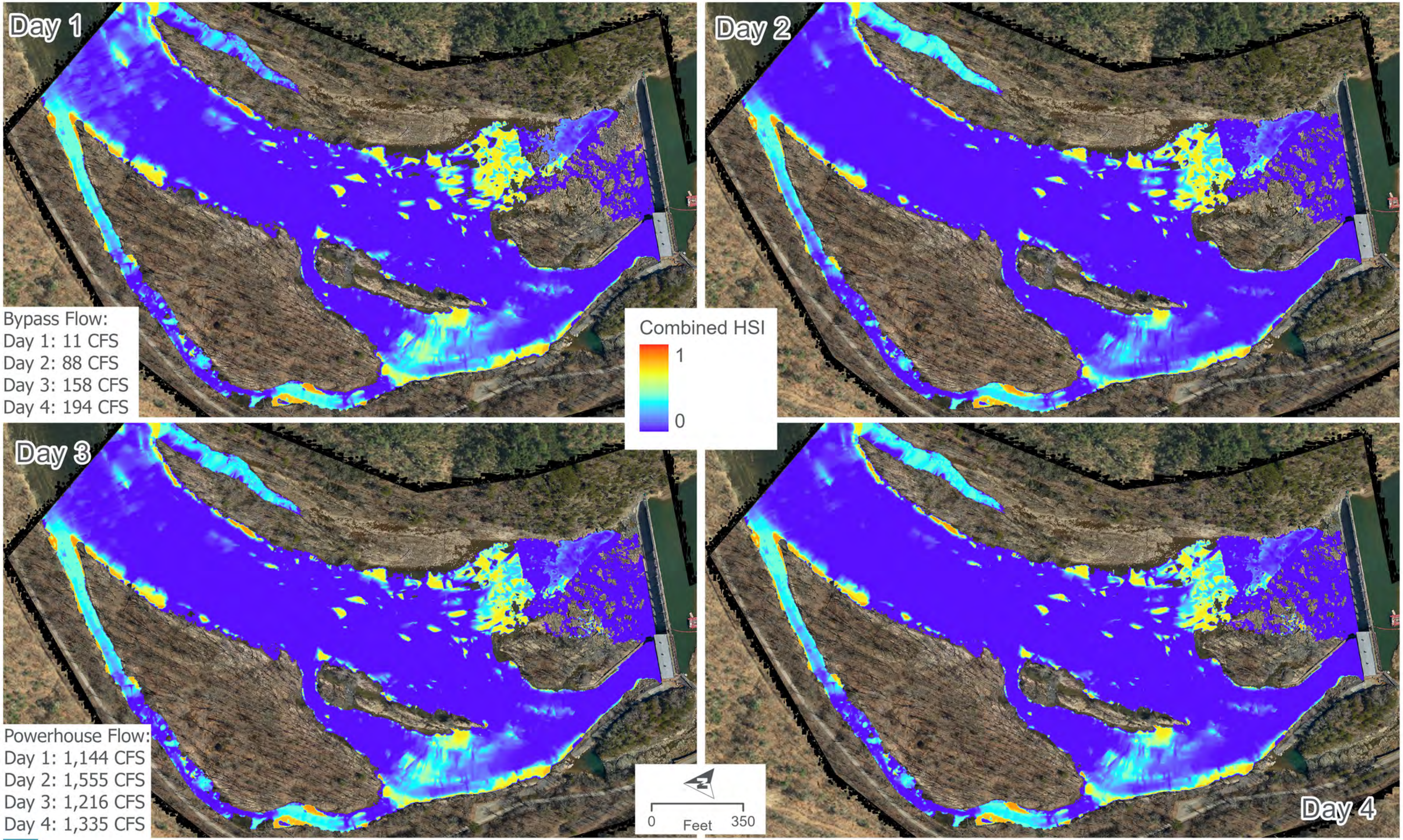
CATEGORY: COVER

PATH: F:\AEP\RELICENSING_2D_MODELS\BYLLESBY\HABITAT\MAPS\BYLL_HABITAT_MAPS.APRX - USER: JDVORAK - DATE: 11/8/2021



SHALLOW-FAST GUILD HABITAT SUITABILITY MAP

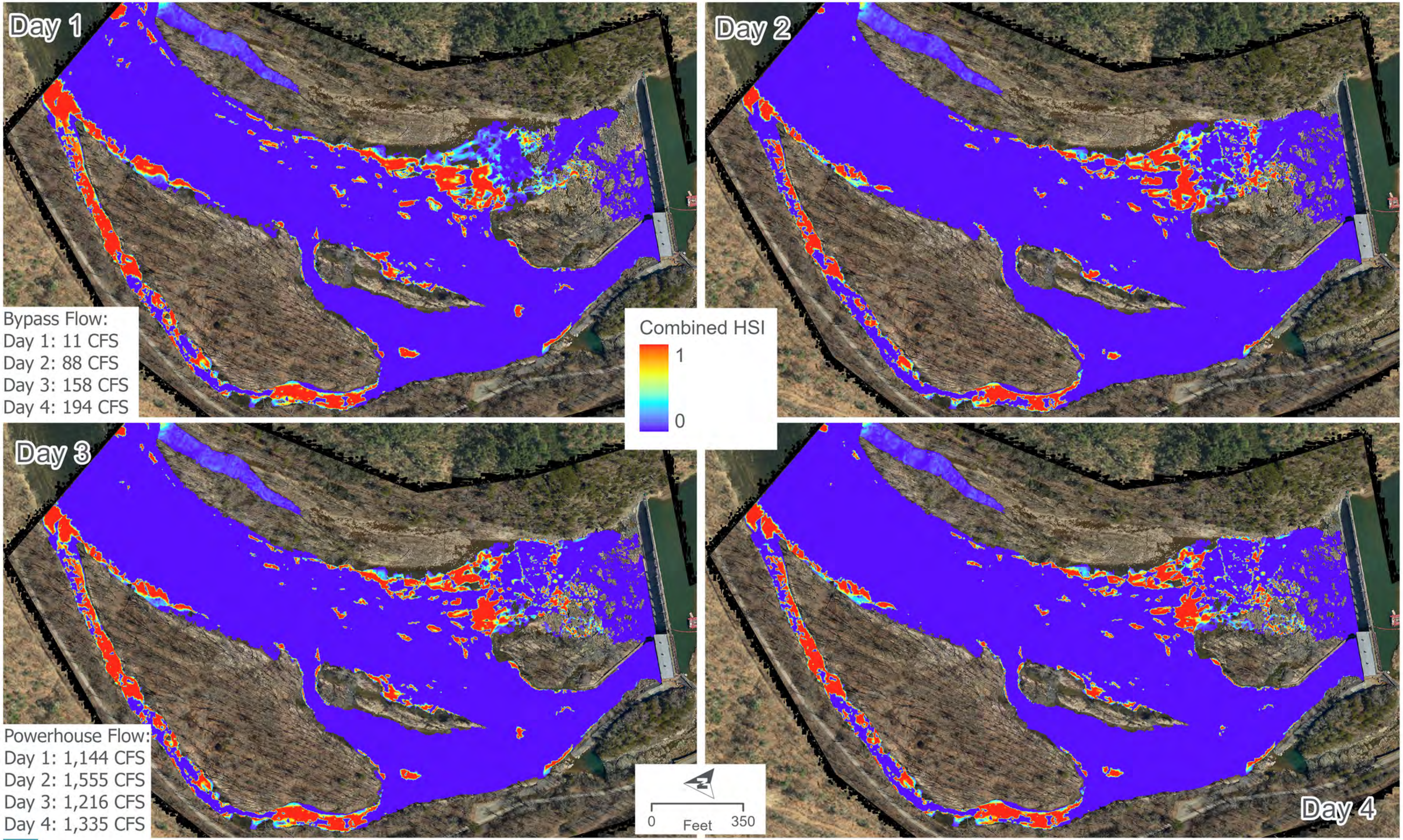
CATEGORY: MODERATE VELOCITY WITH COARSE SUBSTRATE



SHALLOW-SLOW GUILD HABITAT SUITABILITY MAP

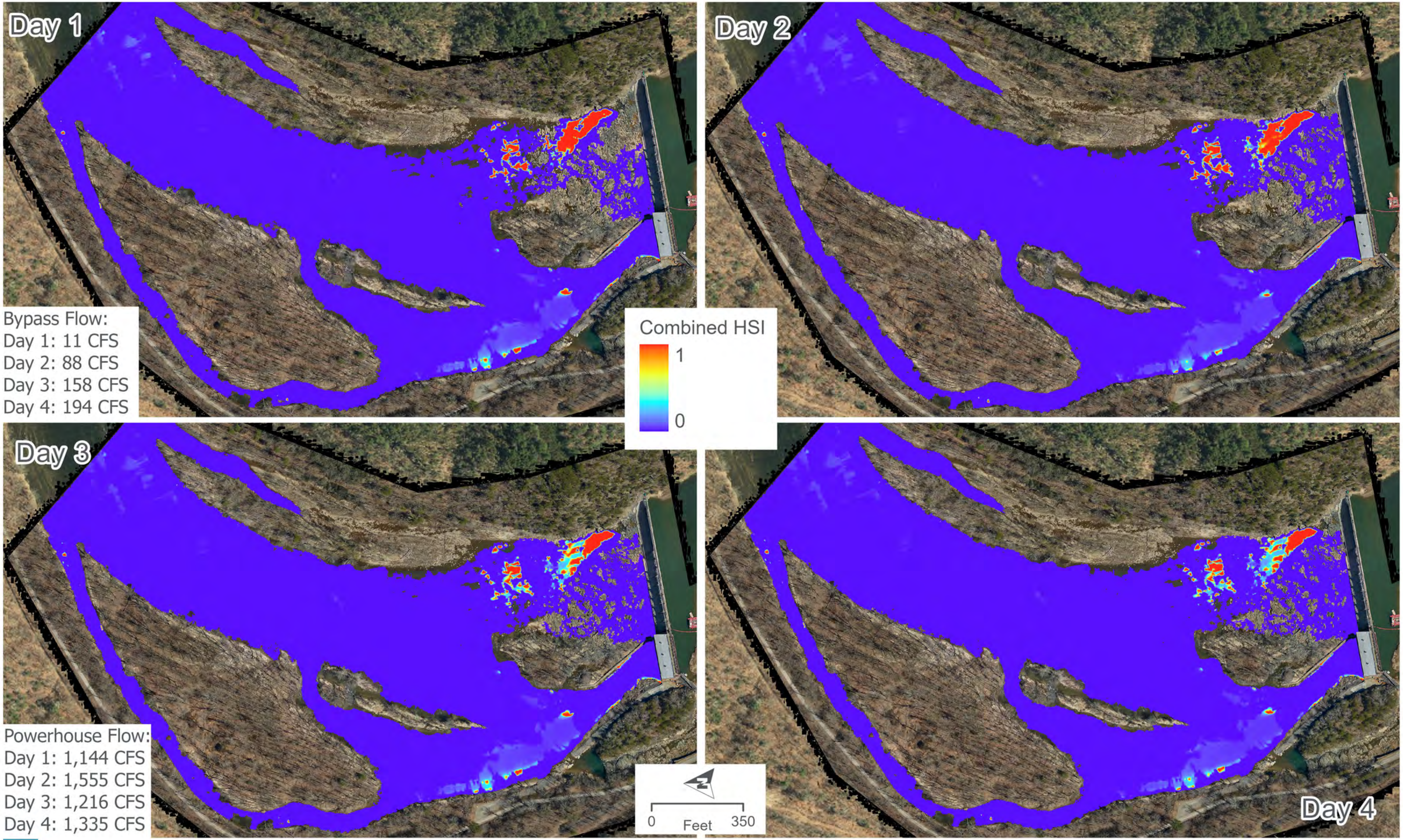
CATEGORY: FINE SUBSTRATE NO COVER

PATH: F:\AEP\RELICENSING_2D_MODELS\BYLLESBY\HABITAT\MAPS\BYLL_HABITAT_MAPS.APRX - USER: JDVORAK - DATE: 11/8/2021



