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HYDROLOGIC ENGINEERING CENTERS RIVER ANALYSIS SYSTEM (HEC-RAS) MODEL

JACKSON BLUE SPRING SYSTEM

FINAL REPORT

Prepared for

Northwest Florida Water Management District
81 Water Management Drive
Havana, Florida 32333-4712

Prepared by

Geosyntec Consultants, Inc., dba ATM
2201 NW 40 Terrace
Gainesville, FL 32605

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Geosyntec Consultants, Inc., d/b/a ATM (ATM) has been asked by the Northwest Florida Water Management District (NWFWMD or District) to complete a constructed and calibrated Hydrologic Engineering Centers River Analysis System (HEC-RAS) model for the Jackson Blue Spring/Merritts Mill Pond/Spring Creek system down to the confluence with the Chipola River. The study area is presented in Figure 1. The goal of this effort was to develop a stable and executable unsteady HEC-RAS model to support the minimum flow and level (MFL) decision making for the Jackson Blue Spring/Merritts Mill Pond/Spring Creek system.

This report provides a description of the Jackson Blue Spring/Merritts Mill Pond/Spring Creek system and the development of a 1-dimensional, unsteady-state HEC-RAS model of the system. The description includes a discussion of model development, construction, testing, calibration and validation.

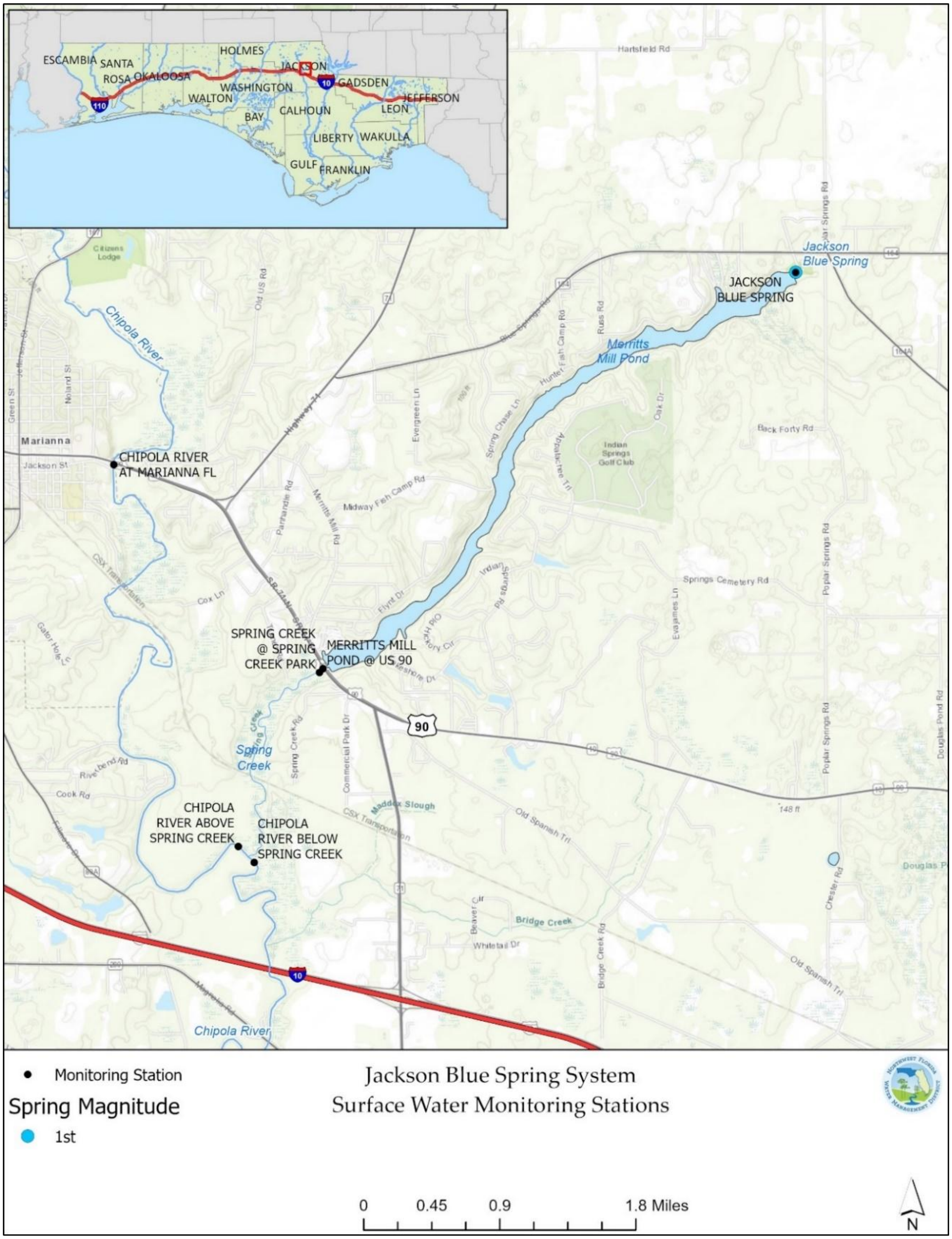

Figure 1: Jackson Blue Spring MFL Study Area and Surface Water Monitoring Stations

2. STUDY AREA AND MODEL DOMAIN

Jackson Blue Spring is a first magnitude spring [average daily flow greater than 100 cubic feet per second (cfs)] located in Jackson County, Florida within the Apalachicola River Basin. Jackson Blue Spring has an average daily flow of 105 cfs, with a flow range of 37 to 250 cfs (based on measurements from December 2004 – September 2023). The Jackson Blue springshed encompasses approximately 130 square miles and extends into southern Alabama. The springshed is located within the Marianna Lowlands physiographic province, which is characterized by gently rolling hills and numerous karst features such as sinkholes, springs, and limestone outcroppings. Land surface elevations in the springshed range from approximately 90 to 190 feet referenced to the North American Vertical Datum of 1988 (ft-NAVD88) (Figure 2). Jackson Blue Spring and several other minor springs are located in the 270-acre Merritts Mill Pond and contribute flow into the pond. The stage in Merritts Mill Pond is managed by a water control structure located at the southern end of the pond along US Highway 90/State Road 71 (US 90). Outflow from Merritts Mill Pond provides the majority of the flow to Spring Creek, which flows into the Chipola River. The Chipola River is the largest tributary in Florida to the Apalachicola River.

The study area for the Jackson Blue Spring MFL and HEC-RAS model encompasses the 6.1-mile reach from Jackson Blue Spring to the confluence of Spring Creek and the Chipola River. This includes the entirety of Merritts Mill Pond, approximately 4.3 miles in length, from Jackson Blue Spring to the US 90 bridge, to the control structure at US 90, as well as the entirety of Spring Creek, approximately 1.8 miles in length, from the control structure at US 90 to its terminus at the confluence with the Chipola River. (Figure 1). An existing HEC-RAS model, developed in 2015 for performing Federal Emergency Management Agency (FEMA) flood evaluations along Merritts Mill Pond, was provided by the District and was considered in the development of the model described in this report for MFL development.

The model domain extends the entirety of the study area, from Jackson Blue Spring to the confluence of Spring Creek and the Chipola River. (Figure 2).

Development of this HEC-RAS model was conducted by ATM, with initial modeling efforts conducted by Verdantas, LLC (Verdantas). The following tasks were performed to develop a HEC-RAS model suitable for supporting MFL development for Jackson Blue Spring:

- Review existing model developed in 2015 for performing FEMA flood evaluations along Merritts Mill Pond and Spring Creek.
- Review of initial modeling work on the system conducted by Verdantas along Merritts Mill Pond and Spring Creek.
- Review available data for use in developing HEC-RAS model for MFL development, including bathymetric data, hydrologic data, and available light detection and ranging (LiDAR) data.
- Determine additional data needs and perform a field reconnaissance of the study area.
- Develop model geometry using best available bathymetric and LiDAR data.

- Develop input flow files and boundary conditions using best available hydrologic monitoring data from District and U.S. Geological Survey (USGS) stations.
- Determine appropriate flow mode, calibration, and simulation period.
- Perform model testing and calibration.

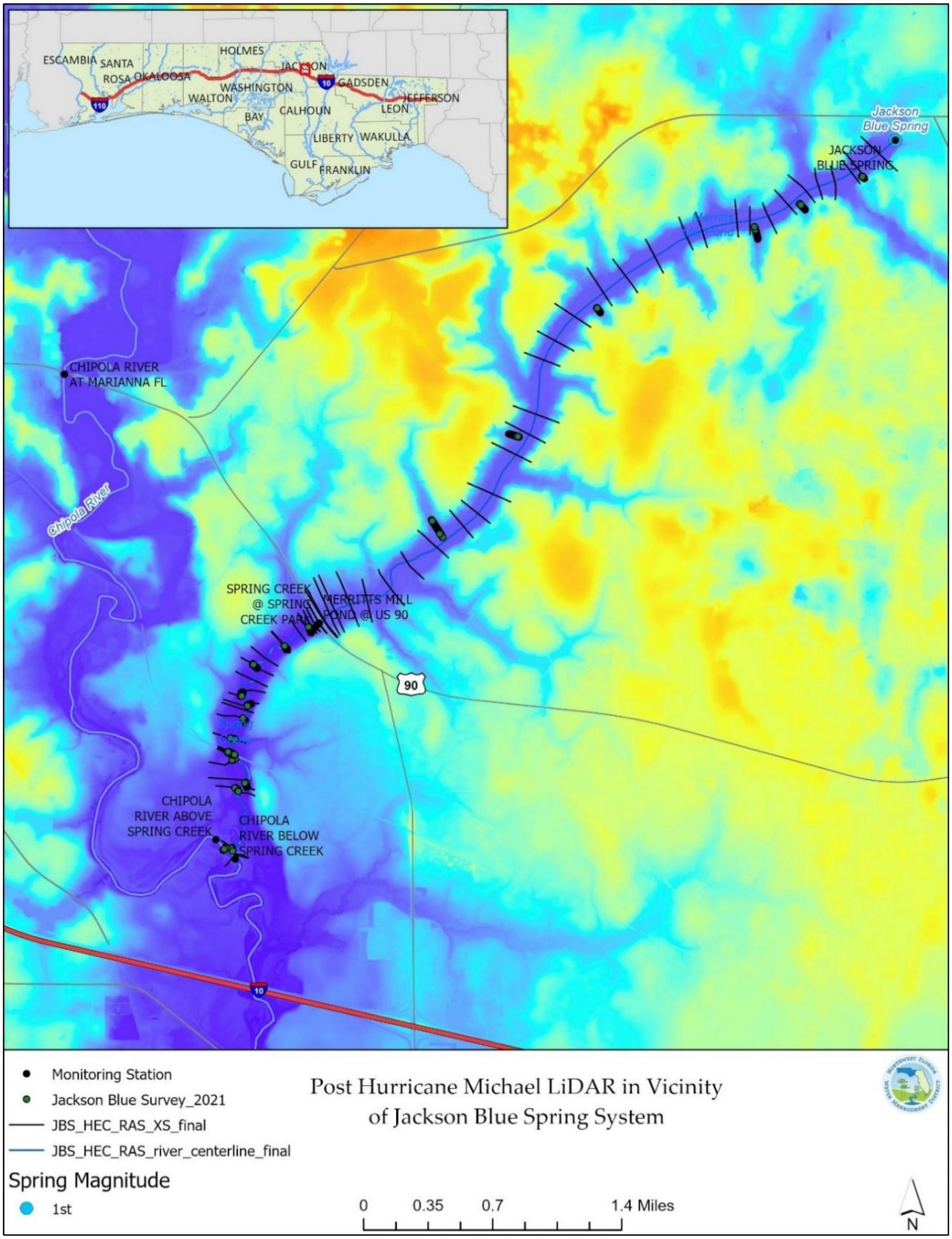

Figure 2: Post Hurricane Michael LiDAR in Vicinity of Jackson Blue Springs

3. HEC-RAS MODEL CONSTRUCTION

An unsteady-state HEC-RAS (HEC-RAS Version 6.4.1) model of the Jackson Blue Spring MFL study area was developed by ATM (with initial modeling efforts conducted by Verdantas) in support of MFL development for Jackson Blue Spring. The model was constructed with best available data, including high resolution Digital Elevation Model (DEM) data, recent cross sectional survey data throughout the model domain, and hydrologic data from all available stream gaging stations along Merritts Mill Pond, Spring Creek, and the Chipola River. Although a HEC-RAS model had previously been developed in 2015 for Merritts Mill Pond and a portion of Spring Creek for performing FEMA flood evaluations, a new model was constructed for purposes of MFL evaluation due to the required model resolution at low flows as well as newly available DEM, survey, and hydrologic data, along with significant changes to the system resulting from Hurricane Michael impacts. Surveyed US 90 bridge and hydraulic control structure dimensions contained in the existing FEMA model were utilized for the updated MFL HEC-RAS model. An additional survey of control structure dimensions was also performed in 2016 to obtain additional dimensions not included in the existing model (DRMP, 2017). The following sections discuss the work performed during the initial modeling efforts.

3.1 Geoprocessing, Projection System, and Digital Elevation Model

HEC-RAS 6.4.1 requires that all geospatial data used in model development use a consistent spatial reference system. The coordinate system used to represent horizontal positions for this project was Universal Transverse Mercator (UTM) zone 16N. The vertical datum used for this project was NAVD88. These are consistent with standard spatial reference system utilized for most geospatial data within NWFWMD. All elevation survey data used within this model development was obtained and provided in NAVD88. Horizontal survey positions were provided using the North American Datum 1983 (NAD83), 2011 adjustment, State Plane Florida- Zone: North horizontal datum. A geographic information system (GIS) layer of provided survey data coordinates and elevations was generated using ArcMap v.10.8.1 and was imported into HEC-RAS reprojected to UTM zone 16N for use within the project. All District station river stage data used within this model development was available in NAVD88. The river stages measured at USGS station 02358789 (Chipola River Near Marianna, FL) required a shift of +0.433 ft to convert the published values from the National Geodetic Vertical Datum of 1929 (NGVD29) to NAVD88.