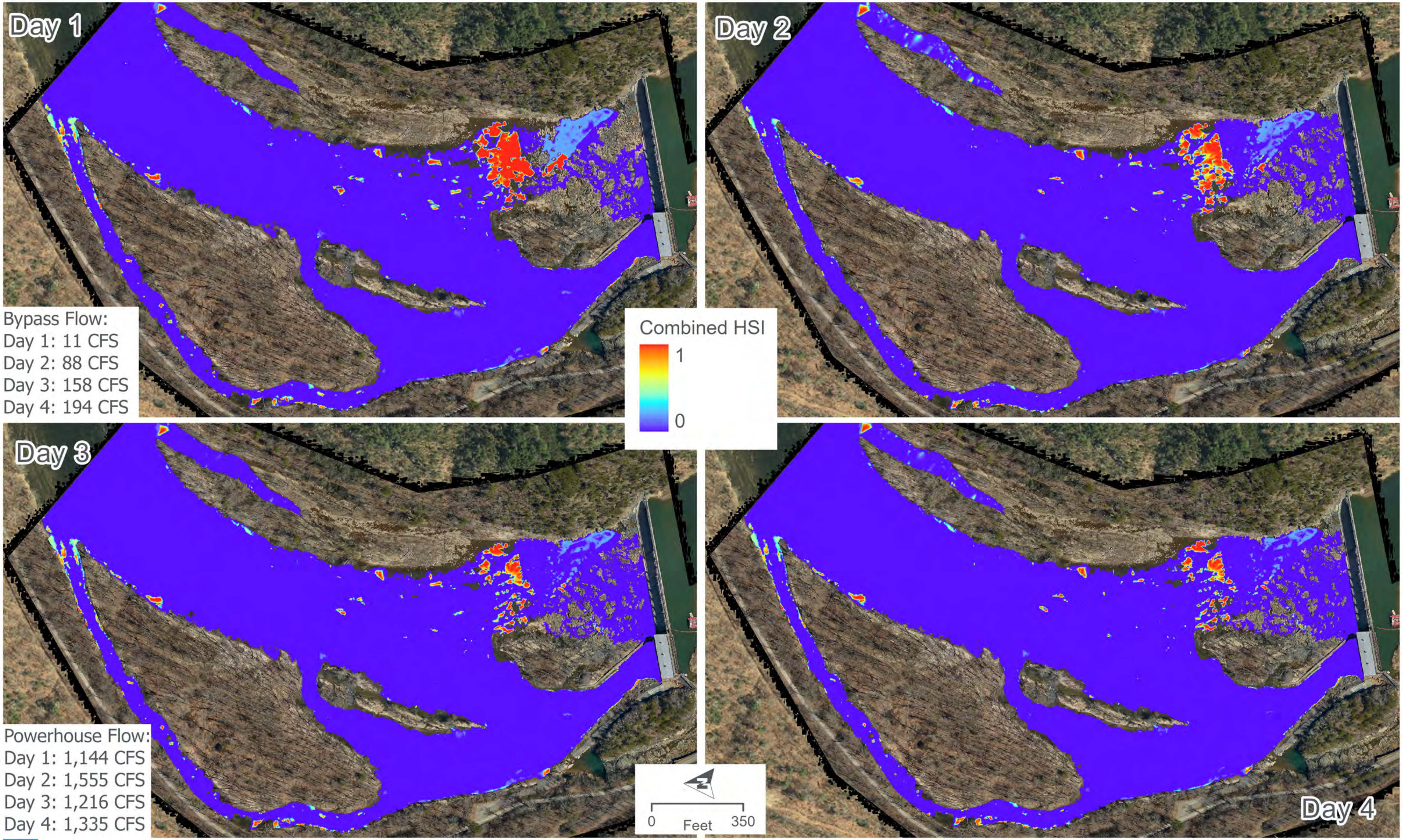
GENERIC SHALLOW-SLOW GUILD HABITAT SUITABILITY MAP

CATEGORY: COARSE SUBSTRATE



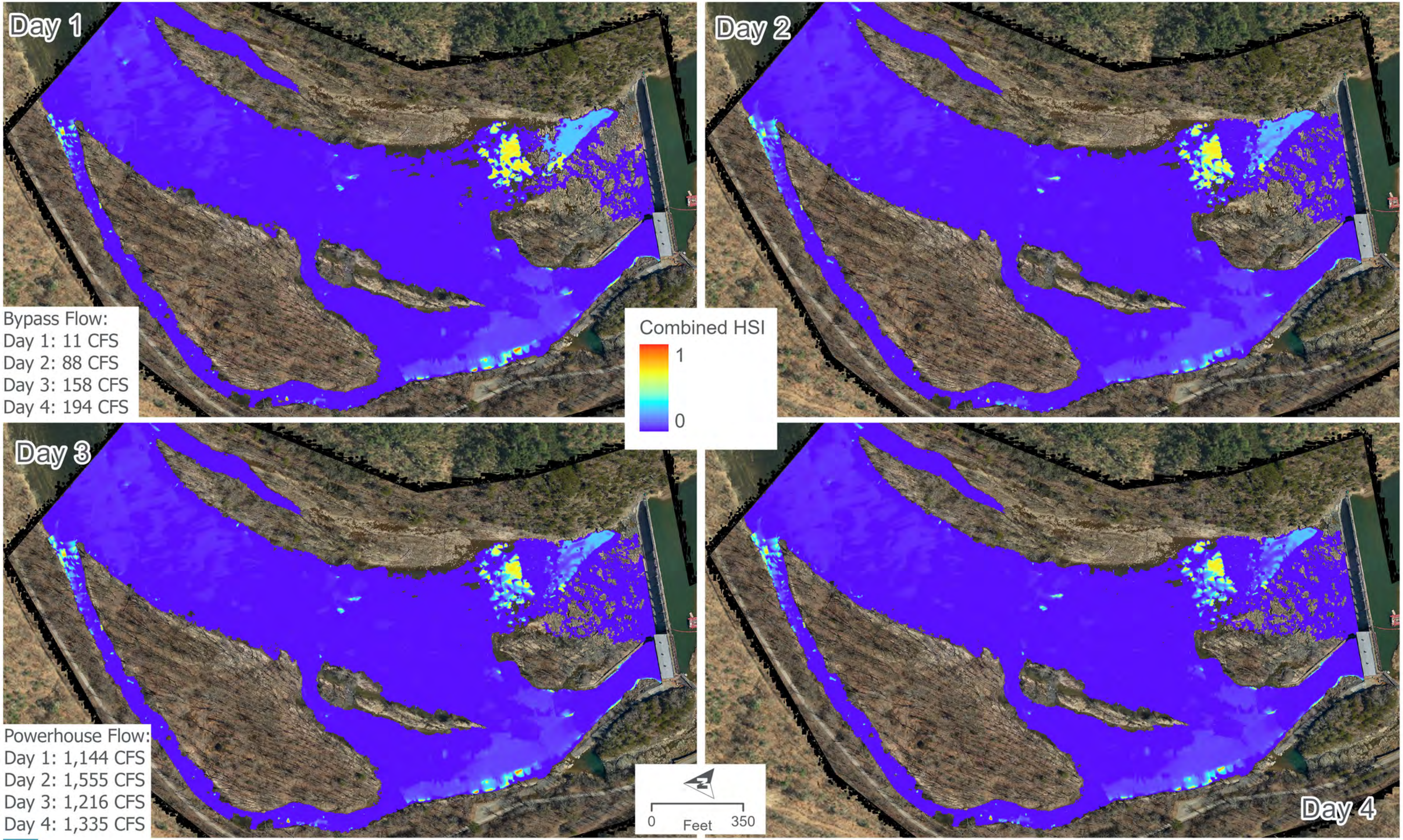
WALLEYE HABITAT SUITABILITY MAP

LIFESTAGE: ADULT



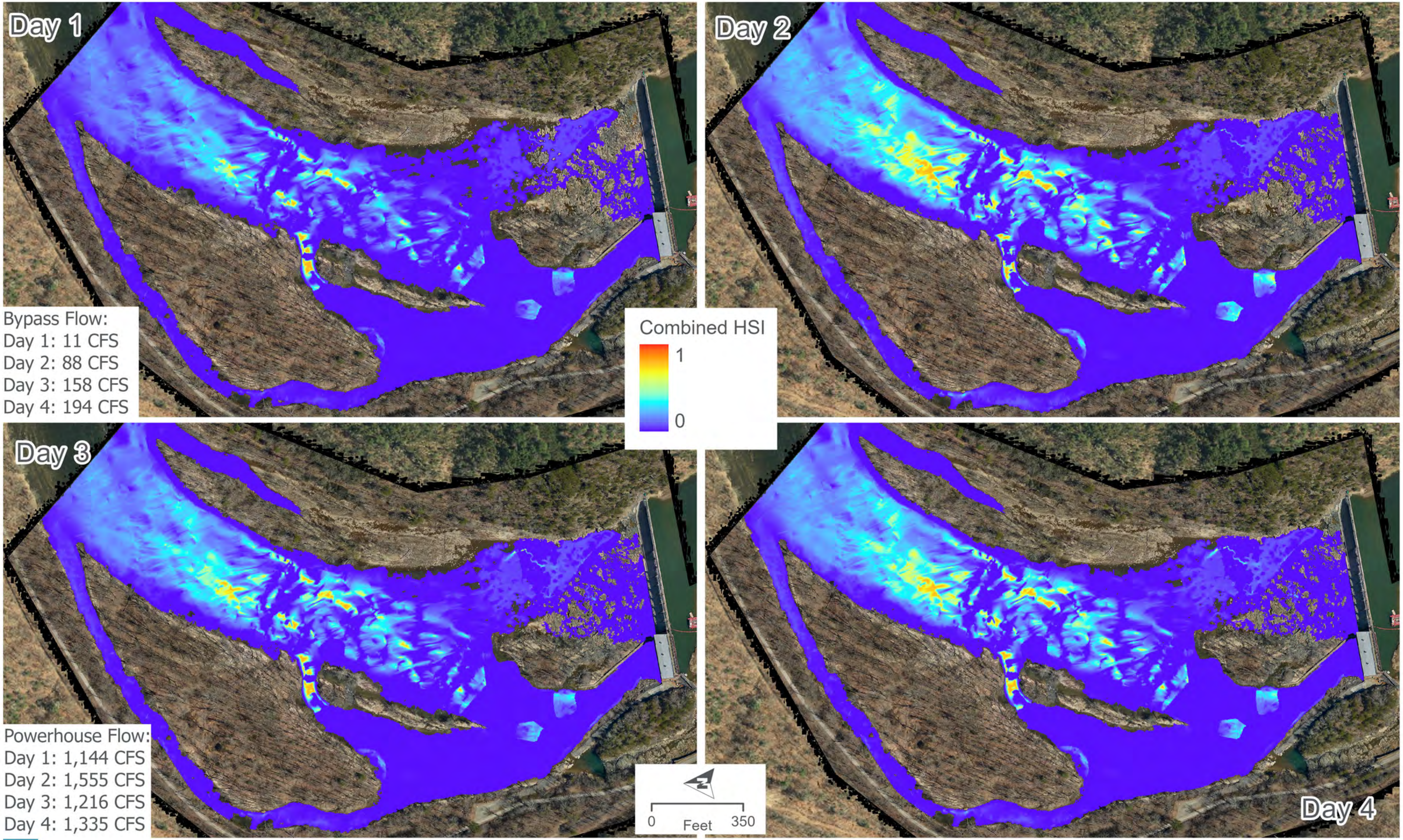
WALLEYE HABITAT SUITABILITY MAP

LIFESTAGE: FRY



WALLEYE HABITAT SUITABILITY MAP

LIFESTAGE: JUVENILE

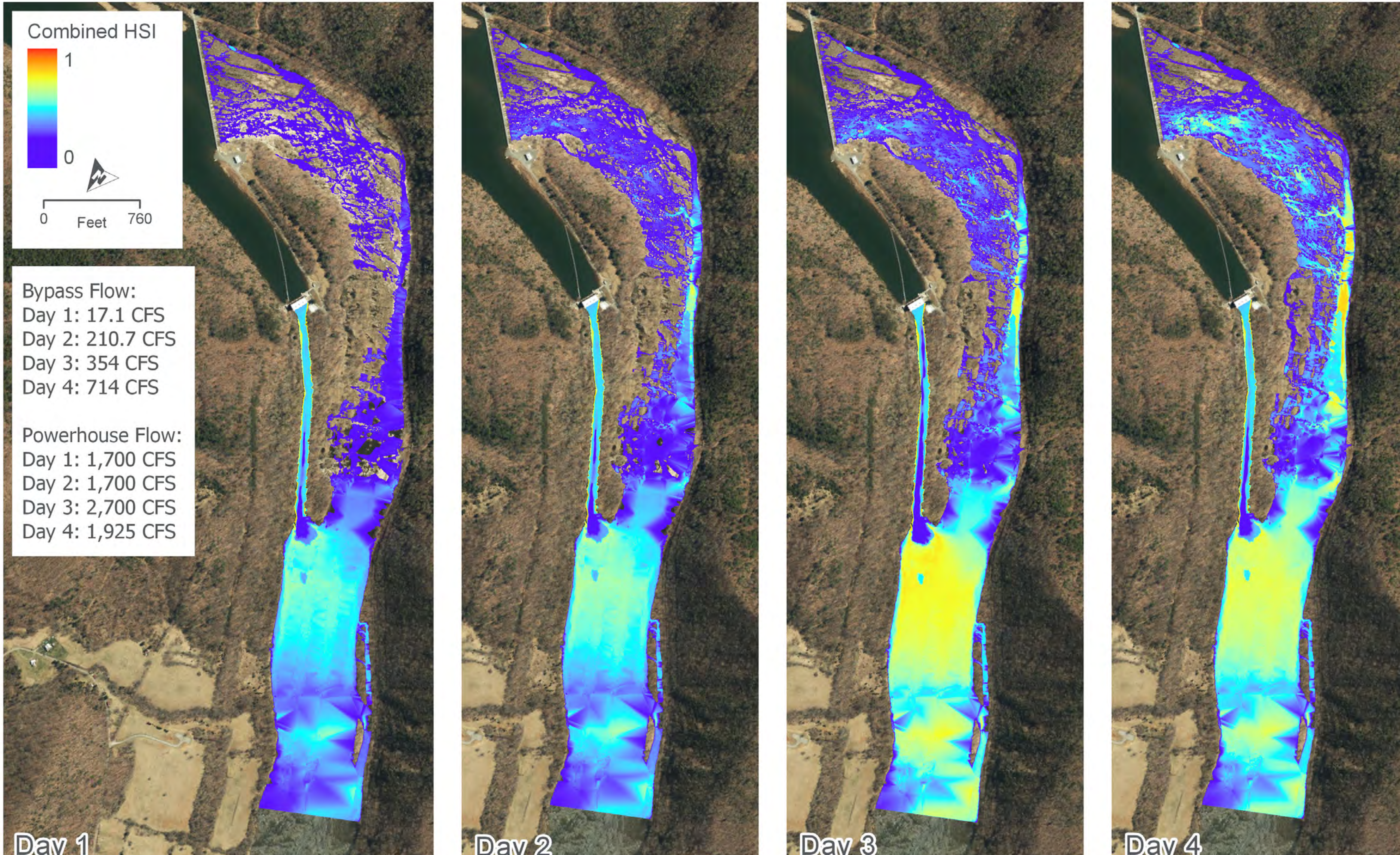


HDR AMERICAN ELECTRIC POWER

WALLEYE HABITAT SUITABILITY MAP

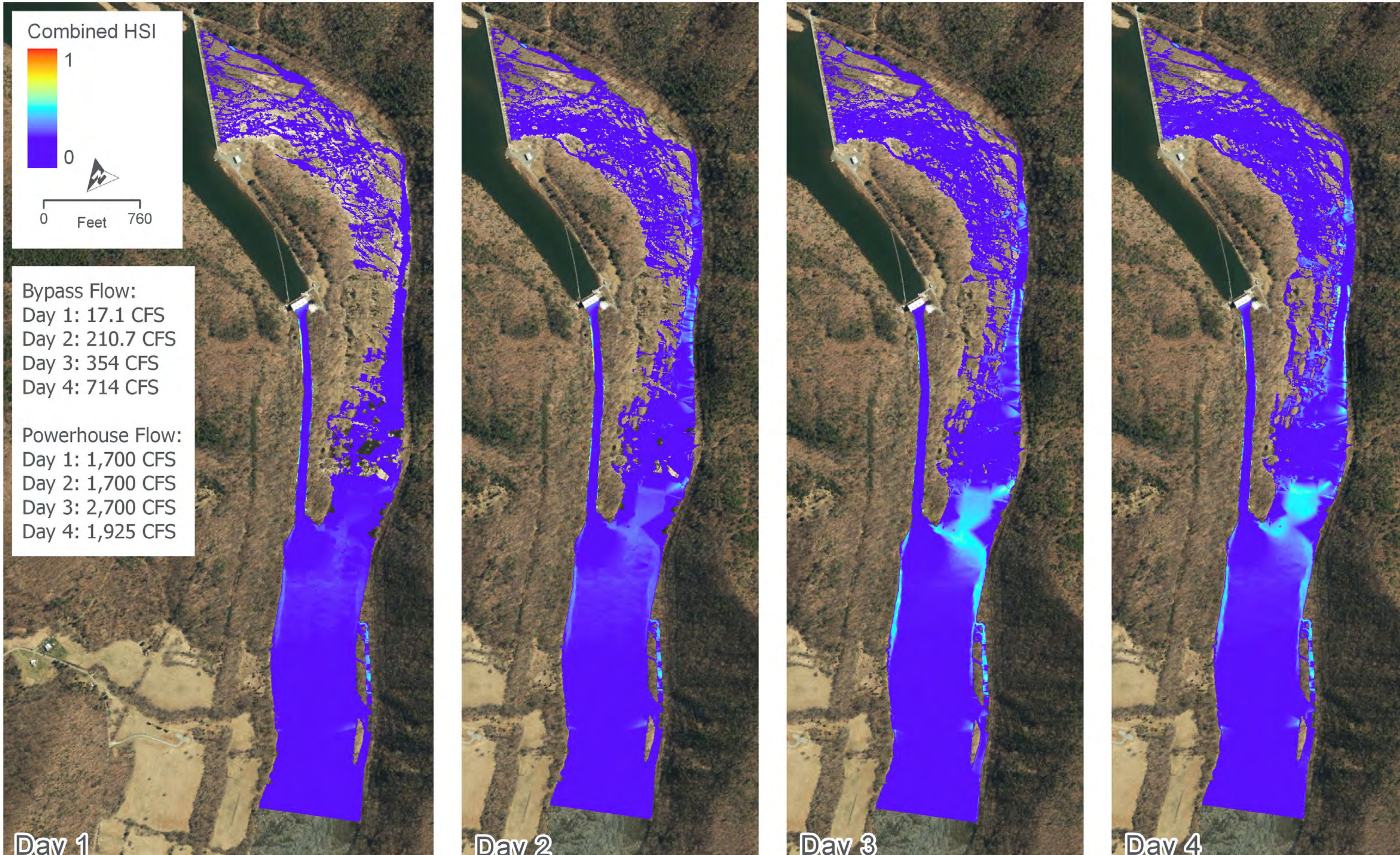
LIFESTAGE: SPAWNING

PATH: F:\AEP\RELICENSING_2D_MODELS\BYLLESBY\HABITAT\MAPS\BYLL_HABITAT_MAPS.APRX - USER: JDVORAK - DATE: 11/8/2021



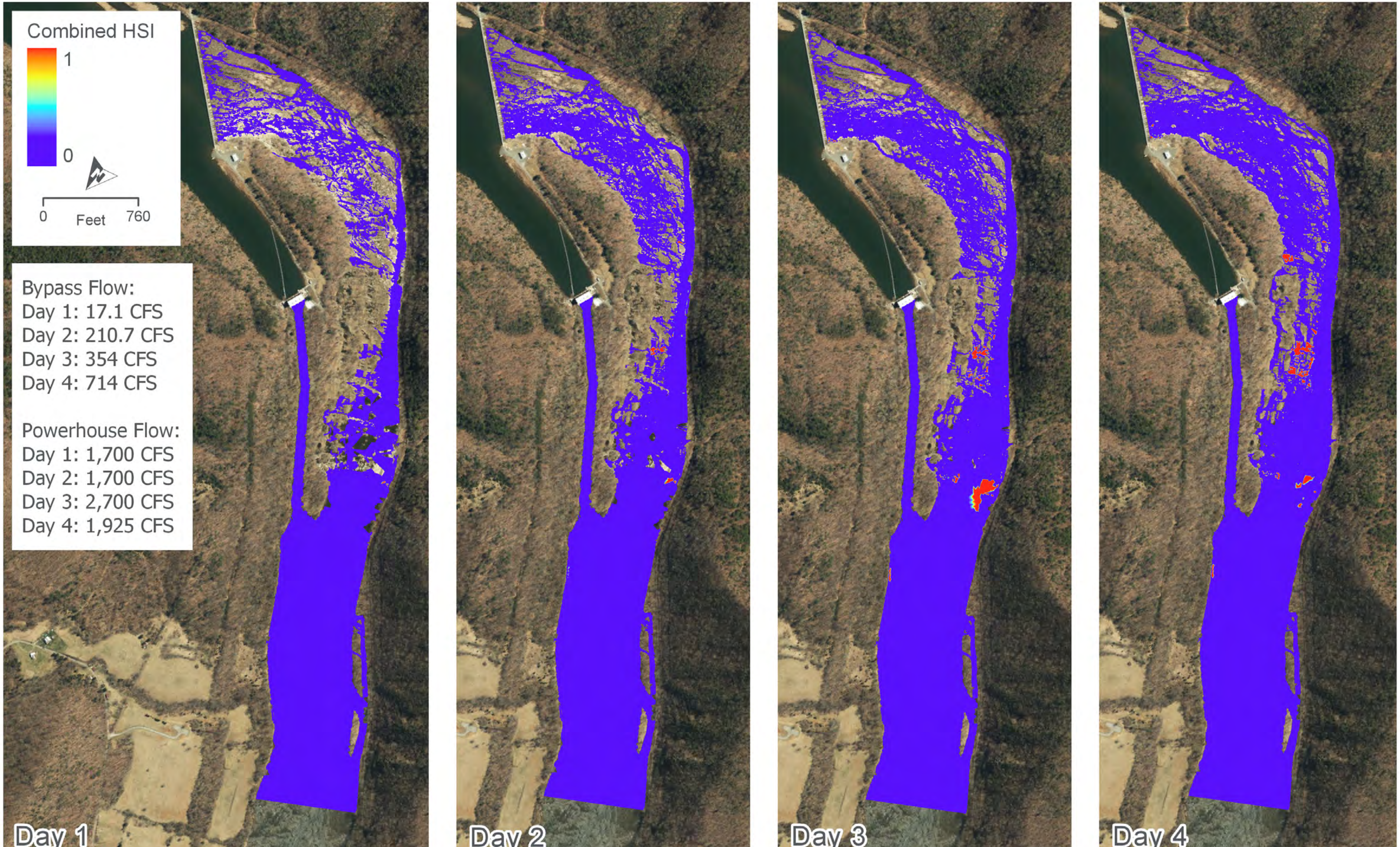
DEEP-FAST GUILD HABITAT SUITABILITY MAP

CATEGORY: COARSE-MIXED SUBSTRATE



DEEP-FAST GUILD HABITAT SUITABILITY MAP

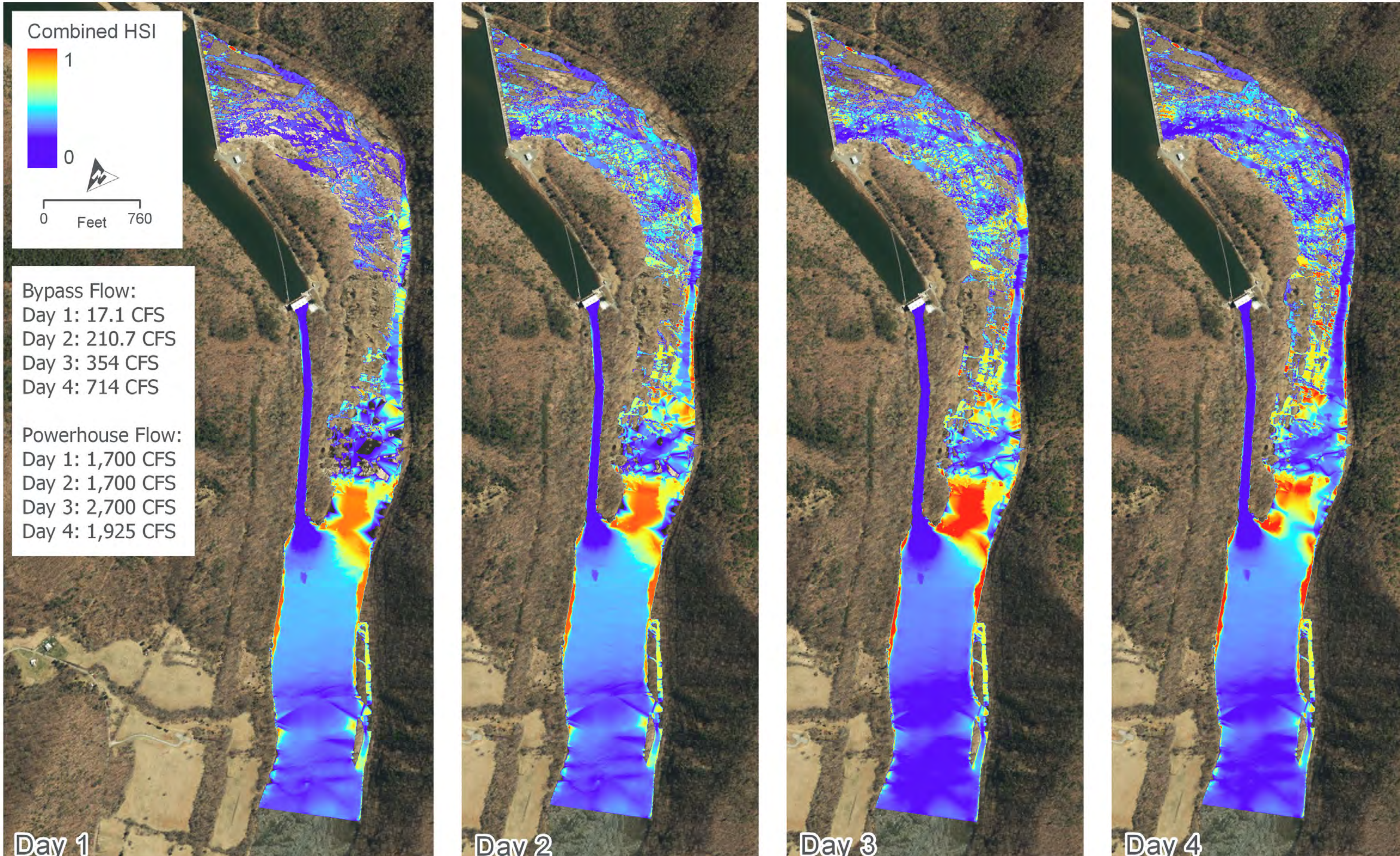
CATEGORY: SLIGHTLY WEIGHTED FOR FINE SUBSTRATE, NO COVER



DEEP-SLOW GUILD HABITAT SUITABILITY MAP

CATEGORY: NO COVER

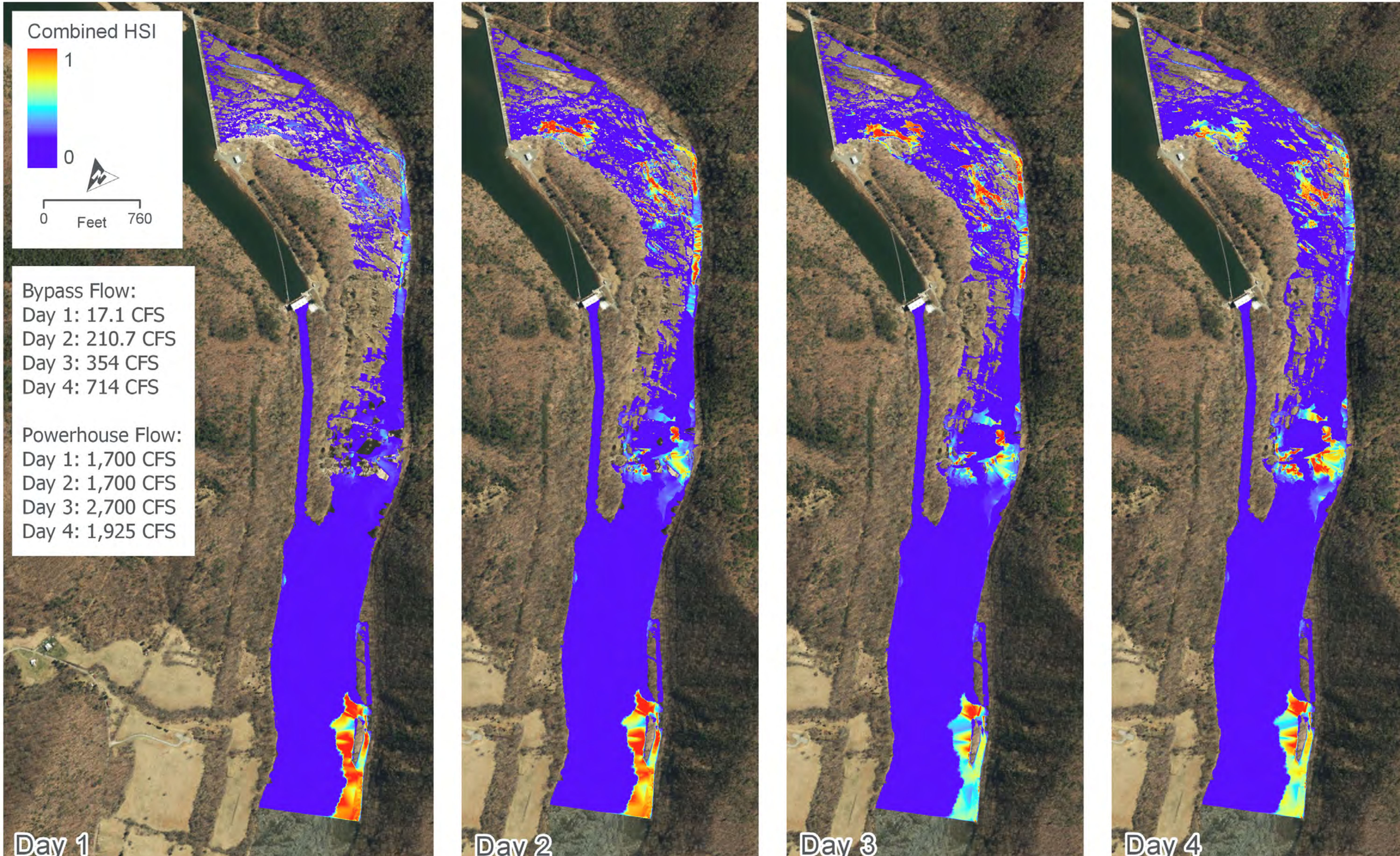
HDR AMERICAN ELECTRIC POWER



HDR AMERICAN ELECTRIC POWER