The District received high-resolution, post-Hurricane Michael LiDAR data in August 2022. These data consisted of raster files with 0.76-meter grid cell resolution and 1-meter vertical resolution for the majority of NWFWMD, including the study area in the vicinity of Jackson Blue Spring. The Post-Hurricane Michael LiDAR for this area was flown between December 2019 and October 2020. The horizontal datum of this data was NAD83, 2011 adjustment, State Plane Florida- Zone: North. District staff developed a mosaic DEM from provided raster files and reprojected to UTM zone 16N. The resulting LiDAR-derived DEM was clipped to the Jackson Blue Study Area to reduce processing time for the purposes of this project. (Figure 2).

3.2 Model Initialization and Digitization

Model initialization was performed within the RAS Mapper feature of HEC-RAS 6.4.1. The coordinate reference system was set to UTM zone 16N, and the clipped DEM was input into RAS Mapper and converted into a Terrain Layer (Figure 3). The river centerline was digitized primarily using the generated Terrain Layer within RAS Mapper. The high-resolution generated terrain allowed for accurate depiction of Merritts Mill Pond and Spring Creek within the model domain. Aerial imagery, post-Hurricane Michael LiDAR, and the National Hydrography Dataset (NHD) (McKay et al. 2012) were also utilized as supporting information to aid in digitizing. Riverbanks and flow paths were also digitized in a similar manner.

3.3 Elevation Survey and Cross Section Channel Geometry

Based on an initial review of the previous Merritts Mill Pond and Spring Creek FEMA model, District staff in conjunction with HSW Engineering, Inc. (HSW, currently Verdantas) determined that all existing transect locations would need to be resurveyed to ensure the channel was represented with appropriate precision to accurately represent low flow conditions (HSW, 2016). Additional survey transect locations were also needed to extend the model domain to the confluence of Spring Creek and the Chipola River, capture river bathymetry in areas with sparse representation, and better represent bridge crossings within the model. District staff, along with HSW, conducted a field reconnaissance along Spring Creek on September 12, 2016, to identify potential additional survey transect locations (Figure 4). A total of 19 potential survey elevation transect locations were identified along Spring Creek based on the above criteria (HSW, 2016). In addition, the District contracted with Research Planning, Inc. (RPI) in 2017 to identify potential ecological transect locations along Merritts Mill Pond and Spring Creek for floodplain data collection and analysis. RPI identified six potential ecological transect locations along Merritts Mill Pond and eight potential ecological transect locations along Spring Creek for further data collection, including land-surface elevations (RPI, 2017).

In 2016, DRMP, Inc. performed six elevation cross section elevation surveys in Merritts Mill Pond, and 14 elevation cross section surveys in Spring Creek, based on the previous recommendations by HSW and RPI. All six cross sections within Merritts Mill Pond and five cross sections in Spring Creek extended into the floodplain as ecological cross sections. The remaining nine cross sections in Spring Creek were only conducted in channel to determine cross section elevations (DRMP, 2017). In addition, DRMP collected additional dimensions of the US 90 control structure to more accurately represent it in the model.

Hurricane Michael made landfall near Mexico Beach, Florida, on October 10, 2018, as a Category 5 storm. The hurricane cut an intensely destructive path across several counties of the Florida Panhandle, including in the vicinity of the Jackson Blue Spring MFL study area. Based on review of elevation survey pre- and post-Hurricane Michael in comparison with post-Michael LiDAR, Merritts Mill Pond and Spring Creek likely experienced extensive scouring and deposition as a result of Hurricane Michael (Verdantas 2022). In addition, the previously forested floodplain was severely damaged, with virtually all trees and canopy in the system lost. Due to these changes, the District determined all elevation transects needed to be resurveyed to represent post-Michael bathymetry in the HEC-RAS model. In 2021, Wantman Group, Inc. (WGI) resurveyed all 20 transects previously conducted by DRMP in 2017 (WGI, 2021).

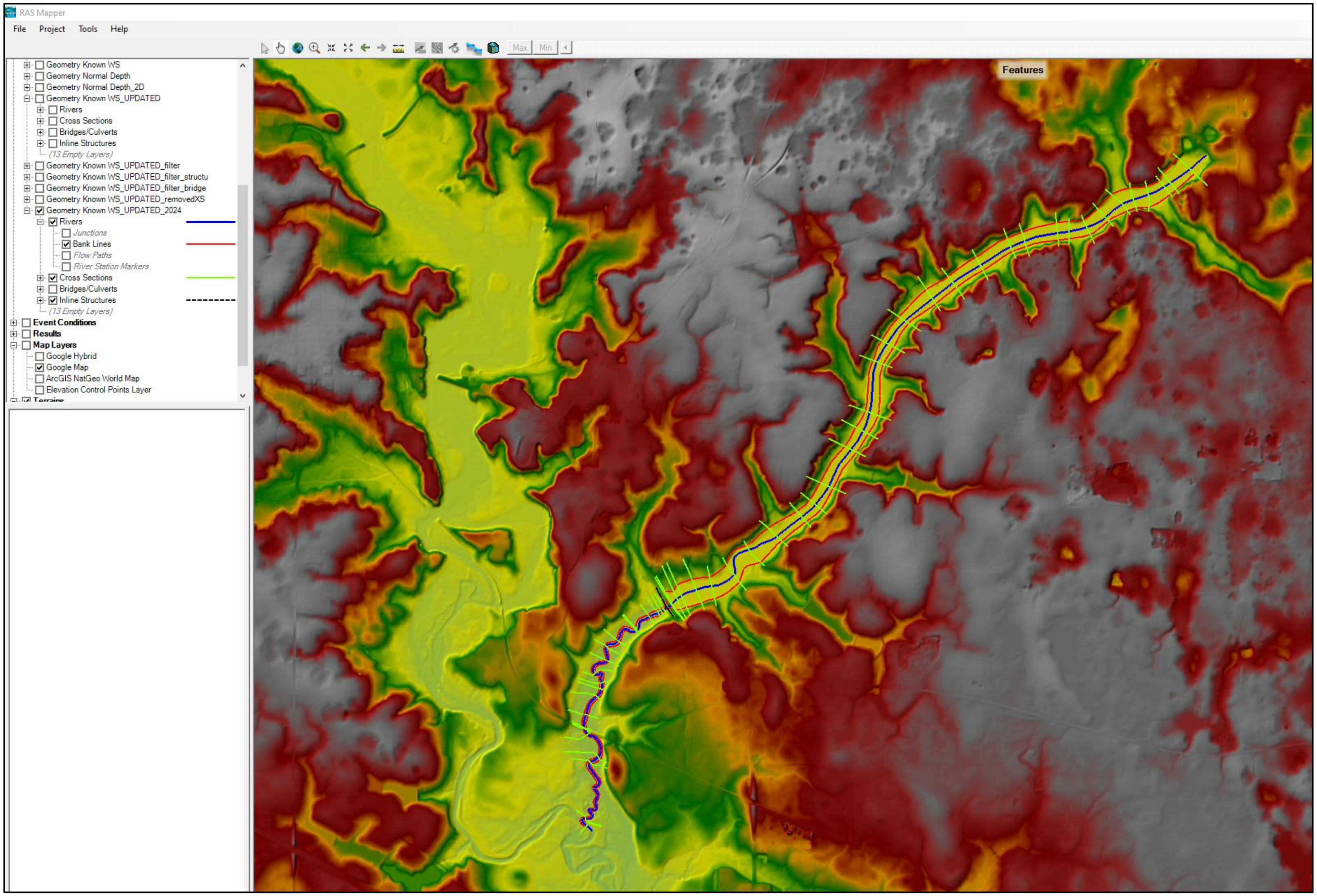

Figure 3: Model Digitization in RAS-Mapper

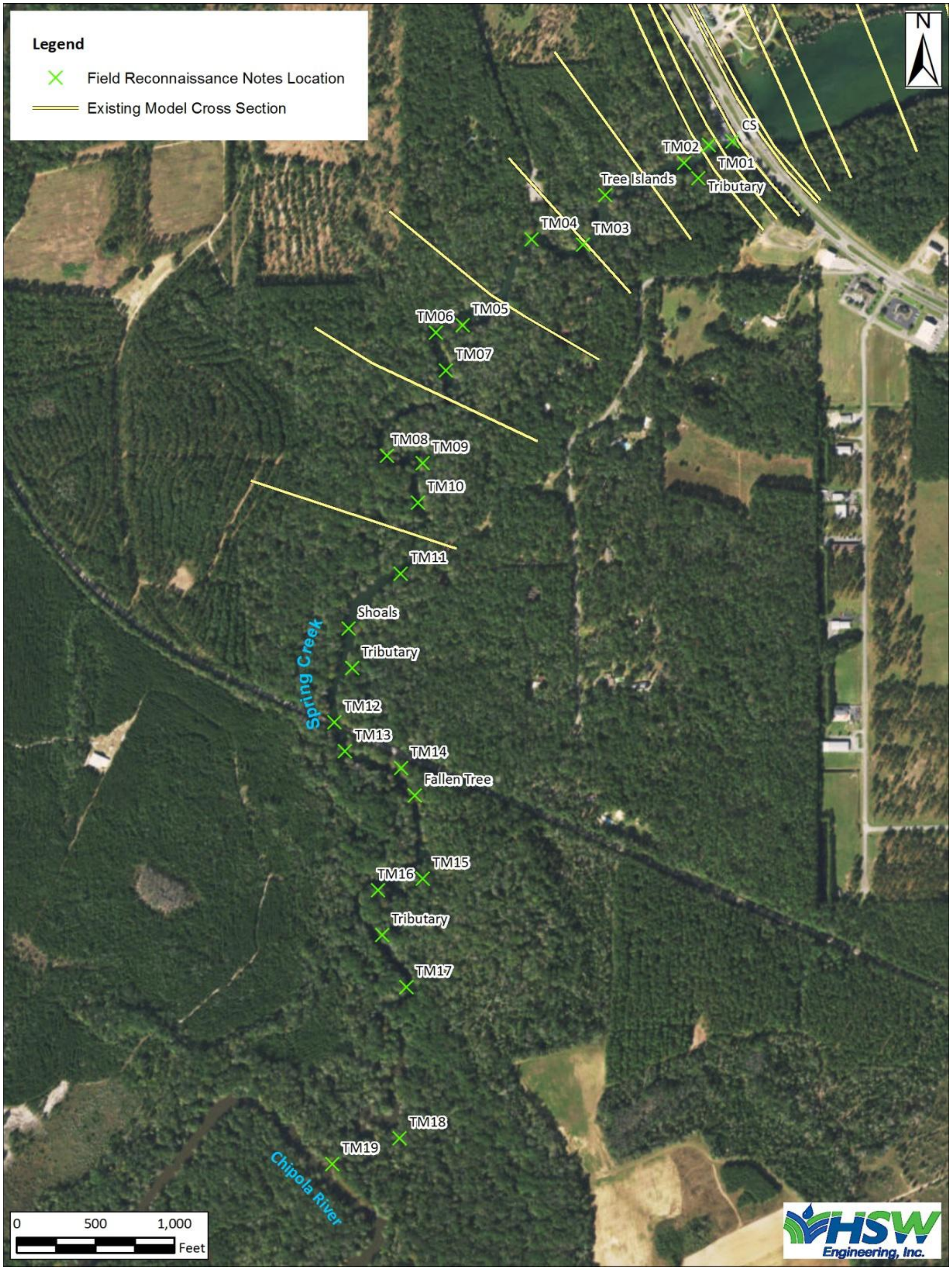

Figure 4: Spring Creek Field Reconnaissance, September 2016

A total of 57 cross sections were digitized within RAS Mapper, extending sufficiently into the floodplain to accommodate high flow scenarios. Cross sections were digitized to coincide with survey locations as well as locations of transects from the FEMA model where applicable. Elevations for all transects were initially determined based on the terrain generated from the post-Michael DEM. Elevation survey points were utilized to replace the terrain-derived elevations within the channel for all cross sections where survey was available (Figure 5). Channel geometry for the remaining cross sections was determined either from existing model bathymetry or interpolated based on the adjacent upstream and downstream transect. For all cross sections, terrain-generated elevations were used for overbank (floodplain) areas. After cross sections were defined in RAS Mapper, each cross section was reviewed in the geometry editor within HEC-RAS. A few minor adjustments were made to the generated elevations from RAS Mapper to be consistent with survey elevations using the geometry editor tools.