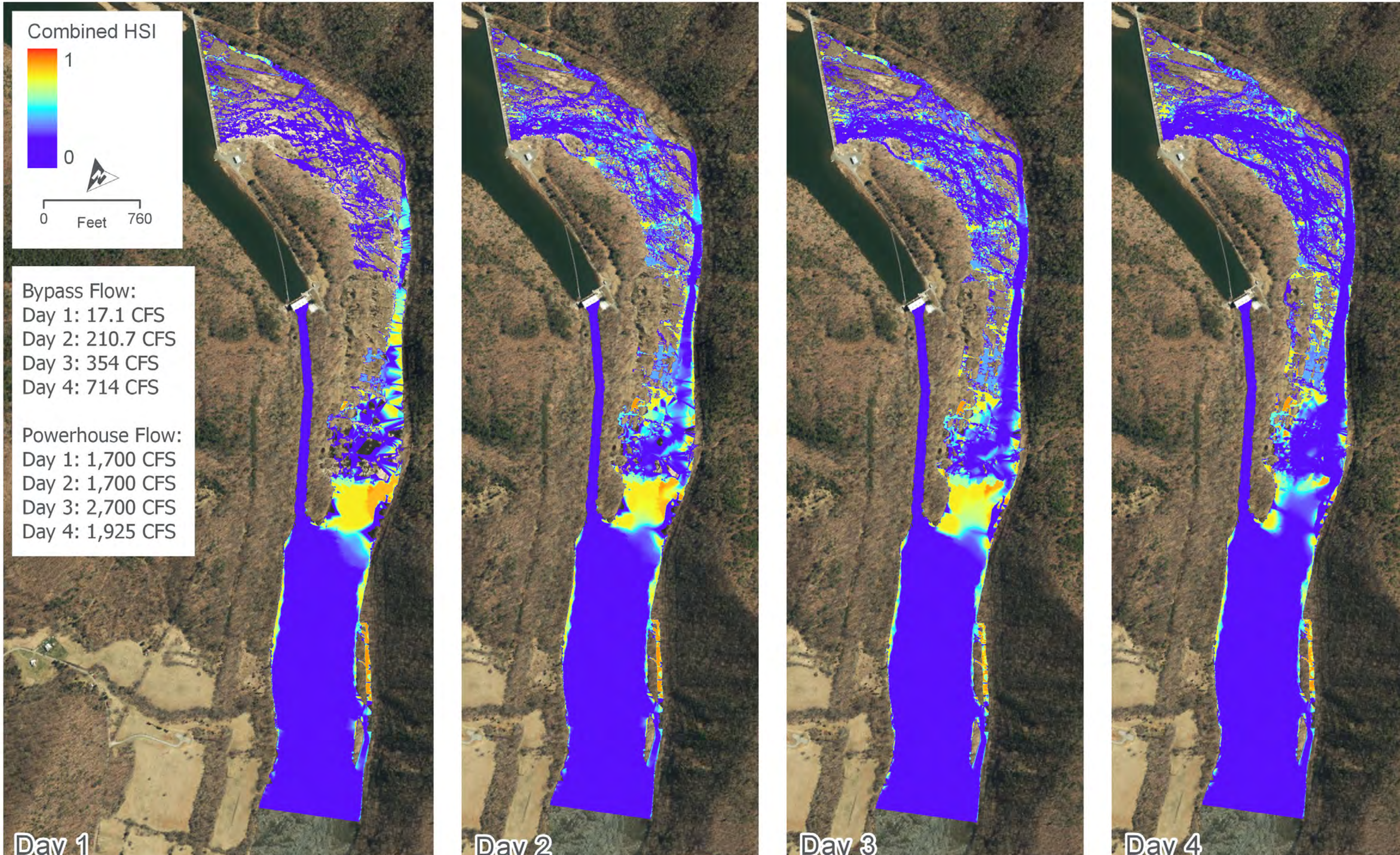
DEEP-SLOW GUILD HABITAT SUITABILITY MAP

CATEGORY: COVER



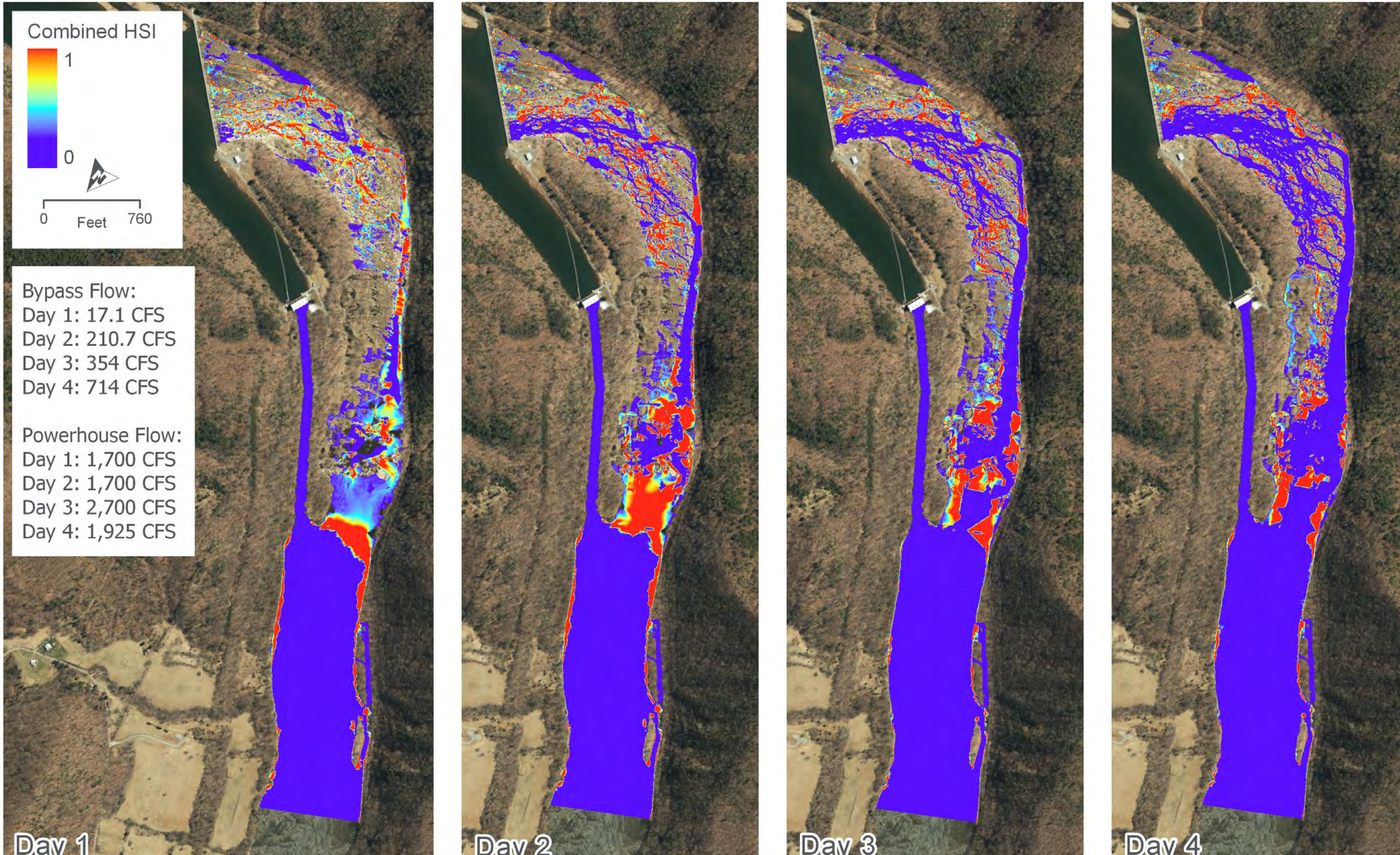
SHALLOW-FAST GUILD HABITAT SUITABILITY MAP

CATEGORY: MODERATE VELOCITY WITH COARSE SUBSTRATE



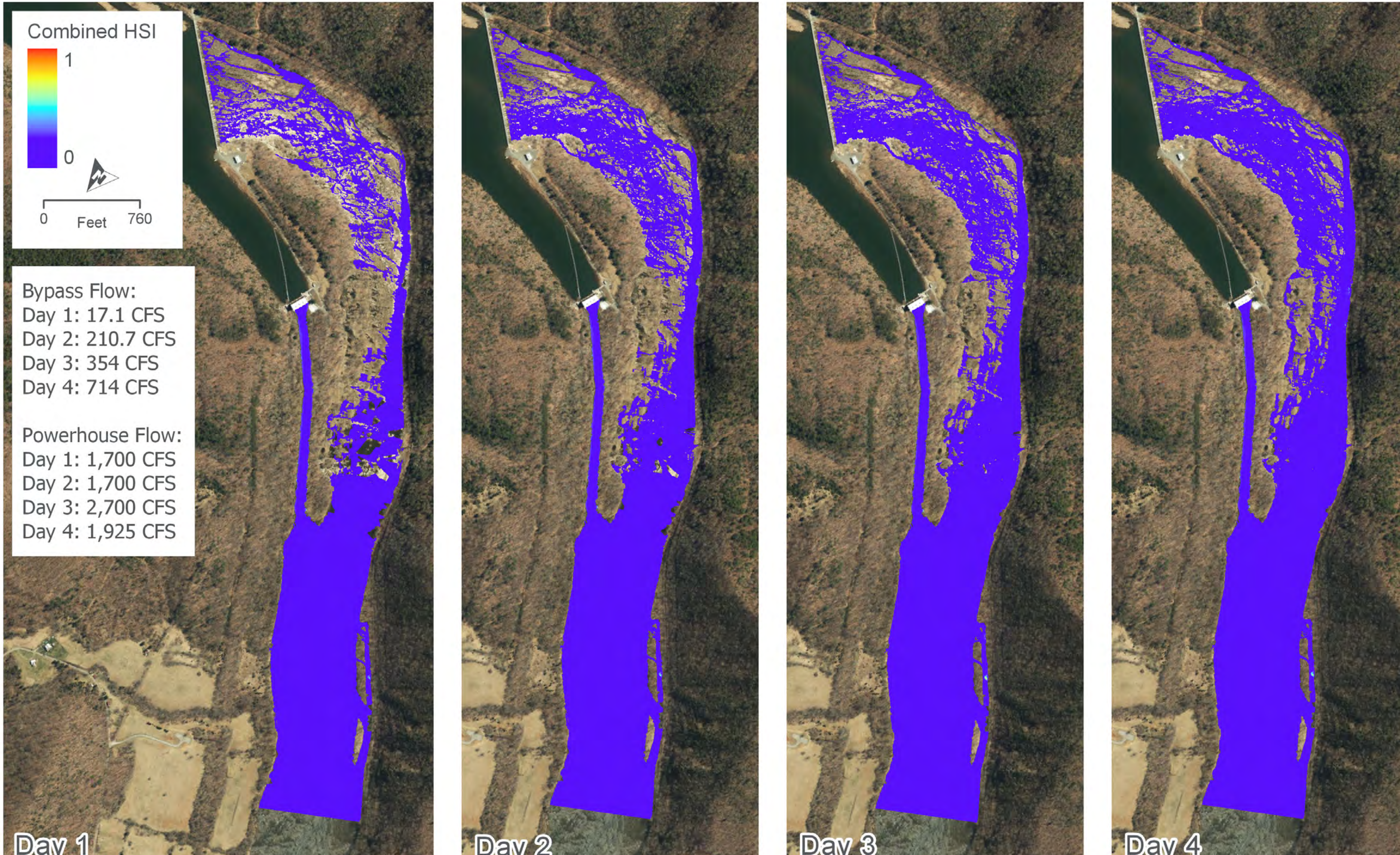
SHALLOW-SLOW GUILD HABITAT SUITABILITY MAP

CATEGORY: FINE SUBSTRATE NO COVER



SHALLOW-SLOW GUILD HABITAT SUITABILITY MAP

CATEGORY: COARSE SUBSTRATE



WALLEYE HABITAT SUITABILITY MAP

LIFESTAGE: ADULT

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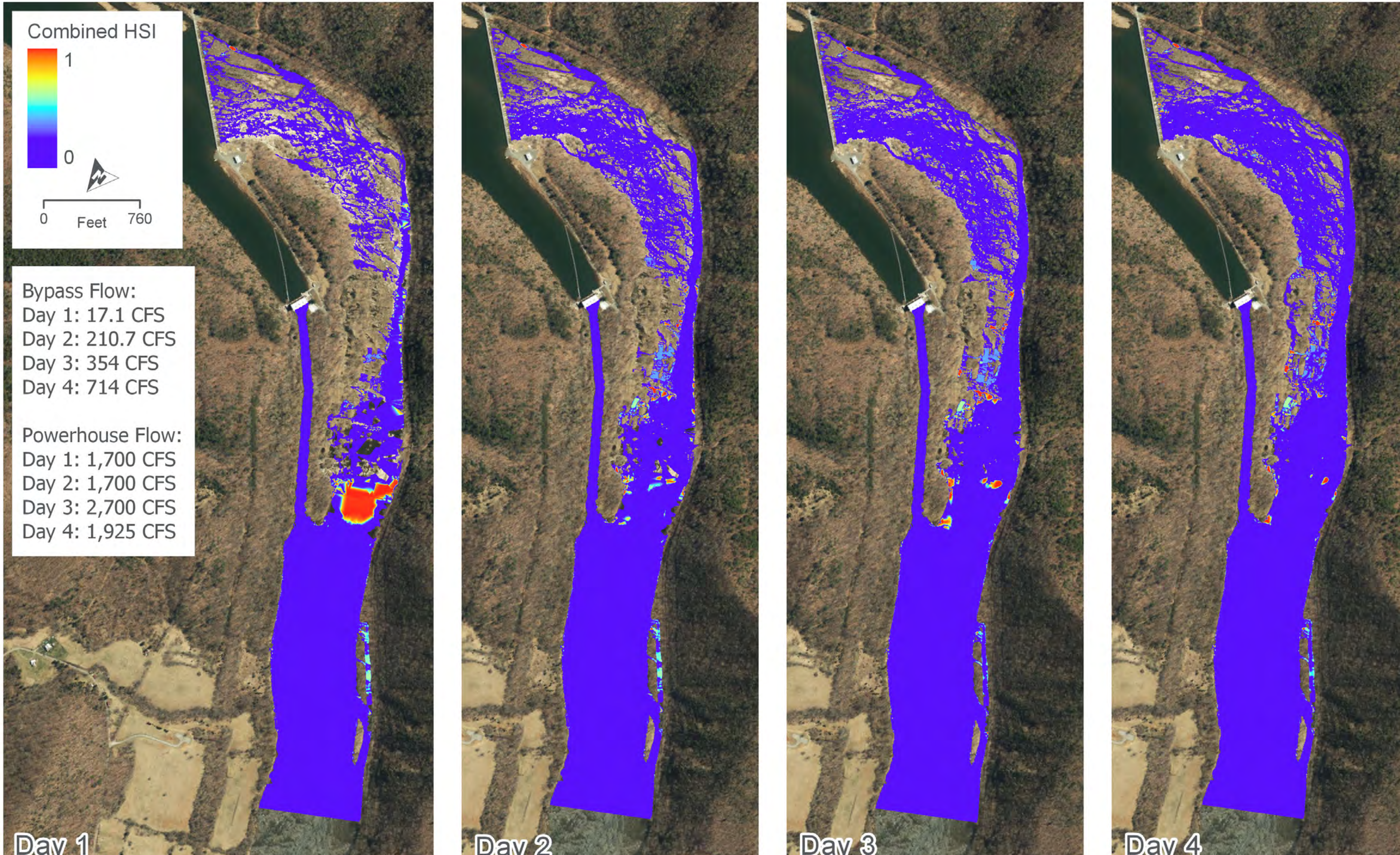
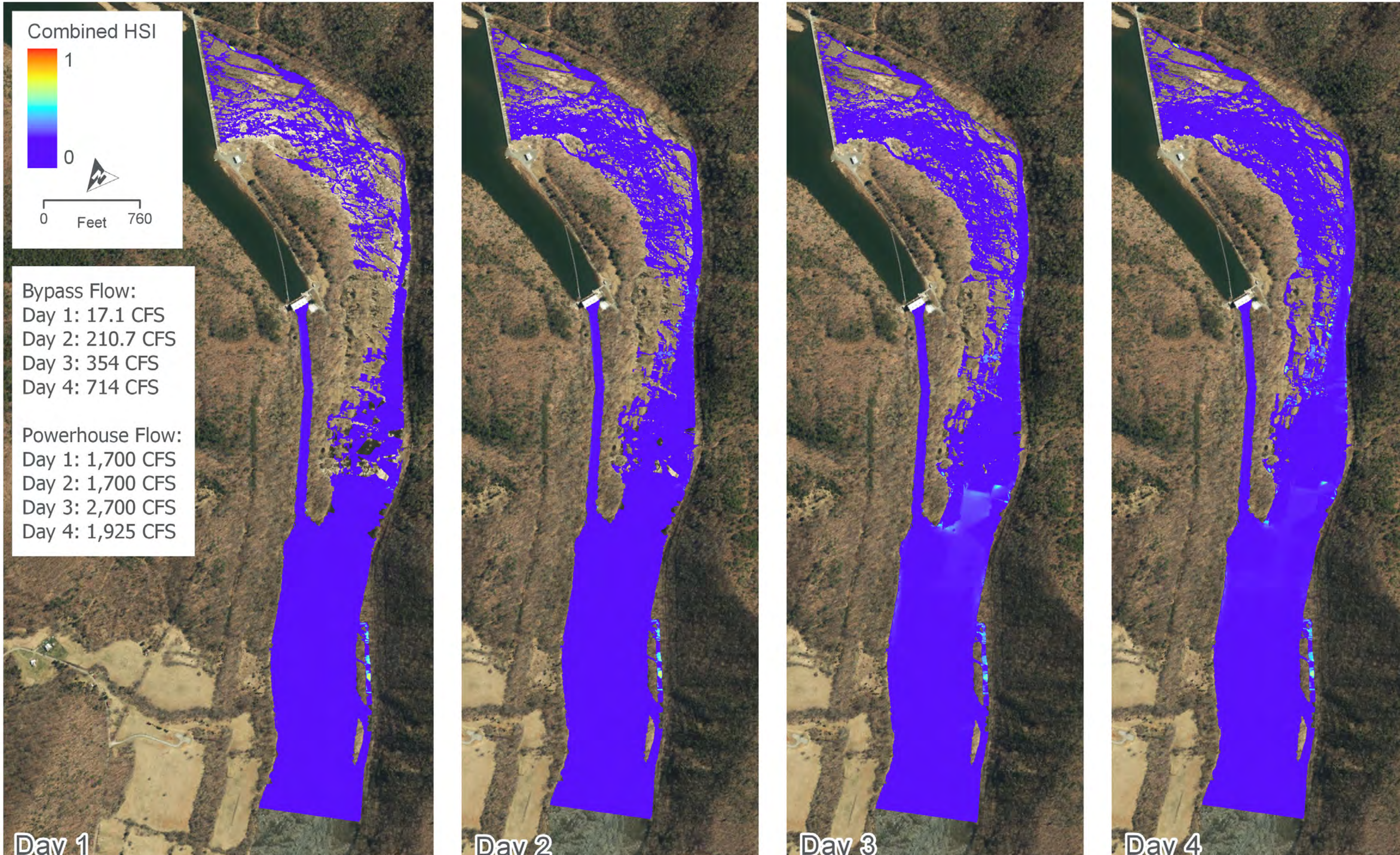


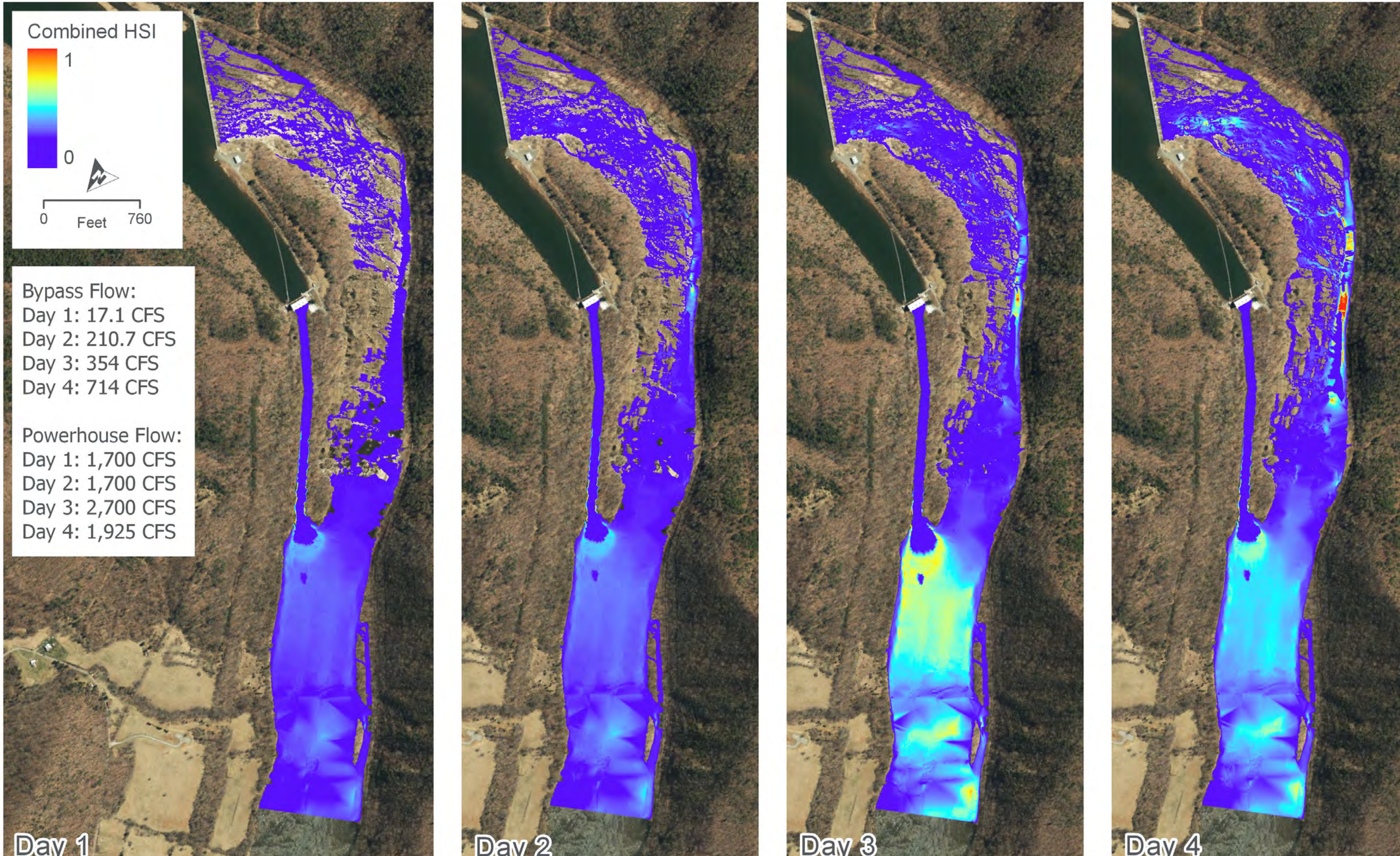
WALLEYE HABITAT SUITABILITY MAP

LIFESTAGE: FRY



WALLEYE HABITAT SUITABILITY MAP

LIFESTAGE: JUVENILE



WALLEYE HABITAT SUITABILITY MAP

LIFESTAGE: SPAWNING

HDR AMERICAN ELECTRIC POWER

Attachment 4

Attachment 4 – Germane Correspondence

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Yayac, Maggie

Subject: FW: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

From: Pica, Jessica E <jessica_pica@fws.gov>
Sent: Friday, September 18, 2020 4:17 PM
To: Norman, Janet <janet_norman@fws.gov>
Cc: Elizabeth B Parcell <ebparcell@aep.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Overall the notes look good. My main question was how confident are folks that calibrating the hydraulic model at lower flows could be extrapolated to higher flows. I think that's captured. I would change the word "why" to "where" in the sentence "Jessica also wanted to understand **where** additional bathymetry data were being collected."