3.4 Boundary Conditions

Four boundary conditions (three flow, and one stage) were used in the model setup and are contained in the model Data Storage System (DSS) file (JacksonBlueMFL_2024.dss). These inputs were derived based on surface water monitoring stations along Merritts Mill Pond, Spring Creek, and the Chipola River maintained by the District and USGS and presented in Table 1 and Figure 1, including:

- USGS 02358789 Chipola River Near Marianna, FL
- NWFWMD 005042 Jackson Blue Spring
- NWFWMD 011107 Merritts Mill Pond @ US 90
- NWFWMD 012820 Chipola River above Spring Creek

Table 1: Summary of Surface Water Monitoring Stations Utilized to Determine Model Inputs

Station Number	Site Name	Parameter: Period of Record
USGS 02358789	Chipola River Near Marianna, FL	Continuous Discharge: Oct. 1999 – present Continuous Stage: Oct 1999 – present
NWFWMD 005042	Jackson Blue Spring	Continuous Discharge: Dec. 2004 – present Field Visit Discharge Measurements: 12 measurements prior to 2001; quarterly measurements 2001 – present
NWFWMD 011107	Merritts Mill Pond @ US 90	Continuous Discharge: May. 2017 – July 2017, Aug. 2018 – Oct 2020, Dec 2020 – Mar. 2021, June 2021 – Nov. 2022 Field Visit Discharge Measurements: quarterly measurements Aug 2013 – Nov. 2022 Continuous Stage: April 2015 – present
NWFWMD 12820	Chipola River above Spring Creek	Continuous Stage: Sept. 2020 – Mar. 2023

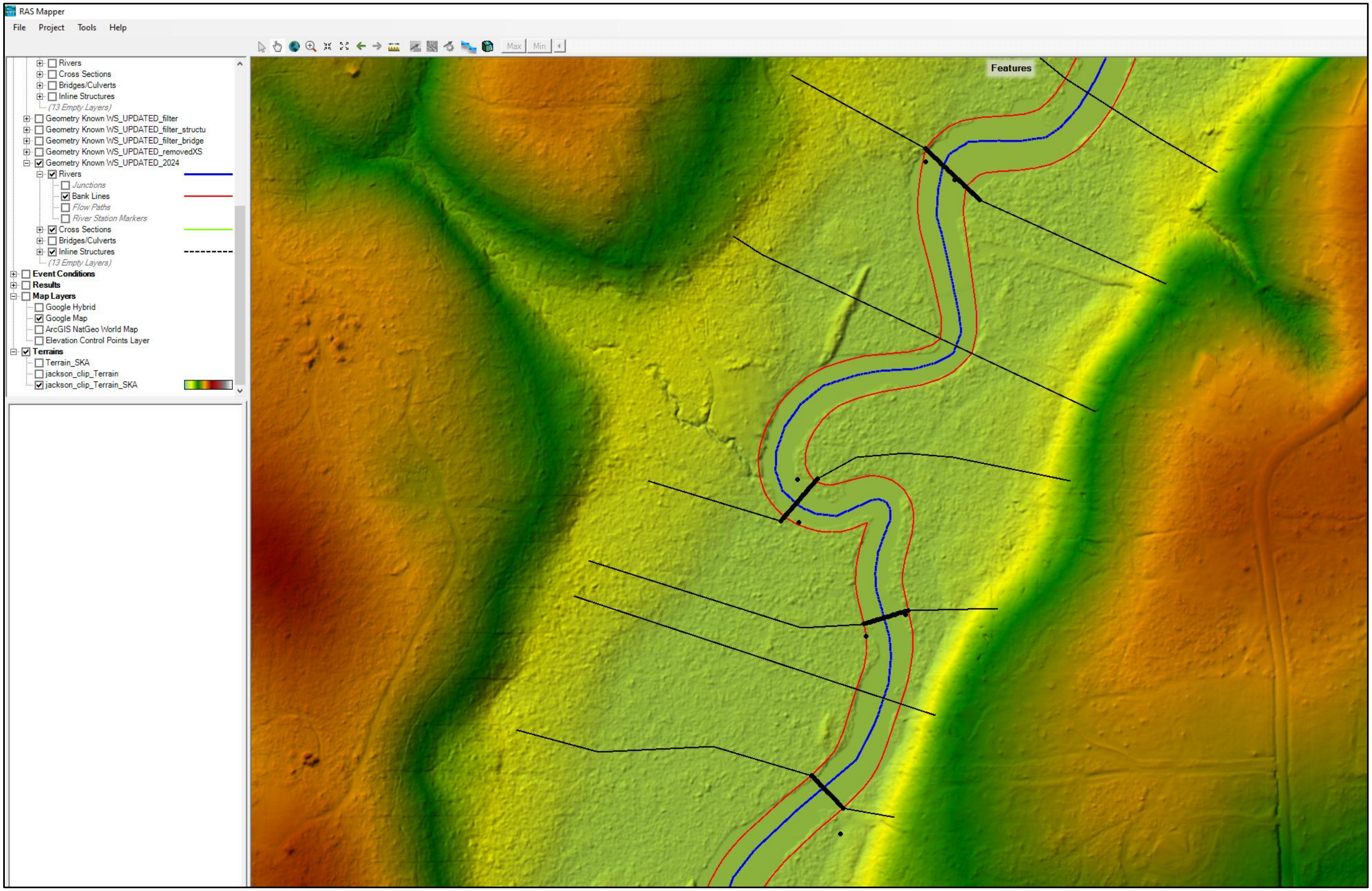

Figure 5: Digitization of Cross Sections Overlaying Survey Points in RAS Mapper

The four boundary conditions are as follows:

1. Jackson Blue Spring Discharge – inflow hydrograph at river station (RS) 26885 at the upstream boundary of the model;
2. Additional flow between Jackson Blue Spring and US 90 as measured at the Merritts Mill Pond @ US 90 gage, specified as a time-varying, uniform lateral inflow hydrograph between RS 25929 and RS 4901;
3. Merritts Mill Pond Control Structure Gate Openings – specified as a time series of Gate Openings at RS 4482.378 (inline structure); and
4. Chipola River Stage – downstream boundary condition stage hydrograph at RS 0.0247.

3.5 Evaluation of Stage- Discharge Relationships for Chipola River and Selection of Period of Record for Model Simulation for Calibration

An evaluation of potential changes to Chipola River stage-discharge relationships over time was conducted to determine an appropriate period of model simulation for calibration that reflects current riverine hydrodynamics and expected future conditions to ensure model results and simulations are protective of the system. Changes caused as a result of downed trees in the channel and floodplain from Hurricane Michael and subsequent debris removal were evaluated. Large amounts of debris fell into Merritts Mill Pond, Spring Creek, Chipola River, and surrounding floodplain areas from Hurricane Michael, causing changes to stage-discharge relationships within the Jackson Blue Spring MFL study area. Downed trees in the channel and floodplain resulted in less conveyance area, resulting in slower water velocities and increased river stage for a given flow. In hopes of restoring stage-discharge relationships to pre-hurricane conditions, debris was removed from portions of the main channels of Spring Creek and Chipola River. No debris removal was conducted in the floodplains.

Analysis of stage-discharge relationships at USGS station 02358789 Chipola River @ Marianna was conducted for three periods (Figure 6). Since this station represents the closest long-term USGS gauge to the Jackson Blue Spring MFL study, the following periods were defined from long-term trends and patterns observed at this station and were assumed to be indicative of the region, including Jackson Blue Spring, Merritts Mill Pond, and Spring Creek:

- Pre-hurricane conditions (pre 10/10/2018)
- Post-hurricane conditions prior to completion of debris clearing (10/10/2018-3/31/2019)
- Post-hurricane conditions after completion of debris clearing (4/1/2019 – present)

Review of Figure 6 shows substantial increases in stage for a given flow following Hurricane Michael as compared to historical conditions pre-hurricane. However, upon completion of debris removal in the Chipola River, the stage-discharge relationship returned to conditions similar to pre-hurricane historical conditions, although stages remain slightly elevated for a given flow, likely due to remaining debris in the floodplain.

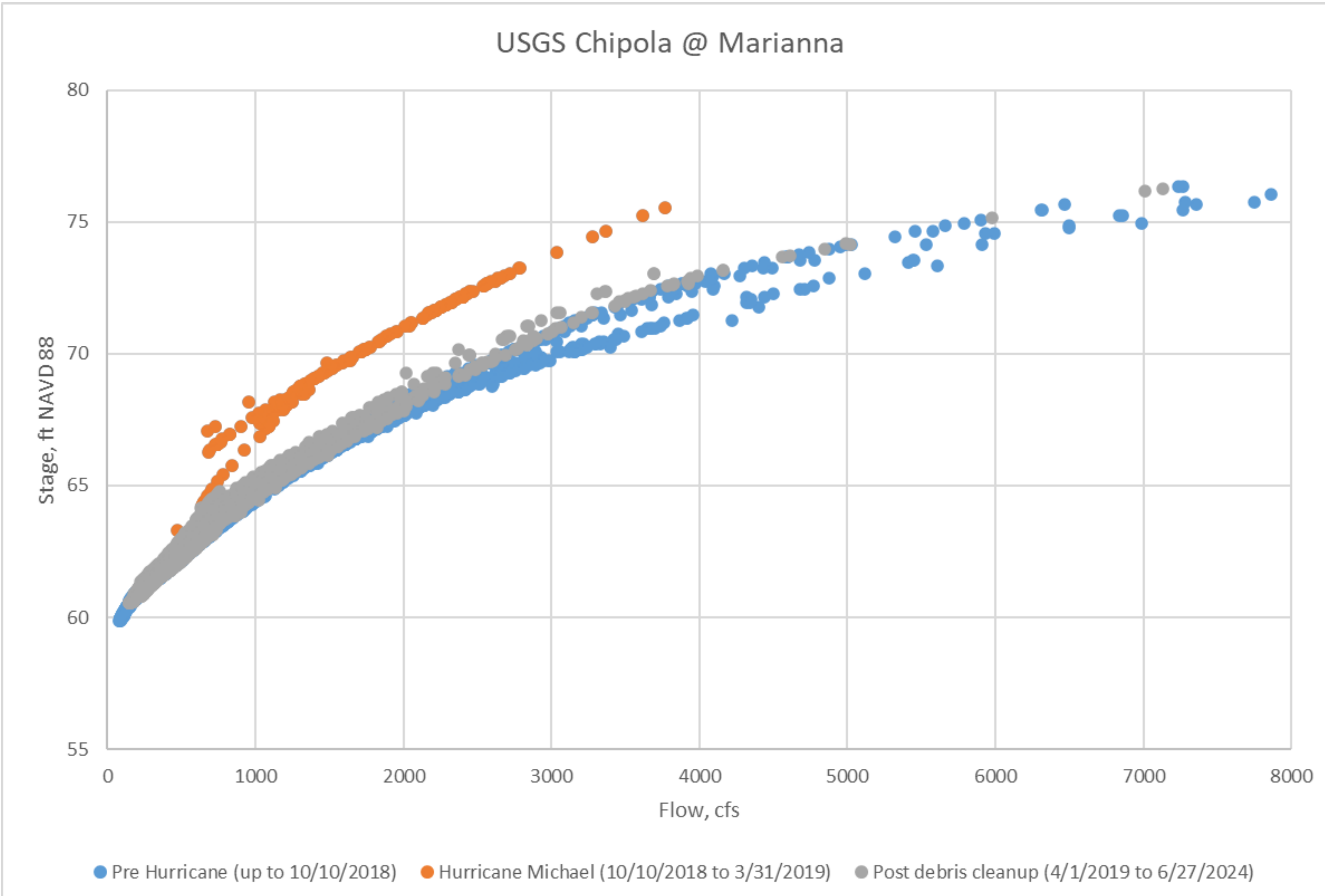

Figure 6: Comparison of Stage-Discharge Relationships for the USGS Station 02358789 Chipola River @ Marianna

Based on this evaluation, a model simulation period for calibration beginning on April 1, 2019, was determined to represent the current stage-discharge relationship for the Jackson Blue Spring system. This period is reflective of debris removal completion and recovery of the system to a stable rating following the impact of Hurricane Michael. Fluctuations in stage-discharge relationships will continue to be monitored for this system as it continues to recover from Hurricane Michael impacts, and floodplain and instream communities continue to recuperate.

3.6 Evaluation of Prior Model Files

NWFWMD provided files including previous versions of HEC-RAS models for the study area, memorandums, and supporting data analyses for work completed to date on August 2, 2023, to develop a stable HEC-RAS model for the Jackson Blue Spring System. The Jackson Blue Spring system HEC-RAS model provided by the NWFWMD was evaluated to determine the reason(s) for model instability and why it would not run to completion as constructed at that time. Given that a stable model did not exist, review of the existing model construction as well as the base data that formed the input data for the model was needed. This task included review of existing model construction and supporting base data, modifications of the existing model where required, and the performance of simulations to achieve a stable, fully executing model. All work was performed using HEC-RAS Version 6.4.1.

Test runs of the model as received were performed to begin diagnosing sources of the model instability. Initial findings based on a 1-month simulation period indicated instabilities in the model reach near the railroad bridge on Spring Creek. This particular model run used a model geometry that did not include the US 90 bridge and had a gate opening of 0.1 ft at the Merritts Mill Pond control structure. Simulations using provided geometry files that included the US 90 bridge crashed almost immediately and were not useful for model diagnostics.

Review of the files revealed the following issues:

1. The unsteady HEC-RAS model, as received from NWFWMD, was not stable and would not run to completion for the set time domain;
2. Uncertainty in the operation history of the control gate at the end of Merritts Mill Pond based on review of operator logs and debris accumulation at the fish barrier; and
3. Limited time periods for calibration and verification in which hydrologic data and available and reliable gate operations records were available.

3.7 Field Reconnaissance

Field reconnaissance was performed December 6 and 7, 2023, to gather insights on the system and to further inform the model diagnostic, construction, and calibration tasks. In preparation for the field reconnaissance, ATM specified the HEC-RAS cross sections to review along the approximately 6.1-mile reconnaissance trip area. The area of the reconnaissance is shown in Figure 7.