Thanks and have a great weekend!
Jessica

From: Norman, Janet <janet_norman@fws.gov>
Sent: Friday, September 18, 2020 3:13 PM
To: Pica, Jessica E <jessica_pica@fws.gov>
Cc: Elizabeth B Parcell <ebparcell@aep.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Great, thanks! Sorry I didn't notice until now. Are you good with the depiction of our conference call in the notes?
Janet

Janet Norman
Fish and Wildlife Biologist
USFWS Chesapeake Bay Field Office
177 Admiral Cochrane Dr.
Annapolis, MD 21401
(O) 410-573-4533
(Fax) 410-269-0832
(cell) 410-320-5519

From: Pica, Jessica E <jessica_pica@fws.gov>
Sent: Friday, September 18, 2020 3:12 PM
To: Norman, Janet <janet_norman@fws.gov>
Cc: Elizabeth B Parcell <ebparcell@aep.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Hi Janet. Liz noticed that my email was wrong and forwarded me the information separately. Thanks for keeping me in the loop!

Yayac, Maggie

Subject: FW: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

From: Norman, Janet <janet_norman@fws.gov>
Sent: Friday, September 18, 2020 2:49 PM
To: Kittrell, William <bill.kittrell@dwr.virginia.gov>; Elizabeth B Parcell <ebparcell@aep.com>; Pica, Jessica E <jessica_pica@fws.gov>
Cc: Copeland, John <john.copeland@dwr.virginia.gov>; Grist, Joseph <joseph.grist@deq.virginia.gov>; Brian Mcgurk <brian.mcgurk@deq.virginia.gov>; Smith, Scott (DGIF) <scott.smith@dwr.virginia.gov>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Yayac, Maggie <Maggie.Yayac@hdrinc.com>; Frederick A Colburn <facolburn@aep.com>; Dvorak, Joseph <Joseph.Dvorak@hdrinc.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Hi Liz and team,

From my perspective, I think our discussion and questions on the Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study conference call were well captured in your summary notes.
I am just noticing that there was unfortunately a typo in including our USFWS Fishway Engineer Jessica Pica on this email review routing, so I am including her in my response her.e I can't speak for her as to whether the notes captured her thoughts.

Thanks much for these efforts and the study plan ahead of us.
Janet

Janet Norman
Fish and Wildlife Biologist
USFWS Chesapeake Bay Field Office
177 Admiral Cochrane Dr.
Annapolis, MD 21401
(O) 410-573-4533
(Fax) 410-269-0832
(cell) 410-320-5519

From: Smith, Scott <scott.smith@dwr.virginia.gov>
Sent: Friday, September 18, 2020 11:09 AM
To: Kittrell, William <bill.kittrell@dwr.virginia.gov>; Elizabeth B Parcell <ebparcell@aep.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

None from me, either.

From: Kittrell, William <bill.kittrell@dwr.virginia.gov>
Sent: Friday, September 18, 2020 10:09 AM
To: Elizabeth B Parcell <ebparcell@aep.com>
Cc: Copeland, John <john.copeland@dwr.virginia.gov>; Grist, Joseph <joseph.grist@deq.virginia.gov>; Norman, Janet <janet_norman@fws.gov>; Brian Mcgurk <brian.mcgurk@deq.virginia.gov>; Smith, Scott (DGIF) <scott.smith@dwr.virginia.gov>; jennifer_pica@fws.gov <jennifer_pica@fws.gov>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Yayac, Maggie <Maggie.Yayac@hdrinc.com>; Frederick A Colburn <facolburn@aep.com>; Dvorak, Joseph (Joseph.Dvorak@hdrinc.com) <Joseph.Dvorak@hdrinc.com>; Huddleston, Misty <Misty.Huddleston@hdrinc.com>
Subject: Re: [EXTERNAL] Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study MEETING NOTES

Liz, Thanks for providing the summary of the August 28, 2020 conference call on the Byllesby-Buck Bypass Flow and Aquatic Habitat Study. I have no additional comments/concerns at this time. Thanks. Bill.

William B. Kittrell, Jr.
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On Thu, Sep 10, 2020 at 4:41 PM Elizabeth B Parcell <ebparcell@aep.com> wrote:

All,

Attached please find a meeting summary on the Byllesby-Buck Flow Study scenarios discussion held via conference call on August 28, 2020. Please let us know by the end of next week (9/18) if there are any comments.

Many thanks.

Liz

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Meeting Summary

Project:	Byllesby-Buck Hydroelectric Project (FERC No. 2514)
Subject:	Bypass Study Flow Test Scenarios Discussion with Stakeholders
Date:	Friday, August 28, 2020
Location:	WebEx (2:00pm-3:30pm)
Attendees:	Bill Kittrell (VDGIF) John Copeland (VDGIF) Janet Norman (USFWS) Jessica Pika (USFWS) Brian McGurk for Joe Grist (VDEQ) Scott Smith (VDWR) Jon Magalski (AEP) Liz Parcell (AEP) Fred Colburn (AEP) Sarah Kulpa (HDR) Misty Huddleston (HDR) Ty Ziegler (HDR) Joe Dvorak (HDR)

Introduction

On August 18, 2020, AEP submitted a proposed flow test scenario plan for Byllesby-Buck for stakeholder review based on mutually agreed timeline discussed on a June 30th call. The purpose of the call was to work through agency questions with AEP and HDR regarding the proposed flow test scenarios and how the bypass study model will be used to assess and inform downstream flow needs for providing fish habitat and maintaining connectivity in the bypass channels.

Flow and Bypass Study Flow Study Status Update

- Ty Ziegler (HDR) kicked off the call by providing a summary of the proposed test flow scenarios presented in the memo submitted on August 18th.
    - Model inputs consist of depth, flow, substrate, and topography.
    - Ty stated that the LiDAR data and orthoimagery have been captured at the Byllesby-Buck Project and were used to build a preliminary hydraulic model to support the Flow and Bypass Reach Aquatic Habitat Study and to perform a desktop GIS-based characterization of substrates in the bypass channel.
    - Preliminary substrate characterization was field confirmed on August 17 and 18.
    - Ty discussed the flow test scenarios and clarified that tests are scheduled to take place at Byllesby and Buck in mid to late September, but is dependent on instream flow conditions and station operations. Sarah Kulpa (HDR) noted the test timing is dependent on having no-spill conditions and no precipitation events at the developments in the days prior to the tests.
    - The next step is to collect additional bathymetry data in areas that were inundated during LIDAR data collection and collect water depths, and velocities at each of the test flows to support model validation.

- Ty clarified that proposed test flows were selected to capture the current operational scenarios and a range of flows based on what the projects are capable of passing, in addition to capturing the existing license requirements.
  - Byllesby 350 cfs minimum downstream flow requirement
  - Buck ramping rate when gates have been opened greater than 2-ft
  - [*AEP Clarification – information not provided during discussion: The 350 cfs minimum downstream flow requirement of License Article 403 pertains to both developments*].

Agency Questions/Responses

<u>Model Scenarios</u>

- Janet Norman (USFWS) expressed concern that the proposed scenarios did not propose a sufficiently wide range of scenarios to inform an adequate evaluation of the need for increased minimum flow requirements. Scott Smith (VDWR) agreed that a test scenario at higher flows may be ideal to help evaluate specific areas for potential to serve as Walleye spawning habitat during spring months in addition to evaluating connectivity.
- Jessica Pika (USFWS's fishway engineer) was interested in understanding which model type was being used, how it worked, and if we know or will be able to identify the flow level where connectivity starts/stops downstream of Buck. Jessica also wanted to understand why additional bathymetry data were being collected.
  - Ty stated that the model will be able to answer that question.
  - Ty also provided additional data, based on field observations, about how the channel topography appears to influence connectivity when the channel is watering up or drawing down. Group discussed how the natural topography and geology of the channel directs flows to the trail side of the river and how that likely contribute to the anecdotal observations of fish getting trapped in the disconnected pool just below the dam on the left side of the river (facing downstream).
  - Ty mentioned that there may be dam operation scenarios that would be capable of releasing sufficient flow in that portion of the channel to maintain connectivity, although they may require installation of new equipment/technology.
  - Bill Kittrell (VDGIF) stated that there may be potential for permitting some form of physical channel alteration that would help maintain channel connectivity to that left-side pool (trail side of river/downstream facing).
  - Ty suggested that an evaluation could be done of the impact on connectivity of altering flows at gates where flashboards are currently experiencing leakage. Bill emphasized that flashboards have historically been part of the problem. Group discussed the challenge that flashboards present to operations and modeling of scenarios due to impacts of flashboard operation and passage of larger flows downstream, or when they are newly installed may allow more leakage flows.

    - Ty explained that additional bathymetry data are needed for areas that were inundated during LIDAR collection to improve model accuracy.
    - Joe Dvorak (HDR) stated that we will be using the Innovyze ICM software to develop a 2-D type model for the flow study. ICM was selected over HEC-RAS because it is better for calculating hydraulics in complex channels, better at capturing the influence of vertical spillways, and better at modeling turbulent flows.
- In response to a question from Scott Smith, Joe Dvorak clarified that the model would allow identification of wetted area, specific flow release values, and velocities and depths in specific areas under specific flow scenarios. Janet, Jessica, and Scott each indicated that they were satisfied with the explanations and stated that they anticipate and hope the model will work well and help provide answers to their questions.
- The group discussed methods and challenges for addressing leakage flows in the models. Ty stated that we intend to try and measure those flows if possible, otherwise, an effort will be made to estimate those flows for inclusion in the model.
- Janet wanted to understand how leakage flows may change over time, is there seasonality to the leakage flows, how frequently do they need replaced, etc.
    - Ty indicated that leakage flows are impacted by flashboard condition (i.e., new versus old) and if they have had time to be silted in.

Model Outputs and HSI Curves

- John Copeland (VDGIF) noted that he would like to see how Walleye use the Buck reach under different flow scenarios, preferably via field observation.
    - Janet stated that evaluation should include a seasonality component to demonstrate availability of suitable conditions throughout the year.
    - Ty clarified that this is part of the evaluation.
        - [HDR *Clarification – while not specifically discussed during the call, as part of the study plan, Walleye habitat suitability curves will be used in conjunction with the hydraulic model results to evaluate potential suitable habitat under various model flow simulations*].
- In the study report, Janet requested additional information be provided to provide characterization of normal hydrological conditions and spilling operations at the developments. The group referred to Table 4-1 in the RSP during discussion. Janet specifically requested the 25^{th} and 75^{th} percentiles be added to the table and better labeling.
    - Sarah suggested that a line graph may be more appropriate for the information being presented.
    - All on call agreed that more information for Table 4-1 is needed **(Action Item)** in the future study report.

- Brian McGurk (VDEQ) asked if the existing license requires monitoring of flows and gate operations. Sarah clarified that this information is monitored and available and was used to create an operations model for the developments.

Based on this discussion, AEP and HDR are proceeding with the flow demonstration study as proposed in the memo, as soon as field conditions allow. The call wrapped up with all indicating they were satisfied with the information presented and AEP's and HDR's responses to questions. Call participants expressed their appreciation of the effort made to share information and improve understand regarding the study.

Yayac, Maggie

Subject: FW: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study

From: Copeland, John <john.copeland@dwr.virginia.gov>
Sent: Tuesday, August 25, 2020 1:11 PM
To: Elizabeth B Parcell <ebparcell@aep.com>
Cc: Grist, Joseph <joseph.grist@deq.virginia.gov>; Norman, Janet <janet_norman@fws.gov>; Kulpa, Sarah <Sarah.Kulpa@hdrinc.com>; Yayac, Maggie <Maggie.Yayac@hdrinc.com>; Jonathan M Magalski <jmmagalski@aep.com>; Ziegler, Ty <Ty.Ziegler@hdrinc.com>; Brian Mcgurk <brian.mcgurk@deq.virginia.gov>; Kittrell, Bill (DGIF) <bill.kittrell@dwr.virginia.gov>; John Copeland <john.copeland@dwr.virginia.gov>; Smith, Scott (DGIF) <scott.smith@dwr.virginia.gov>
Subject: Re: Byllesby-Buck Project: Flow and Bypass Reach Aquatic Habitat Study

Thank you for your email communication with this group about your plans to initiate flow release scenario tests for the Byllesby Buck Project starting Monday, August 31. Most of the agency people copied on your email had a conference call regarding this proposal yesterday. I had a brief discussion and email exchange with Joe Grist (Department of Environmental Quality) yesterday and today.