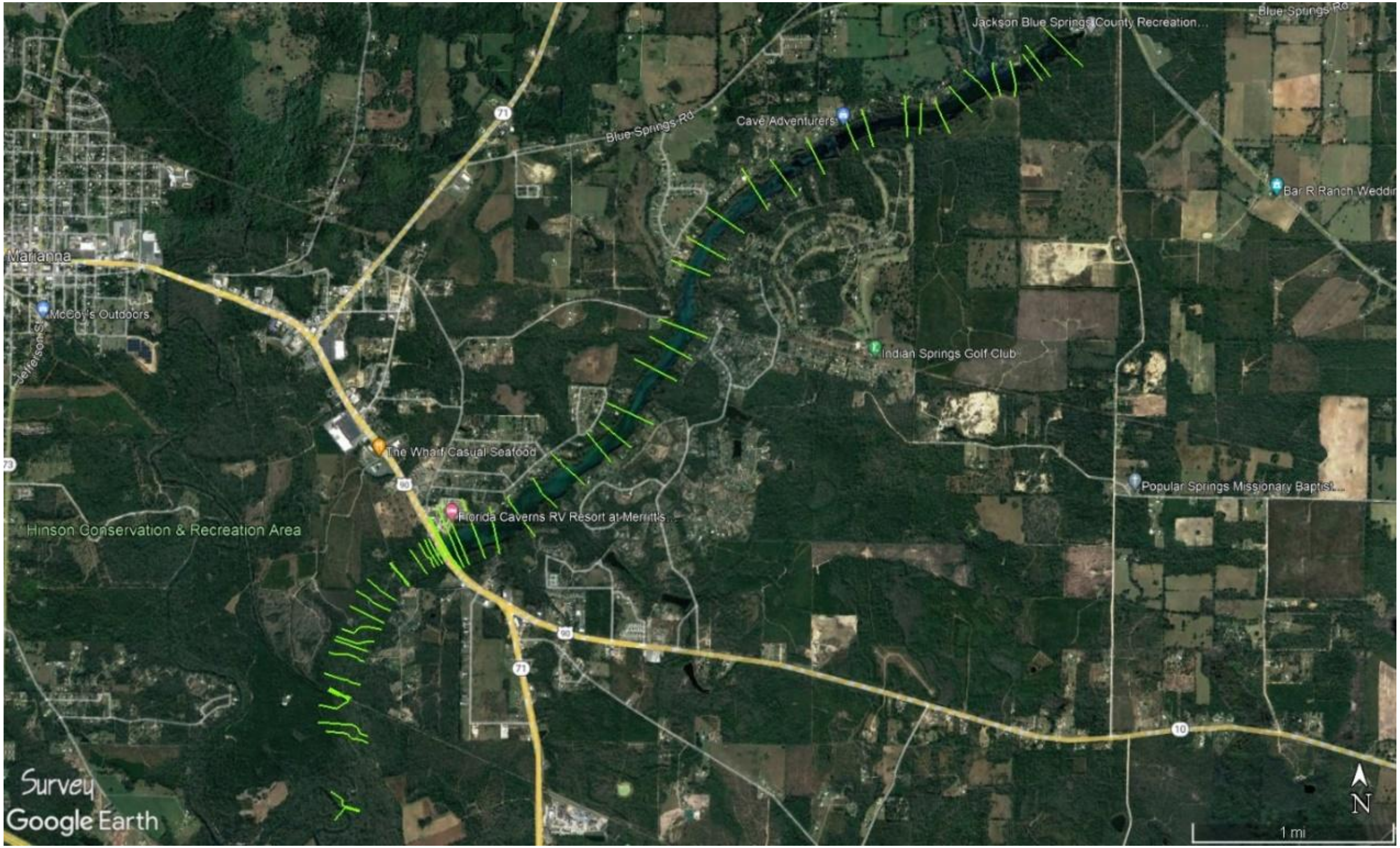

Figure 7: Jackson Blue Spring System Field Reconnaissance including HEC-RAS Cross Sections

ATM, along with NWFWMD staff, conducted a field reconnaissance of Jackson Blue Spring/Merritts Mill Pond/Spring Creek System, inspection of Merritts Mill Pond control structure, and kayak trip down the Spring Creek system. Objectives of the field reconnaissance trip included review of gate operations to determine appropriate modeling parameters and assumptions regarding gate operation and physical representation in the model, assessment of vegetation and substrate characteristics along Spring Creek and Merritts Mill Pond to accurately depict channel and floodplain roughness and channel geometry, and review of cross section assumptions in the vicinity of the railroad crossing along Spring Creek. Figure 7 presents the extent of the field reconnaissance along with the location of HEC-RAS cross sections.

The Merritts Mill Pond Control Structure @ US 90 was one of the focal points of the reconnaissance. Prior to beginning the kayak trip, a meeting was held with Rett Daniels (Deputy Administrator, Field Operations, Jackson County Public Works) at Spring Creek Park to discuss the operation of the control structure at US 90, operational record keeping, and his observations of water levels in Merritts Mill Pond. He noted that they have had the gates closed most of the time and were not able to raise water levels in Merritts Mill Pond as high as they have in the past. Given the goal of trying to keep water levels high, he did not anticipate opening the gate in the foreseeable future.

The control structure at the pond outlet consists of a modified rectangular notch weir over three sluice gates. A fish barrier just upstream of the weir and gates serves to limit downstream migration of fish. Periodically, the fish barrier is lifted and cleaned to remove accumulated vegetative matter and other debris. Figure 8 presents a view from Spring Creek of the control structure at US 90. Figure 9 presents a view of the control structure from US 90 (looking downstream). Figure 10 presents an as-built drawing of the control structure details.

Water levels in Spring Creek were not high during the December 6, 2023, field reconnaissance, with observed depths ranging from 1 to 3 ft for most of the creek. The general conditions were that the creek channel seemed to be wider and shallower than historical observations of District staff and Mr. Daniels. The goal of the kayak trip was to observe the general characteristics of the channel geometry and its representation in the HEC-RAS model, occurrences of very shallow locations, noted locations of inflows, and flow characteristics of Spring Creek. Photos taken during the course of the trip are contained in the companion .kmz file previously submitted to the District, and photo locations are shown in Figure 11. Figure 12 and Figure 13 illustrate the general character of Spring Creek. Observations of note were as follows.

- The Spring Creek channel is generally shallow, with some locations shallow enough that the kayaks ran aground due to the shallow depths, making navigation more challenging.
- There was one small surface water inflow into Spring Creek, north of the railroad bridge. It appeared to be a small tributary inflow, with a flow rate estimated to be about 0.5 cfs.

Figure 8: Merritts Mill Pond Control Structure @ US 90 (Date of Photo: December 6, 2023)

Figure 9: View of Merritts Mill Pond Control Structure from US 90 (Date of Photo: December 6, 2023)

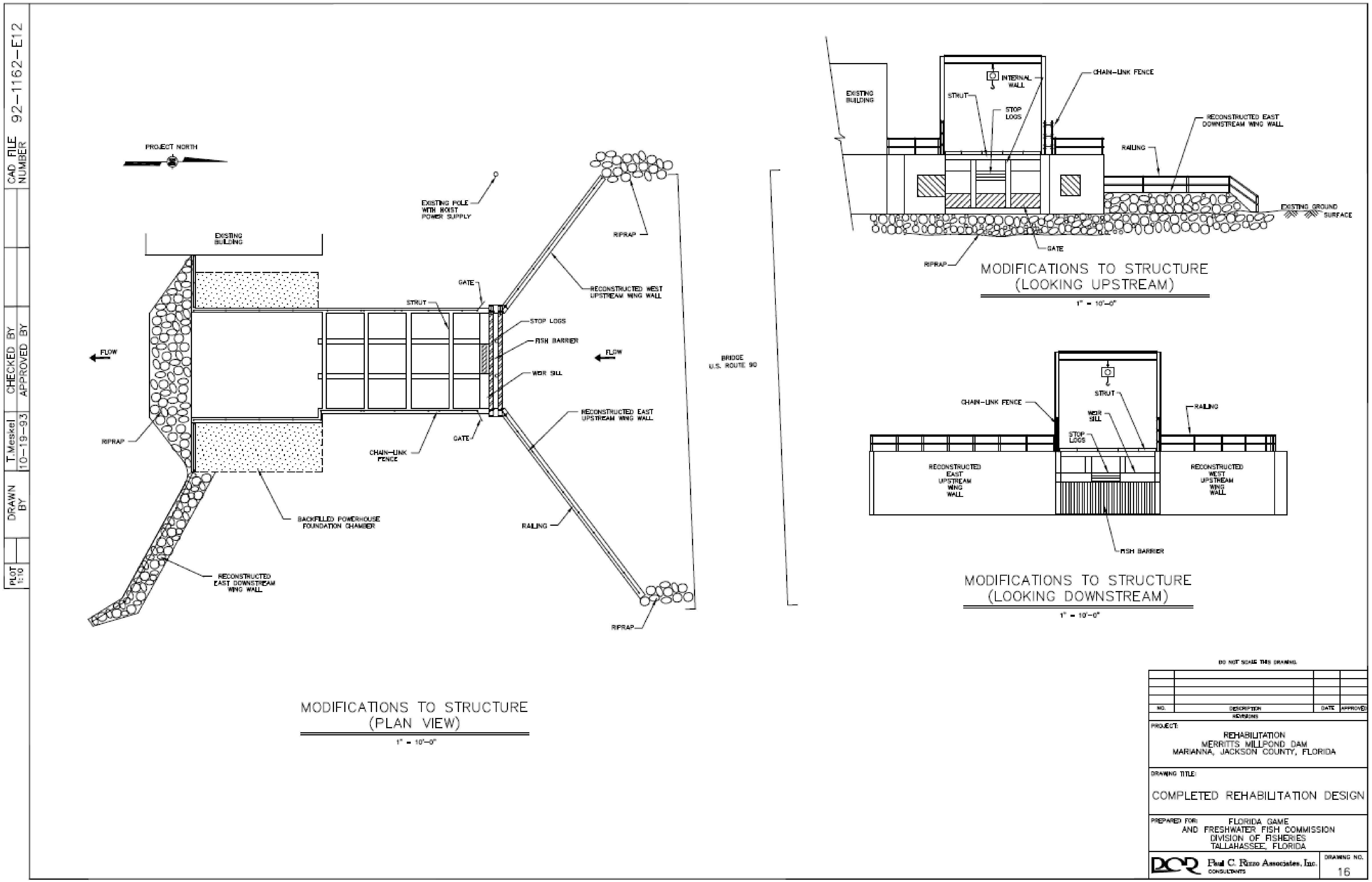

Figure 10: As-Built Drawing of Merritts Mill Pond Control Structure

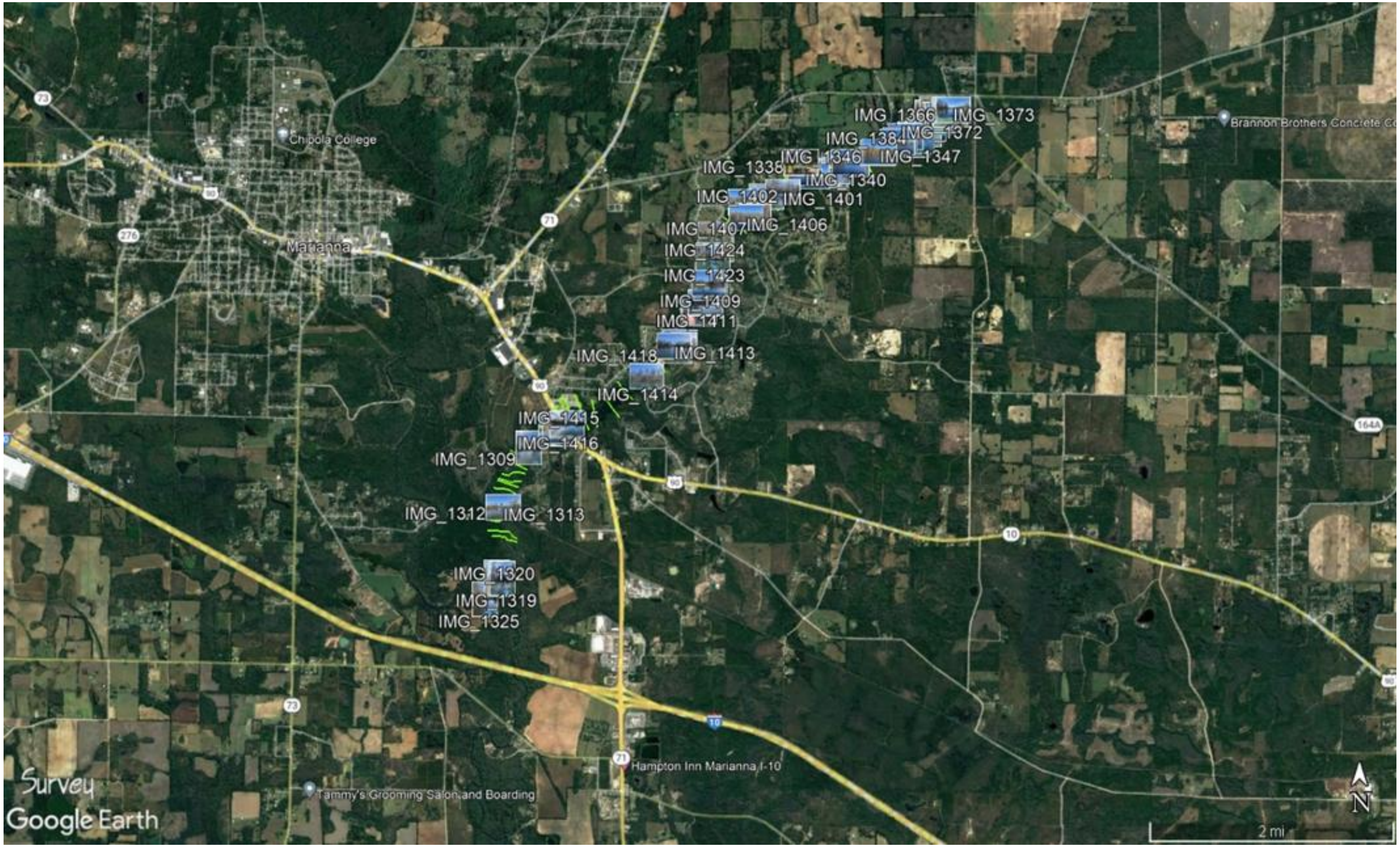

Figure 11: Locations of Photographs Taken during the December 6 and 7, 2023, Field Reconnaissance
A companion kmz file allows for detailed viewing of photo location and the image itself.

Figure 12: Spring Creek during the December 6, 2023, Field Reconnaissance

Figure 13: Spring Creek Approaching Chipola River

- Changes in the flow characteristics (reduced velocities and greater water depths) in Spring Creek were noted approaching the railroad bridge due to the backwater influence of the Chipola River.
- There were locations in the Spring Creek channel where velocity noticeably increased, indicating the possibility of sub-critical/super-critical flow conditions, depending on water levels in Spring Creek and the Chipola River. These were typical in locations where a sill or lime rock was near surface.

A reconnaissance of Merritts Mill Pond from Jackson Blue Spring to the US 90 bridge was performed via pontoon boat on December 7. Merritts Mill Pond measures approximately 4.3 miles in length from its headwaters at Jackson Blue Spring to the outfall into Spring Creek and has an average width of about 500 ft. Depths are generally in the 10-ft to 12-ft range. A number of photos taken during the reconnaissance are contained in the previously described companion .kmz file. Figure 11 shows the reconnaissance study area, along with locations where photographs were taken.