During our conversation yesterday, we concluded that our questions are numerous enough that we simply could work things out much better in a conference call. I have conferred with all the agency parties: Janet Norman (USFWS), Bill Kittrell (DWR), Scott Smith (DWR instream flow expert), as well as Joe Grist (DEQ - who has appointed Brian McGurk to participate) regarding a conference call this Friday afternoon (August 28). All parties are available.

We hereby request a conference call at your convenience on Friday afternoon, August 28.

FYI - Please note that our agency email extension has changed from DGIF to DWR, effective July 1, 2020. DGIF still works, but we are requesting use of the DWR extension. This email has the corrected email addresses.

Respectfully submitted,

John R. Copeland
Fisheries Biologist III

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Virginia Department of Wildlife Resources

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On Tue, Aug 18, 2020 at 3:09 PM Elizabeth B Parcell <ebparcell@aep.com> wrote:

Good afternoon,

As we discussed in our June 30th ILP study update call for Appalachian's Byllesby-Buck Project, HDR has prepared a brief memo describing the flow release range and locations for the upcoming flow tests to be conducted as part of the Flow and Bypass Reach Aquatic Habitat Study. As this fieldwork is presently scheduled to begin as early as August 31, we would greatly appreciate receipt of any questions or comments on the attached by close of business Tuesday, August 25th. That will leave us time to schedule a conference call for later next week, if needed to further discuss.

Thank you for your support of this process.

Sincerely,

Liz

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Memo

Date:	August 17, 2020
Project:	Byllesby-Buck Hydroelectric Project (FERC No. 2514)
To:	Bill Kittrell (VDWR) John Copeland (VDWR) Joseph Grist (VDEQ) Janet Norman (USFWS)
From:	Sarah Kulpa (HDR)
CC:	Liz Parcell (AEP) Jon Magalski (AEP) Ty Ziegler (HDR)
Subject:	**Flow and Bypass Reach Aquatic Habitat Study – Proposed Flow Test Scenarios**

Appalachian Power Company's (Appalachian's) Revised Study Plan (RSP), as approved and modified by the Federal Energy Regulatory Commission (FERC), for the Byllesby-Buck Hydroelectric Project (Project) includes a Flow and Bypass Reach Aquatic Habitat Study (Study). The Project includes the Byllesby development and the Buck development, both located on the New River in Carroll County, Virginia. The Buck development is located approximately three river miles downstream of the Byllesby development and 44 miles upstream of Claytor Dam. The objectives of this Study are to conduct a flow and habitat assessment in the tailwater area and bypass reach of both developments (excluding the Byllesby development auxiliary spillway channel) using a combination of desktop, field survey, and hydraulic modeling methodologies to achieve the following goals:

1. Delineate and quantify aquatic habitat and substrate types in the Byllesby and Buck developments' bypass reaches.
2. Identify and characterize locations of habitat management interest within the Byllesby and Buck bypass reaches.
3. Develop an understanding of streamflow travel times and water surface elevation responses under variable base flow and spillway release flow combinations in the tailwater and bypass reach of each development to:
    - Demonstrate the efficacy of ramping rates required by the existing license.
    - Demonstrate the efficacy of the existing powerhouse minimum flow requirement (i.e., 360 cubic feet per second (cfs) minimum flow to maintain aquatic resources, including resident fish species, downstream of each

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development consisting of the tailwater areas below each powerhouse and the bypass reaches below the main spillways).

- Evaluate the impacts of providing seasonal minimum flows to the bypass reaches.

Flow and Water Level Assessment - Proposed Flow Test Scenarios

The Flow and Water Level Assessment fieldwork included in Task 3 of the Flow and Bypass Reach Aquatic Habitat Study is presently scheduled to be conducted the weeks of August 31 and September 7, 2020 (suitable inflow and field condition-dependent). The proposed flow release quantities and locations are described below. The proposed flow test scenarios are designed to capture existing (baseline) Project operations and also support the development and calibration of hydraulic models that will allow for visualization and evaluation of flow releases from other gate openings (i.e., demonstration flows at a specific gate location are not required to model flows from that location).

For the Byllesby development, the target flow scenarios (see Table 1) are designed to evaluate the effect of passing the entire minimum downstream flow requirement of 360 cfs through the bypass reach. Tainter Gate #6 is the proposed gate to pass flows as it is near the center of the spillway structure and under existing operating procedures is the first gate operated for releases into the bypass reach (see Figure 1). The three target flows proposed in Table 1 will allow a hydraulic model simulation range from leakage up to approximately 500 cfs.

For the Buck development, the target flow scenarios (see Table 1) are designed to evaluate the effect of the existing ramping rate requirements. Appalachian is required to discharge flows through a 2-foot gate opening for at least three hours following any spills released through a gate opened 2 feet (ft) or more. They are required to reduce the opening to 1 ft for at least an additional three hours, after which time the gate may be completely closed. This gradual reduction of flow allows adequate time for fish that may have traveled upstream into the bypass reach to respond to receding water levels, reducing instances of fish strandings that can potentially occur with sudden flow discontinuation.

Tainter Gate #1 will be utilized at the Buck development to pass the target flows since this reflects current operations (i.e., Tainter Gate #1 is first to open and last to close during high flow events where flows are routed into the bypass reach) (see Figure 2). Gate openings of 2 ft and 1 ft will be evaluated (as per existing ramping rate operating protocols) as well as a gate opening of 0.5 ft to represent flows that would occur between a 1-foot gate opening and leakage conditions. The three target flows proposed in Table 1 will allow a hydraulic model simulation range from leakage up to approximately 2,250 cfs.

Table 1. Byllesby-Buck Bypass Reach Aquatic Habitat Study – Proposed Flow Test Scenarios

Byllesby Bypass Reach				
Pool Range: 2078.2 - 2079.2 NGVD 29; Assume starting Pool Elevation is 2078.7 NGVD 29)				
Powerhouse Discharge Capacity: 5,868 cfs				
Powerhouse Minimum Discharge Capacity: 85 cfs/unit				
Tainter Gate #6				
Opening* (ft)	Proposed Target Flows (cfs)	Flow Test Duration (hours)	Volume (acre-ft)	Model Simulation Range (cfs)
0.0	Leakage	NA	0	Leakage ↓ 500
0.10	40	5	17	
0.25	105	5	43	
0.5	203	5	84	
Buck Bypass Reach				
Pool Range: 2002.4 - 2003.4 NGVD 29; Assume starting Pool Elevation is 2002.9 NGVD 29				
Powerhouse Discharge Capacity: 3,540 cfs				
Powerhouse Minimum Discharge Capacity: 73 cfs/unit				
Tainter Gate #1				
Opening* (ft)	Proposed Target Flows (cfs)	Flow Test Duration (hours)	Volume (acre-ft)	Model Simulation Range (cfs)
0.0	Leakage	NA	0	Leakage ↓ 2,250
0.5	224	8	148	
1.0	448	8	296	
2.0	897	8	593	

Notes: * Assume starting point is midpoint of operating range with adequate inflow to maintain pond levels during flow tests.

Figure 1. Byllesby Dam Spillway Gates

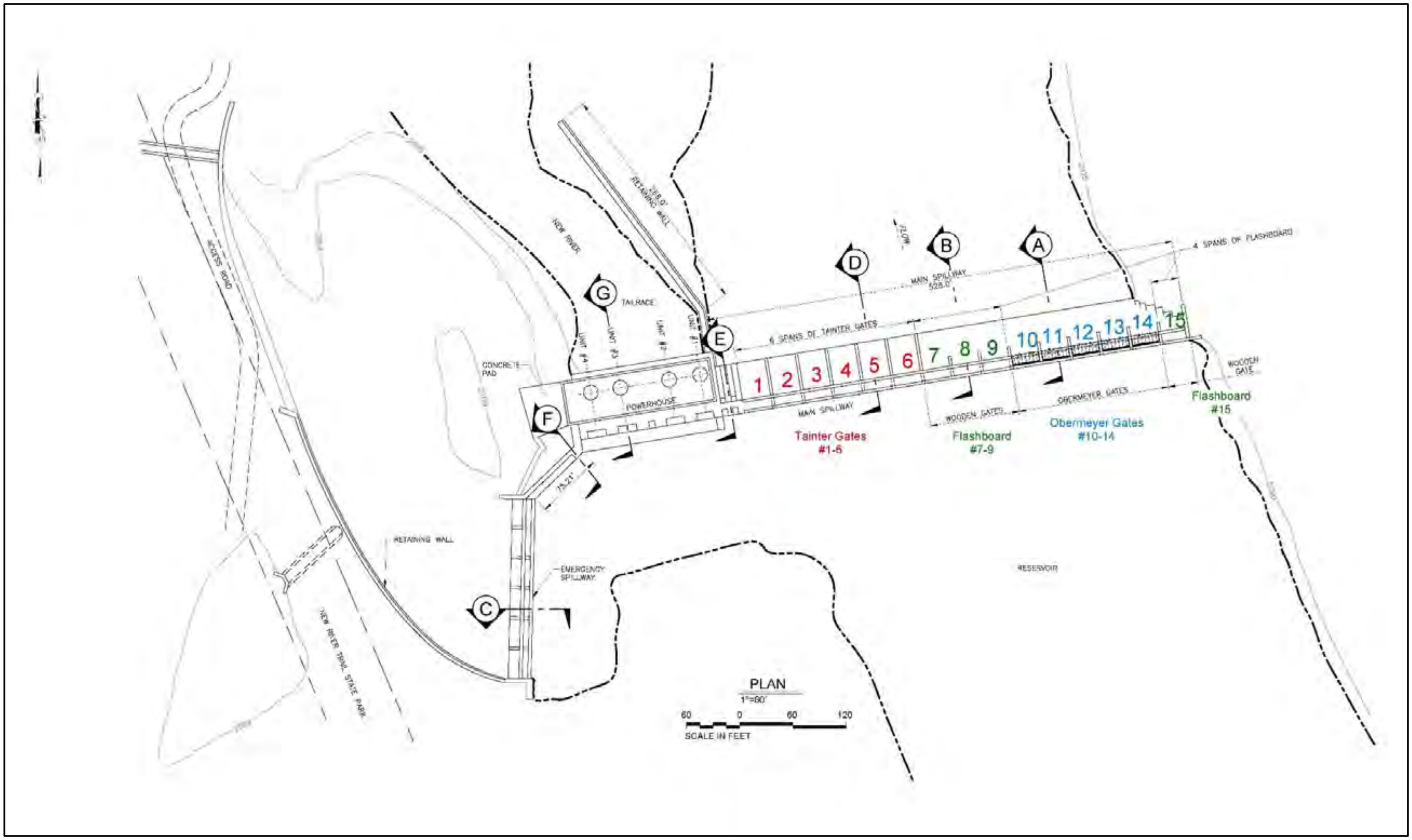

Figure 2. Buck Dam Spillway Gates