The goal of the reconnaissance was to get general observations of Jackson Blue Spring (Figure 14) and Merritts Mill Pond and to confirm that the model reflects the physical system observed with respect to channel geometry, inflow characteristics, and bottom and bank vegetation communities and includes important flow control points such as shallow areas and control structures. A number of known springs were located (Figure 15).

The reconnaissance supported the conclusion that the shallowness of Spring Creek was the primary cause of the model instability. Evaluation of the computed energy grade line over time in Spring Creek confirmed that at certain locations, particularly around the railroad bridge, flow was varying between sub-critical and supercritical state, as evidenced by the Froude number (Fr). The Froude number is the dimensionless ratio of the inertial and gravitational forces and is used to determine what flow state is present (Critical: Fr=1, Sub-critical: FR<1, Super critical: Fr>1). Figure 16 presents an example of the longitudinal plot of Froude number versus channel length at one point during the simulation. Running HEC-RAS model in "mixed flow mode," which is useful when flow can vary rapidly between sub-critical and super-critical, was employed and resulted in stabilizing the model. Further investigation indicated that the shallowest cross section at the railroad bridge was neither a surveyed cross section nor part of a previous HEC-RAS model. This cross section was modified so that the minimum elevation was approximately equal to the adjacent cross sections, which were surveyed sections. After this change and some further testing, the model could be run in sub-critical mode, as well as in mixed-flow mode. This allowed for a more complete evaluation of model performance after these modifications were made to the model.

Figure 14: Merritts Mill Pond Approaching Jackson Blue Spring

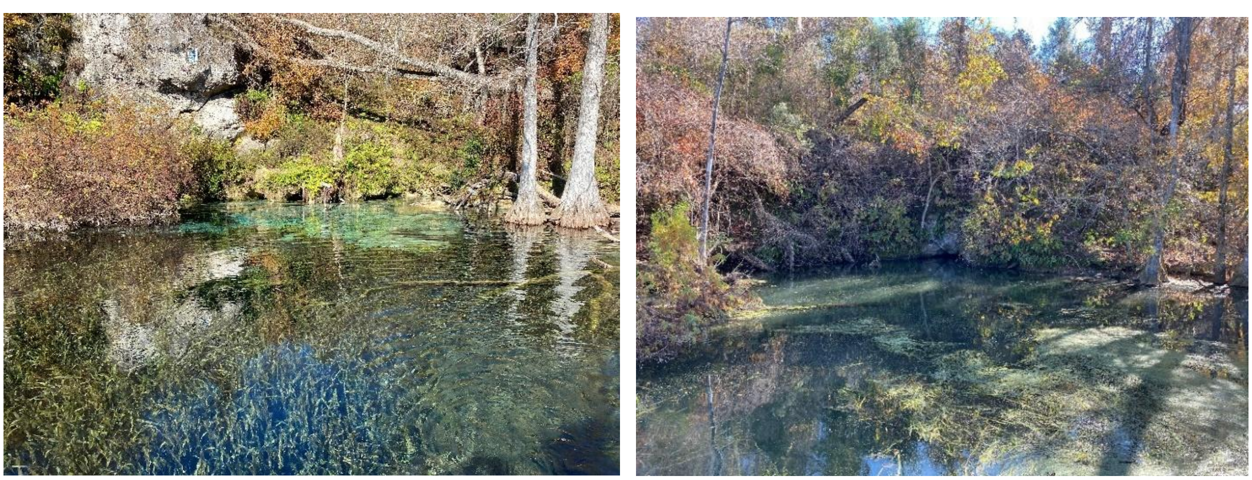

Figure 15: Minor Springs in Merritts Mill Pond

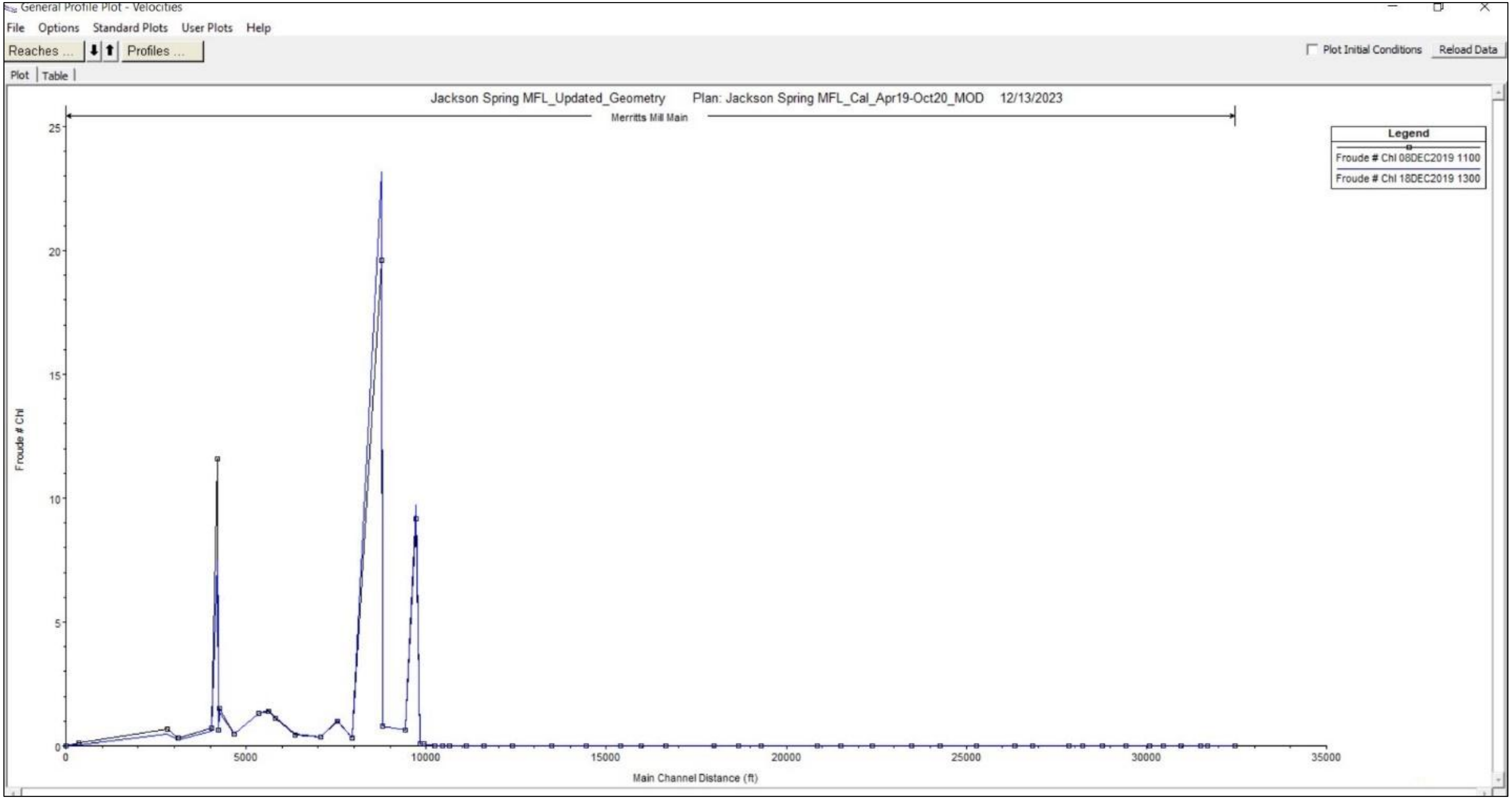

Figure 16: Plot of Froude Number vs Channel Distance For Simulation Time December 8, 2019 at 1100 and 1300 hrs

4. MODEL SIMULATION PERIOD, BOUNDARY CONDITIONS, AND ADDITIONAL MODIFICATIONS

Following the evaluation of model performance and diagnosis of instability issues, several modifications to the model input data were completed. The unsteady flow file was revised so that model boundary conditions including flow, stage, and gate operations time series could be read from a HEC-DSS file (JacksonBlueMFL_2024.dss). Additions to the DSS file included the updated Jackson Blue Spring discharge record, Chipola River at the mouth of Spring Creek stage record, and the gate operations record. A uniform lateral inflow hydrograph time series was created by subtracting Jackson Blue Spring discharge hydrograph from the measured discharge hydrograph upstream of the US 90 bridge (Merritts Mill Pond @ US 90 station). The resulting time series was imported into the DSS file as a uniform lateral inflow hydrograph boundary condition between the spring boil and the US 90 bridge. In this case, uniform means that the lateral inflow rate (inflow per unit distance along the reach, in units of cfs per foot) is the same at all locations during a given model time step along the model reach between Jackson Blue Spring and the gage at US 90. Details of the model modifications performed are discussed below.

The District provided all stage and flow data that had been compiled previously, including an updated Jackson Blue Spring discharge record. The data were reviewed to check for unit and time zone consistency and representation in the model, including interpolation techniques used to fill in small data gaps and to generate 15-minute time series from daily averages. All other base data used to develop boundary conditions remained unchanged from that previously provided to ATM. ATM confirmed with District staff that all source flow and stage datasets were accurate and current prior to evaluation.

The Merritts Mill Pond control structure was assessed to confirm structure physical dimensions and representation in the model, including overflow/invert elevations. This was accomplished by comparing structure rehabilitation plans and as-builts provided by the District to existing model representation. Review of the plans and as-built documents indicated that all information needed to incorporate the control structure as an inline structure in HEC-RAS was present. Therefore, additional surveying of the control structure was not required.

Associated cross sections upstream and downstream of the control structure were assessed to ensure their location with respect to the structure met HEC-RAS guidelines, and ineffective flow area definitions were added. Weir and gate discharge coefficients and exponents for the control structure were reviewed, and minor adjustments were made based on field observations and professional judgment. Additional adjustments would be made during model calibration.

The US 90 bridge was added to the geometry file, which included adding required upstream and downstream cross sections to support the inclusion of the bridge and its interaction with the control structure. Ineffective flow areas were defined, particularly around the US 90 bridge and the control structure.

Modifications were made in the Spring Creek portion of the model in which the location of in-channel and overbank areas of some cross sections were adjusted to better match both field surveys and observations. After these changes were made, modifications to Manning's n coefficients were made at all cross sections (0.03 in-channel, 0.08 overbank). These values reflect a somewhat straight and clean channel and were chosen for the initial test runs. These values would be adjusted later as part of model calibration.

Figure 17 presents the overall model schematic. The model contains 57 cross sections, one bridge (US 90 bridge), one inline structure (US 90 Control Structure), and four boundary conditions (three flow, one stage, described further in the text below). Figure 18 presents a zoomed-in view of the model schematic around the US 90 bridge (shown in gray) and water control structure (black line immediately downstream of US 90).

The railroad bridge located on Spring Creek near the Chipola River was not included in the model because bridge details were not surveyed. However, the immediate upstream and downstream cross sections at the bridge were surveyed. Given the high elevation of the bridge low chord and the minimal channel constriction at the bridge, it was deemed likely that the actual bridge would affect flow only during the most extreme high flow events.

4.1 Simulation Time Periods

The District provided an analysis of available data from which model simulations could be performed. Review of the input data, which included Jackson Blue Spring discharge, Merritts Mill Pond @ US 90 discharge, and Chipola River stage at the US 90 gage, confirmed limited time periods from which concurrent flow and stage data were available. Time periods when concurrent data for discharge and water surface elevation (WSE) were available are presented in Table 2. Table 3 presents the time periods when gate operations data were available

Table 2: Time Periods of Concurrent Discharge and Water Surface Elevation (WSE) Data

Data	Start Date	End Date	Days
Discharges and WSE	4/1/2019	10/10/2020	558
Discharges and WSE	12/17/2020	3/30/2021	103
Discharges and WSE	6/8/2021	6/23/2021	15
Discharges and WSE	9/22/2021	10/9/2021	17
Discharges and WSE	10/25/2021	2/23/2022	121

Table 3: Time Periods of Available Gate Operations Records

Data	Start Date	End Date	Days
Gate	11/1/2019	4/30/2020	181
Gate	6/1/2020	7/31/2020	60
Gate	9/1/2020	10/31/2021	425
Gate	1/1/2022	4/30/2022	119

The period from April 1, 2019, through October 10, 2020, was the longest time period of concurrent data available and was used to demonstrate that the constructed model would run successfully and was able to be calibrated. However, this entire period did not have complete gate operations records for specifying gate conditions in the model. Therefore, estimating missing gate operations was necessary, which is discussed in Section 6.1, Model Calibration.

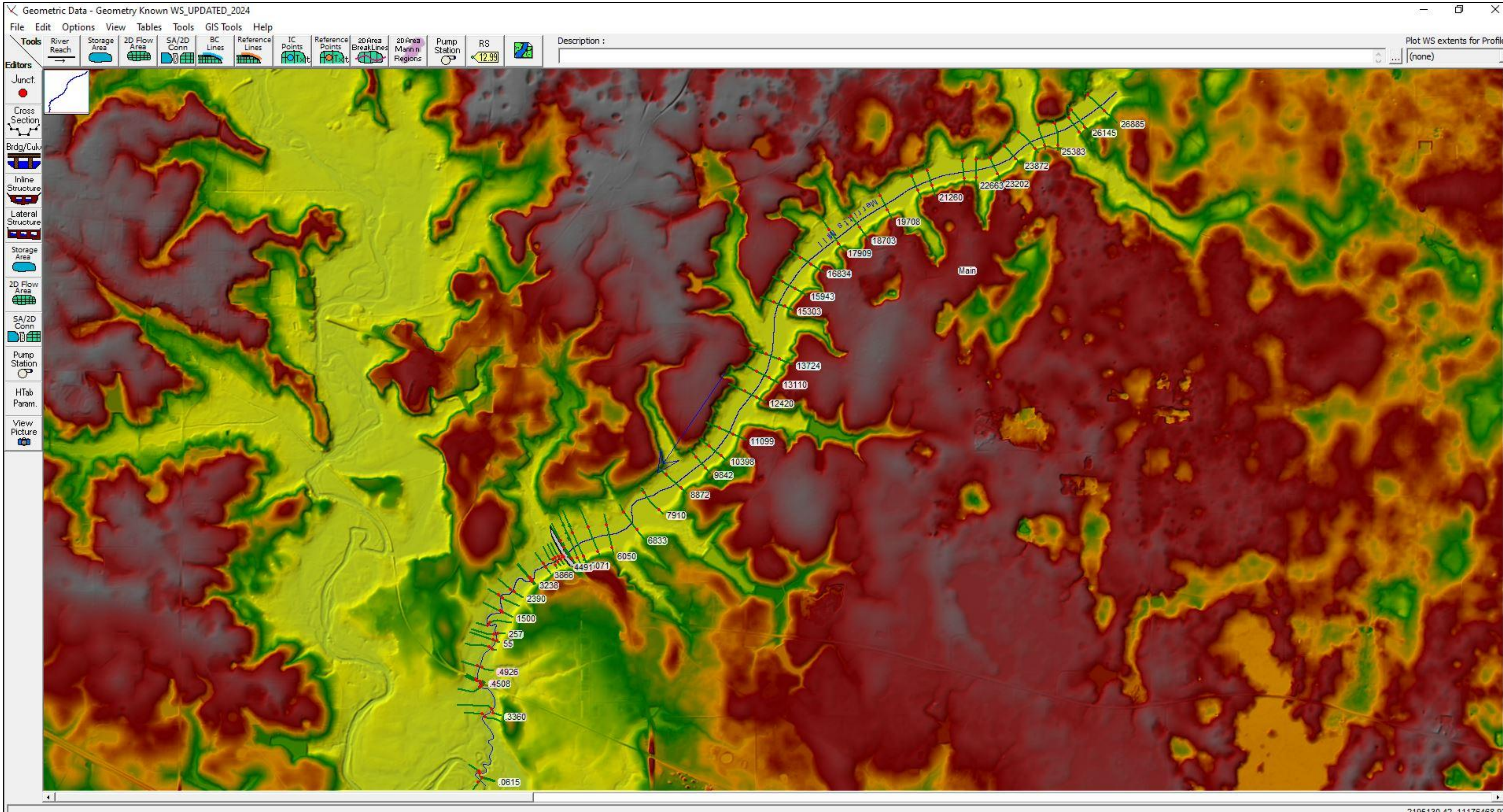

Figure 17: Jackson Blue Springs System HEC-RAS Model Schematic

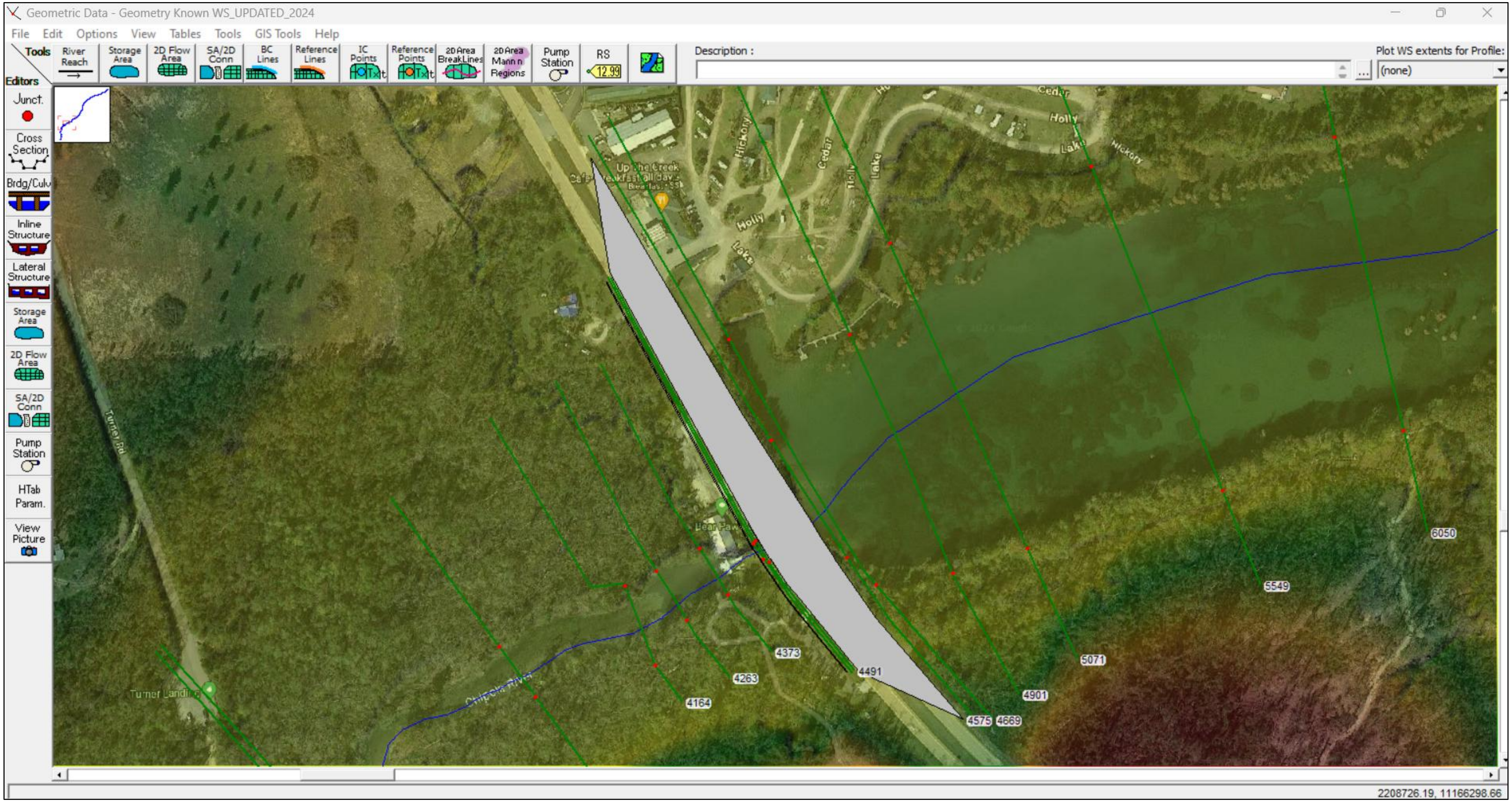

Figure 18: Jackson Blue Springs System HEC-RAS Model Schematic showing the US 90 Bridge and Merritts Mill Pond Control Structure

4.2 Boundary Conditions

Four boundary conditions, three flow and one stage, used in the model setup are contained in the model DSS file (JacksonBlueMFL_2024.dss). The four boundary conditions are as follows:

1. Jackson Blue Spring Discharge – inflow hydrograph at HEC-RAS RS 26885 at the upstream boundary of the model;
2. Additional flow between Jackson Blue Spring and US 90 as measured at the Merritts Mill Pond @ US 90 gage, specified as a time-varying, uniform lateral inflow hydrograph between RS 25929 and RS 4901;
3. Merritts Mill Pond Control Structure Gate Openings – specified as a time series of Gate Openings at RS 4482.378 (inline structure); and
4. Chipola River Stage – stage hydrograph at RS 0.0247.

The boundary conditions are discussed in more detail in the following sections.

4.2.1 Jackson Blue Spring Inflow Boundary Condition

Jackson Blue Spring discharge is an updated time series of daily discharge values provided to ATM by the District. This time series was subsequently converted to a 15-minute discharge time-series using HEC-DSS tools for input into the HEC-RAS model. The resultant 15-minute time series is presented in Figure 19 for the period of concurrent discharge and stage data.

4.2.2 Chipola River Downstream Stage Boundary Conditions

The Chipola River stage at the Spring Creek confluence serves as the downstream boundary condition for the HEC-RAS model. The District established a stage gage at this location called the "above Spring Creek" gage. The period of available data extends from 16:45 on September 23, 2020, to April 5, 2022. These data included one short period (less than 1 hour) of missing data on January 20, 2022, which was filled in using linear interpolation. These data also included a long period of missing data between March 3, 2021 at 19:00 and July 1, 2021 at 19:50. A method was developed to estimate missing data on the basis of measured water surface elevations at the USGS gage 02358789 Chipola River at Marianna, which is about 5 miles upstream from the District's above Spring Creek gage (Verdantas, 2022). The resultant time series is presented in Figure 20.

4.2.3 Merritts Mill Pond Internal Lateral Inflow Boundary Condition

Merritts Mill Pond lateral inflow between Jackson Blue Spring and the US 90 bridge occurs due to groundwater seepage, discharge from minor spring vents, and during larger storm events that contribute surface runoff to the pond. The Merritts Mill Pond @ US 90 gage measured stage and discharge at the US 90 bridge. Figure 21 presents a comparison of 15-minute flow time series for Jackson Blue Spring and the Merritts Mill Pond @ US 90 gages.

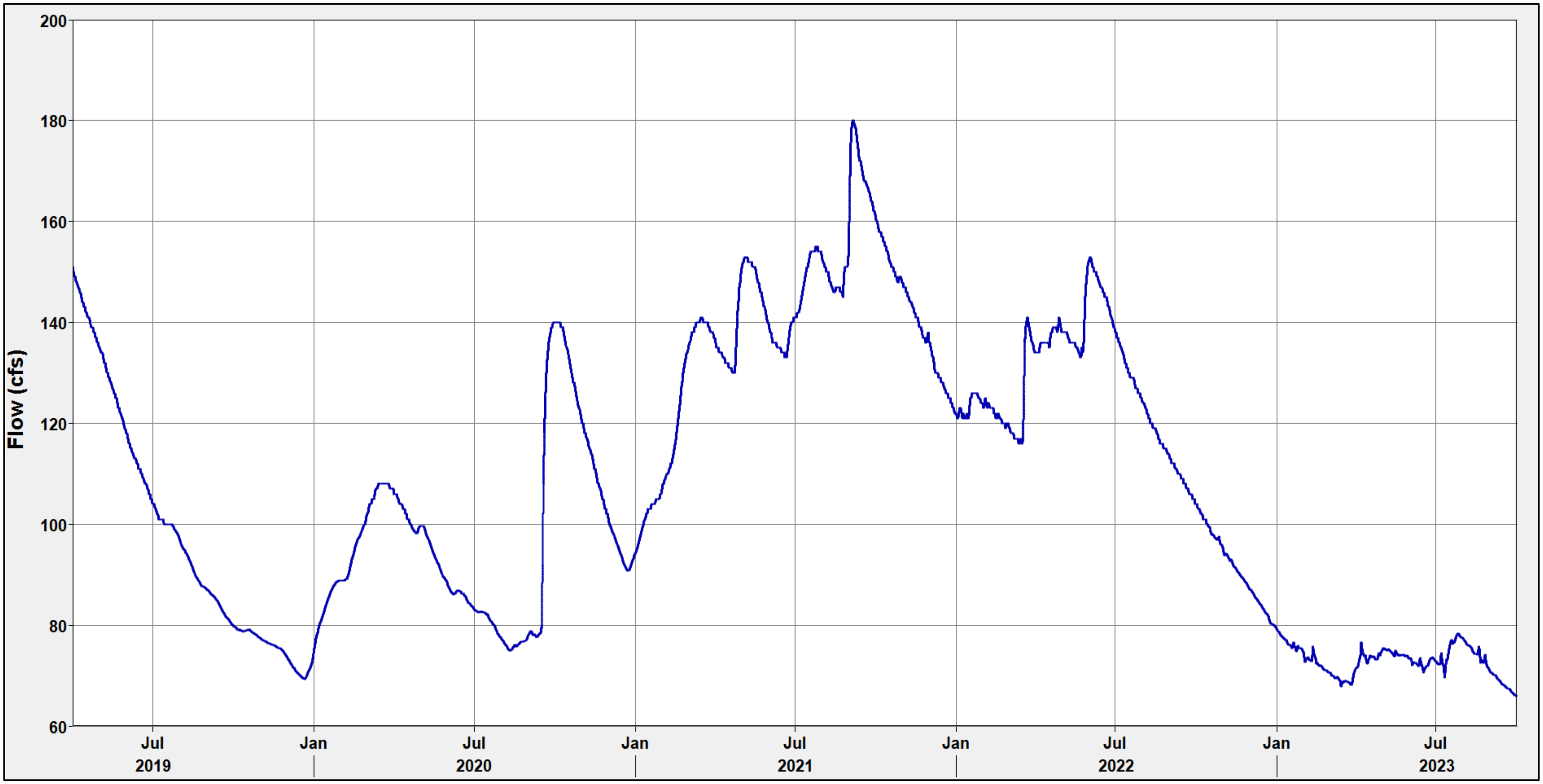

Figure 19: Jackson Blue Spring Discharge, April 1, 2019 – September 30, 2023

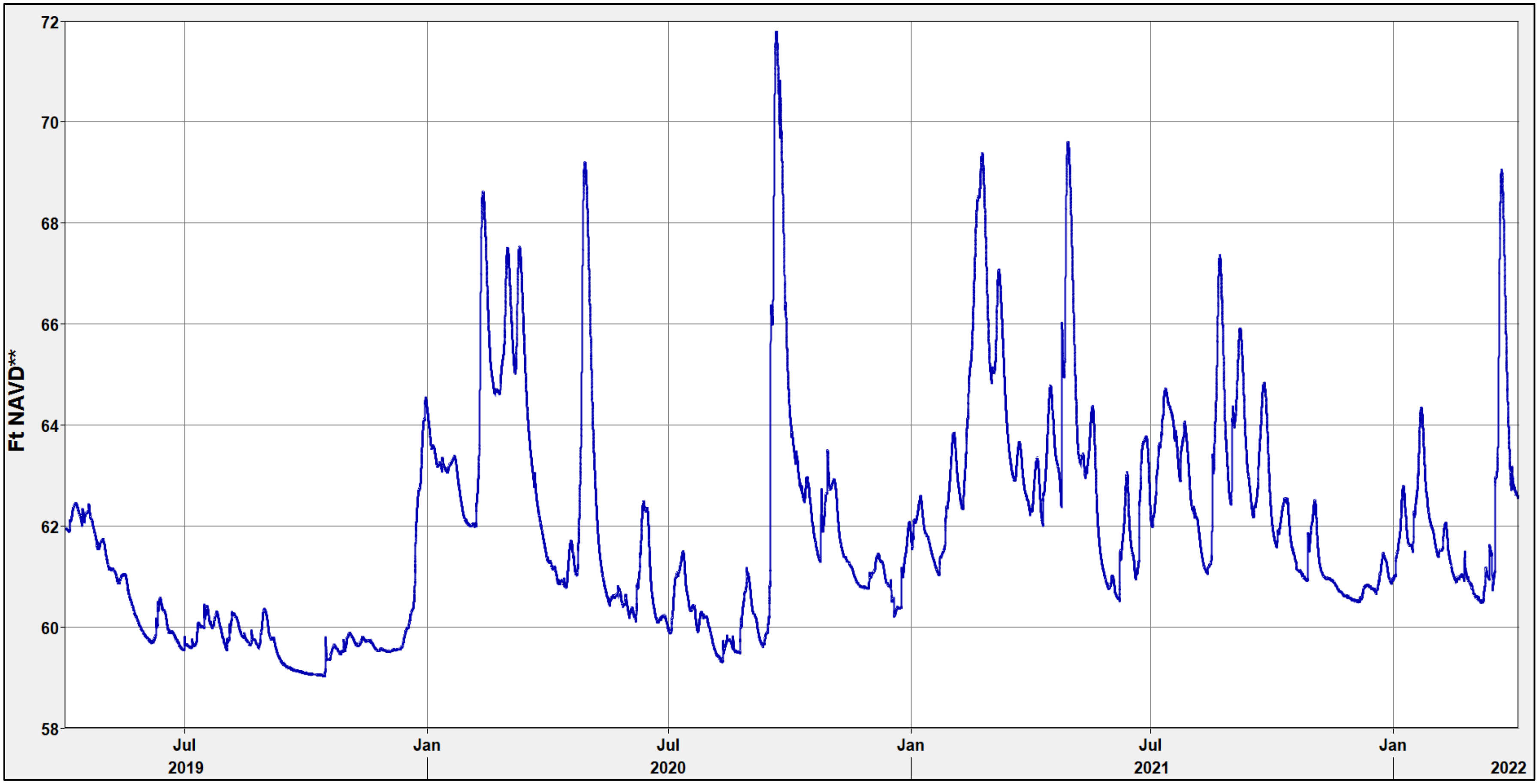

Figure 20: Chipola River Stage at the Confluence with Spring Creek (April 1, 2019 – April 5, 2022)

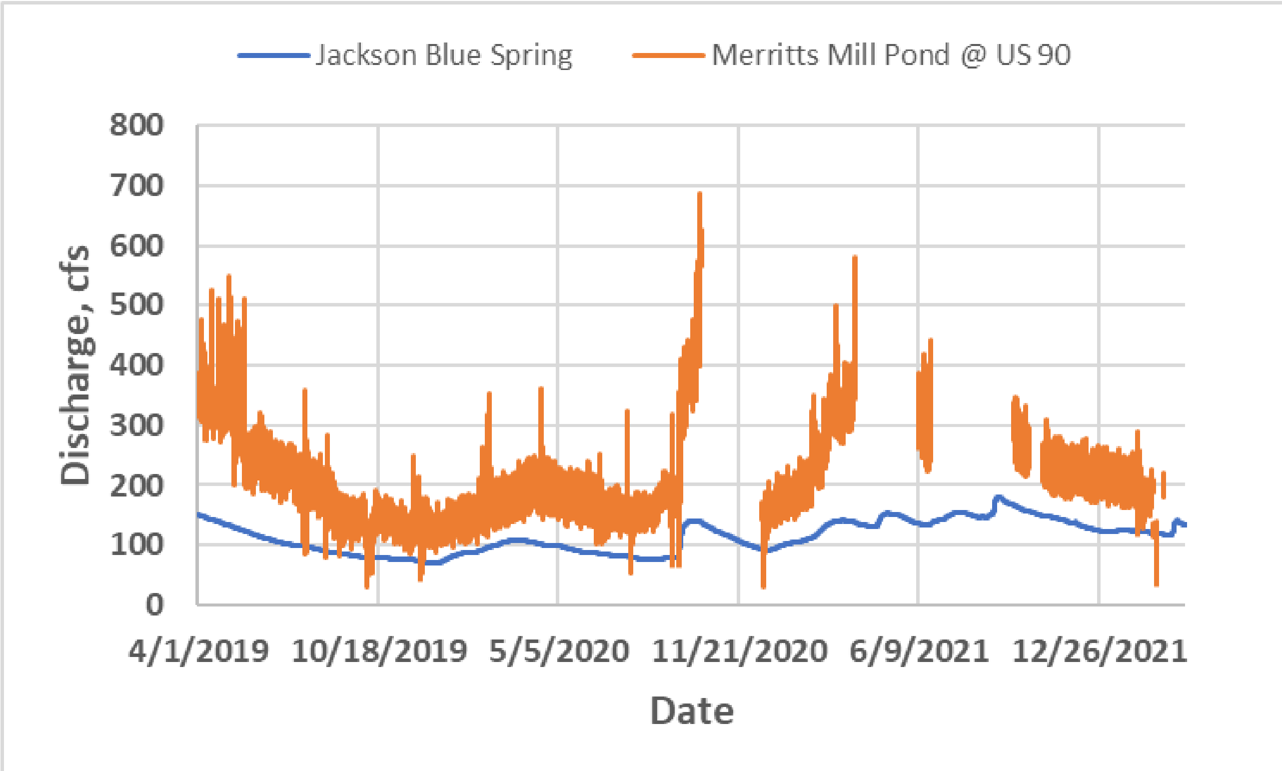

Figure 21: Measured Discharge at the Jackson Blue Spring and Merritts Mill Pond @ US 90 Gages from April 1, 2019, to April 1, 2022

The measured discharge at the Merritts Mill Pond @ US 90 gage comprises inflows from groundwater discharge/seepage and surface runoff during normal gate operations when Merritts Mill Pond stages are not changing rapidly. The measured discharge is also affected by the gate operations and the height of the gate openings, as well as turbulence as water approaches the control structure. During periods when the gate is opened dramatically, measured flow can suddenly increase substantially, causing more rapid declines in Merritts Mill Pond water levels. It is during such times when water storage changes in Merritts Mill Pond contribute more to the discharge measured at the Merritts Mill Pond @ US 90 gage.

Given the complexities of the various flow components, the difference in discharge measurements was incorporated as an internal boundary condition as a uniform lateral inflow hydrograph. The difference in measured discharges at the Merritts Mill Pond @ US 90 gage and Jackson Blue Spring was input as a uniform lateral inflow hydrograph between the edge of the Jackson Blue Springs pool (RS 25929) and the US 90 bridge (RS 4901), covering 21,028 ft. During consistent and non-extreme gate operations, this approach is a reasonable approximation of the flow contributions between the Jackson Blue Spring and the US 90 bridge and still allows for the measured stage at the Merritts Mill Pond @ US 90 gage to be used as a calibration target. It should be noted that during rapidly changing conditions in which the gate is opened dramatically, the rapid flow change can result in some flow imbalances and possible model instability. Figure 22 presents the resulting flow time series that was input as a uniform lateral inflow hydrograph internal boundary condition. The spikiness/noisiness of the time series is largely due to turbulence near the gage sensor (velocity meter) and is also affected at times by wind-induced fetch, which can push water in Merritts Mill Pond toward or away from the gage sensor. Figure 23 compares the flow measured at the Merritts Mill Pond @ US 90 gage and the simulated flow at that location (RS 4669) during model testing. The smoothing of the simulated hydrograph as compared to the measured flow hydrograph is largely due to the attenuating effect of Merritts Mill Pond.

4.2.4 Gate Operations Record @ US 90 Control Structure

Gate operations logs were received from Jackson County and provided to the District and ATM. Figure 24 presents an example of one month of gate operations logs. The logs were converted into a time series for incorporation into the DSS file for the model calibration period. Inconsistent nomenclature in operation logs resulted in uncertainty in determining gate opening magnitudes for portions of the calibration period. However, Jackson County staff confirmed all gate operations provided are accurate. The conversion of the gate operation logs into a time series for import into the DSS file revealed some issues with the record keeping that made completion of this time series challenging and sometimes confusing. First, there was not a standard nomenclature used (e.g., 3", bottom, bottom +10", raised main gate 3", raised main gate 2" to 14, open,). This made it difficult to know with certainty what the actual magnitude of the gate opening was when the starting point was not known, or a word description was used, and how to interpret the entries. This was more of an issue in the early part of the record than the latter part of the record, because Jackson County corrected these issues.

The number of gaps in the operations record prevented the inclusion of a long record and limited available time periods for subsequent model calibration and verification tasks. These apparent limitations of the gate operations record create challenges to performing a proper model calibration. Additionally, the gate contains a fish barrier screen through which flow passes most of the time. This screen is periodically lifted to clear debris from behind the gate. Cleaning occurs on average 2 to 3 times per month but is somewhat dependent on the rate of debris accumulation. Flow through the fish barrier will have larger losses than flow through the opening when the barrier is raised. Review of the Merritts Mill Pond stage hydrograph during times when cleaning of the fish barrier was recorded in the operations log indicates a drop in stage of 0.25 to 0.40 ft following lifting the fish barrier. In the interim periods between cleaning, the resistance to flow through the fish barrier would gradually increase as debris is collected. These dynamically changing losses were not modeled in this HEC-RAS simulation, which limited the ability of the model to simulate stages at the US 90 gage during and shortly after the barrier is raised or lowered, thereby creating additional challenges when calibrating the model.

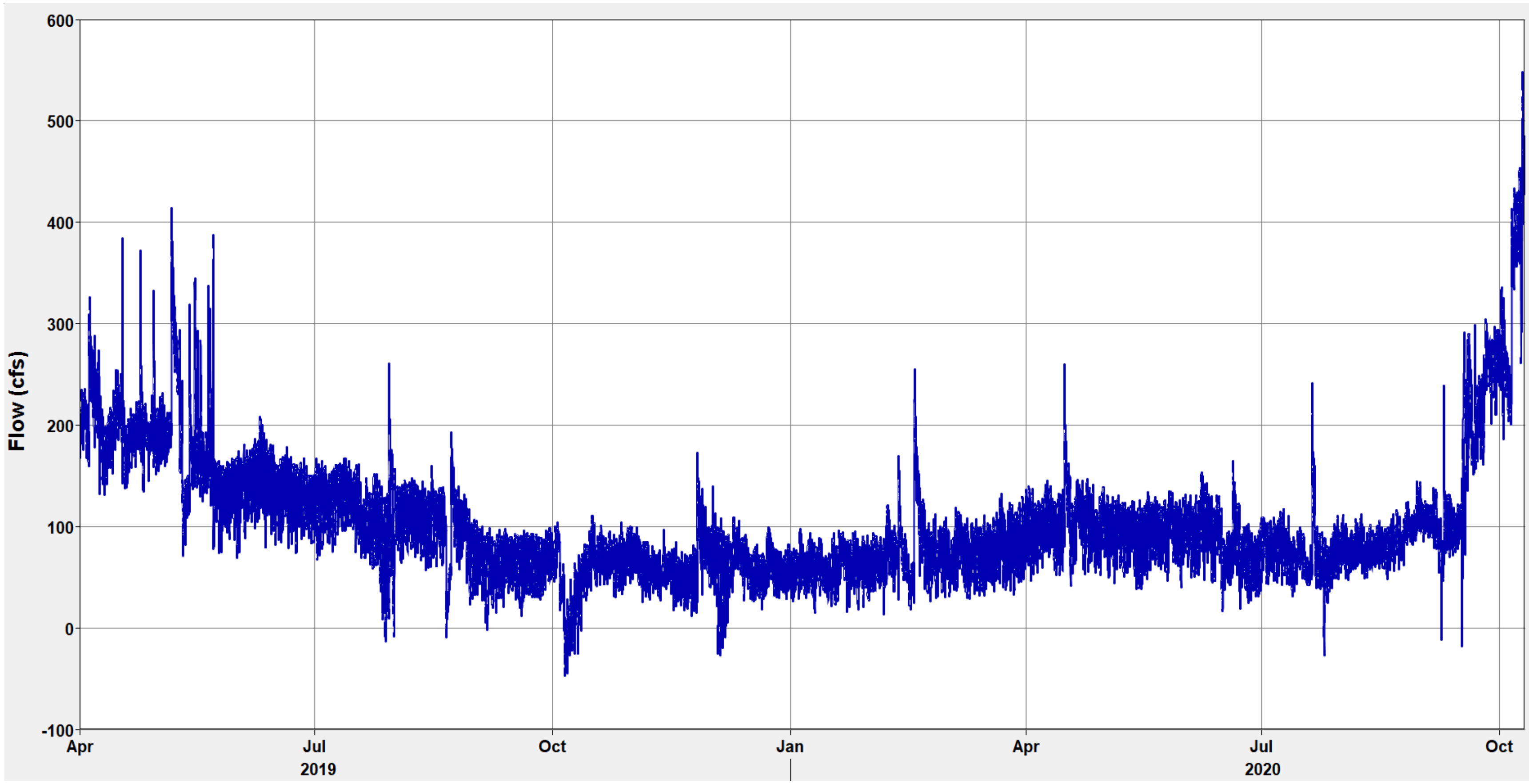

Figure 22: Uniform Lateral Inflow Hydrograph Internal Boundary Condition for Merritts Mill Pond (April 1, 2019 – October 10, 2020)

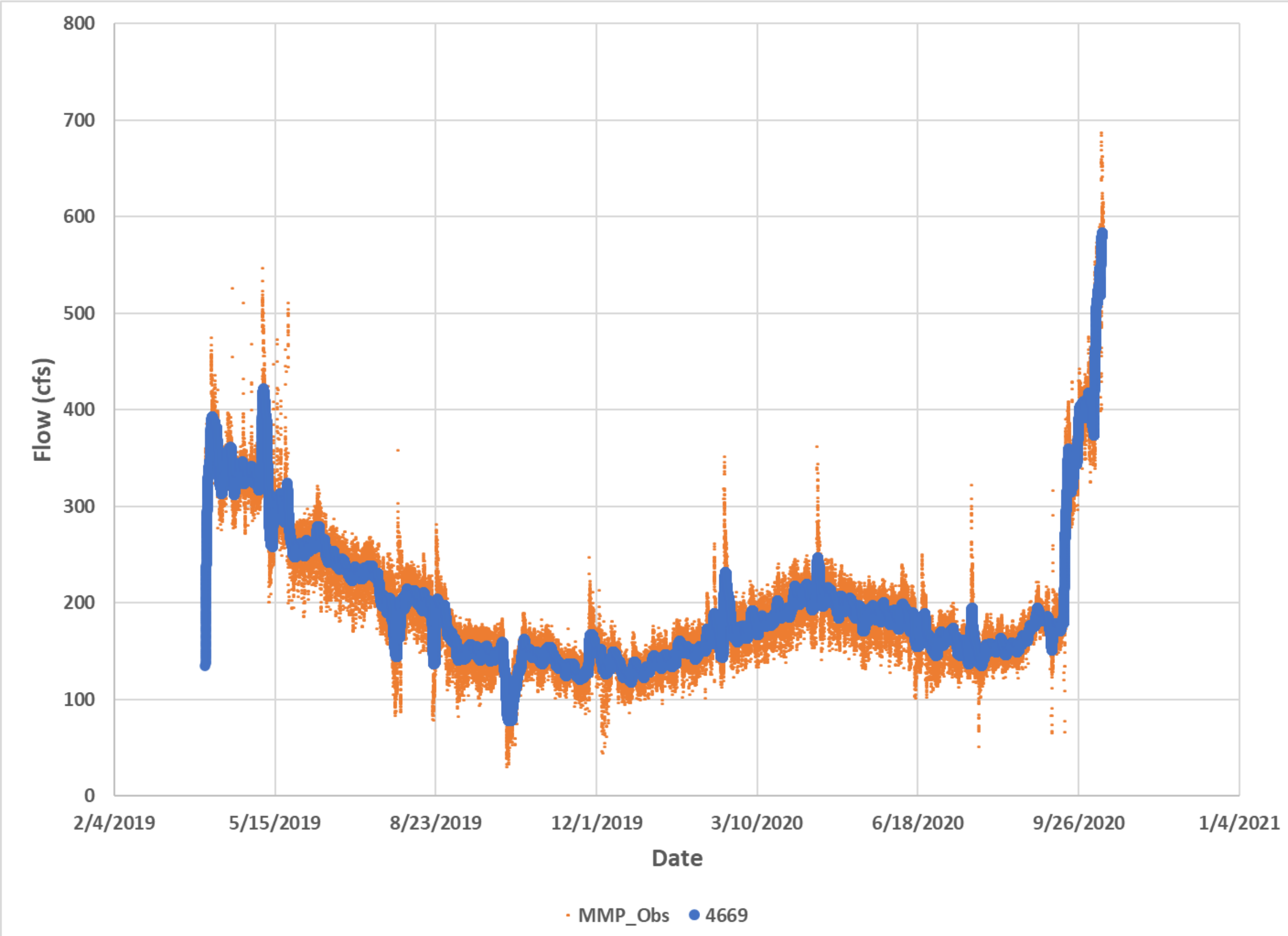

Figure 23: Comparison of Measured and Simulated Flow at the Merritts Mill Pond @ US 90 Gage (River Station 4669)

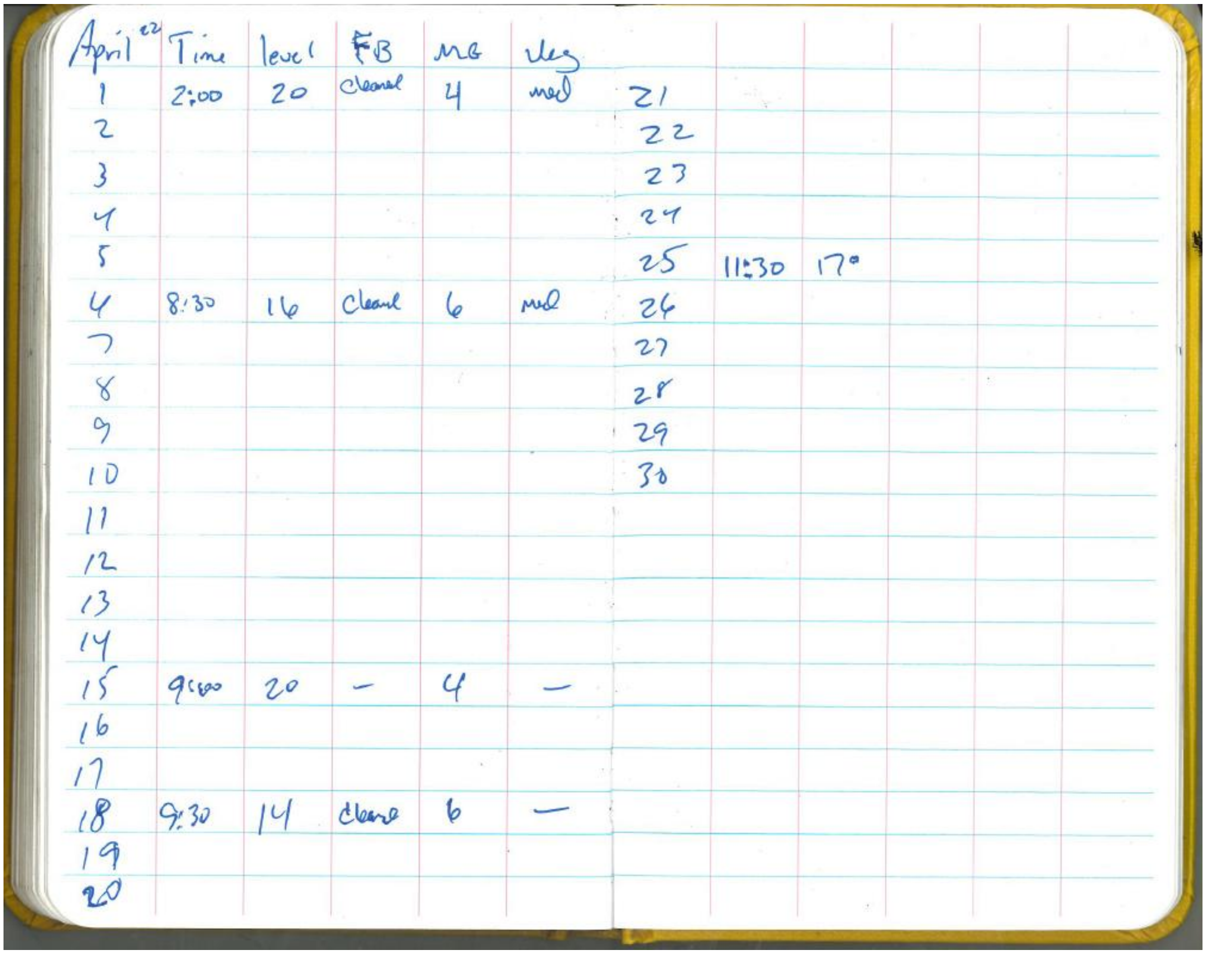

Figure 24: Example of One Month of Gate Operations Logs

5. MODEL TESTING

Model modifications were made to the geometry file, the flow and stage boundary conditions, and the unsteady flow file. These modifications are described in Section 4 and summarized in this section. The model was then tested by simulating the period from April 2019 to October 2020 to assess model execution and assess performance, including model stability, continuity error, and computational errors and warnings. The model was modified to address instability and continuity issues, errors, and warnings and then re-run. A stable and complete simulation was achieved for the simulation period April 2019 to September 2020, which preceded a pond drawdown event that occurred in early October 2020. A scheduled drawdown of Merritts Mill Pond occurred from October 2020 – December 2020 to perform maintenance and renovations at the Jackson Blue Spring county park. Due to these renovations, stage at Jackson Blue Spring was unavailable. During the drawdown, stage was lowered in the pond to approximately 69 ft. (Figure 25). As depicted in Figure 25, stage in Merritts Mill Pond is typically maintained between 74 ft and 78 ft. Due to the rapidly changing system conditions during this time, model testing was not performed during the drawdown event as the model would become unstable. Due to the short distance between cross sections in the area around the US 90 bridge and the Merritts Mill Pond control structure (less than 10 ft), a computational time step of 6 seconds was required. Model construction and testing sequence is described in the following paragraphs.

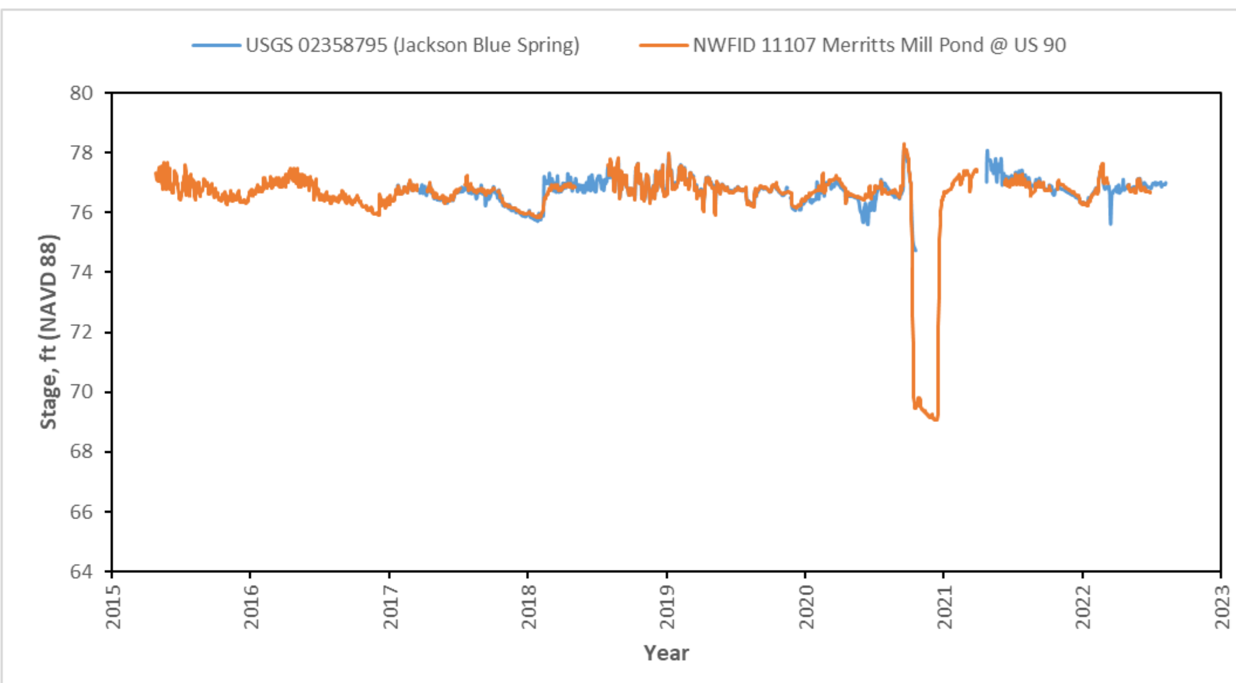

Figure 25: Comparison of Stage at USGS 2358795 Jackson Blue Spring Near Marianna with Stage at NWFID 11107 Merritts Mill Pond @ US 90

Four modeling plans were developed, reflecting various stages of updating the geometry file and the unsteady flow file. In HEC-RAS, a plan defines which geometry and unsteady flow data are to be used, as well as providing a description and short identifier for the run. The plan information includes the selected programs to be run, simulation time window, computation settings, and the simulation options. Once a simulation plan led to successful model execution, selected modifications to the geometry file and/or the unsteady flow file were made. The rationale was to change a limited number of items each step so that it would be easier to diagnose model execution issues from a more limited set of changes. By the time the final step was reached, all identified required changes to the model files would be implemented successfully and would result in a fully parameterized and executing model. The four plans were as follows.

1. Plan 14 – Utilized the unsteady flow file as received from NWFWMD. The geometry file was modified by removing the high spot in the profile at the Railroad Bridge. It included the control structure configuration as received from NWFWMD and did not include the US 90 Bridge. The simulation was run in "Mixed Flow" mode. This plan was the first version that ran successfully for the entire simulation period April 2019 to October 2020.

2. JBS_TEST – Used the same Geometry File as Plan 14. The Unsteady Flow File was revamped to use a HEC-DSS file for all boundary conditions (stage and flow) and Gate Operations Records. This plan was primarily used to begin implementation of a DSS file for all boundary conditions, structure operations and for comparison to measured flow and stage data. A simple hypothetical Gate Operations Record was used for model testing purposes. The actual Gate Operations Record was not incorporated at this point

3. JBS_DSS – This plan used a revised Geometry file in which a modified control structure configuration was entered, and the US 90 Bridge was included. Cross sections were added to support the inclusion of the bridge and also its interaction with the control structure. The Unsteady Flow File was unchanged from Plan JBS_TEST.

4. Plan 19 – This plan used a modified Geometry file in which ineffective flow areas were defined, particularly around the US 90 bridge and the control structure. Also, modifications were made in the Spring Creek portion of the model in which the location of in-channel and overbank areas of some cross sections were modified. Following this, Manning's n coefficients were updated at all cross sections for all channel and floodplain areas to reflect conditions observed during the field reconnaissance. The Unsteady Flow file was modified to include the recorded Gate Operations Record by importing the record into the DSS and modifying the unsteady flow file to reflect that boundary condition in the DSS file. Figure 26 presents the simulation results from Plan 19 at the location of the Merritts Mill Pond @ US 90 gage.

It should be noted that the model eventually became unstable during rapidly changing conditions that occurred near the end of the simulation period in which the gate was opened dramatically, dropping stage in the pond more than 5 ft, so that a major rehabilitation project could be completed (known as The Drawdown Event).

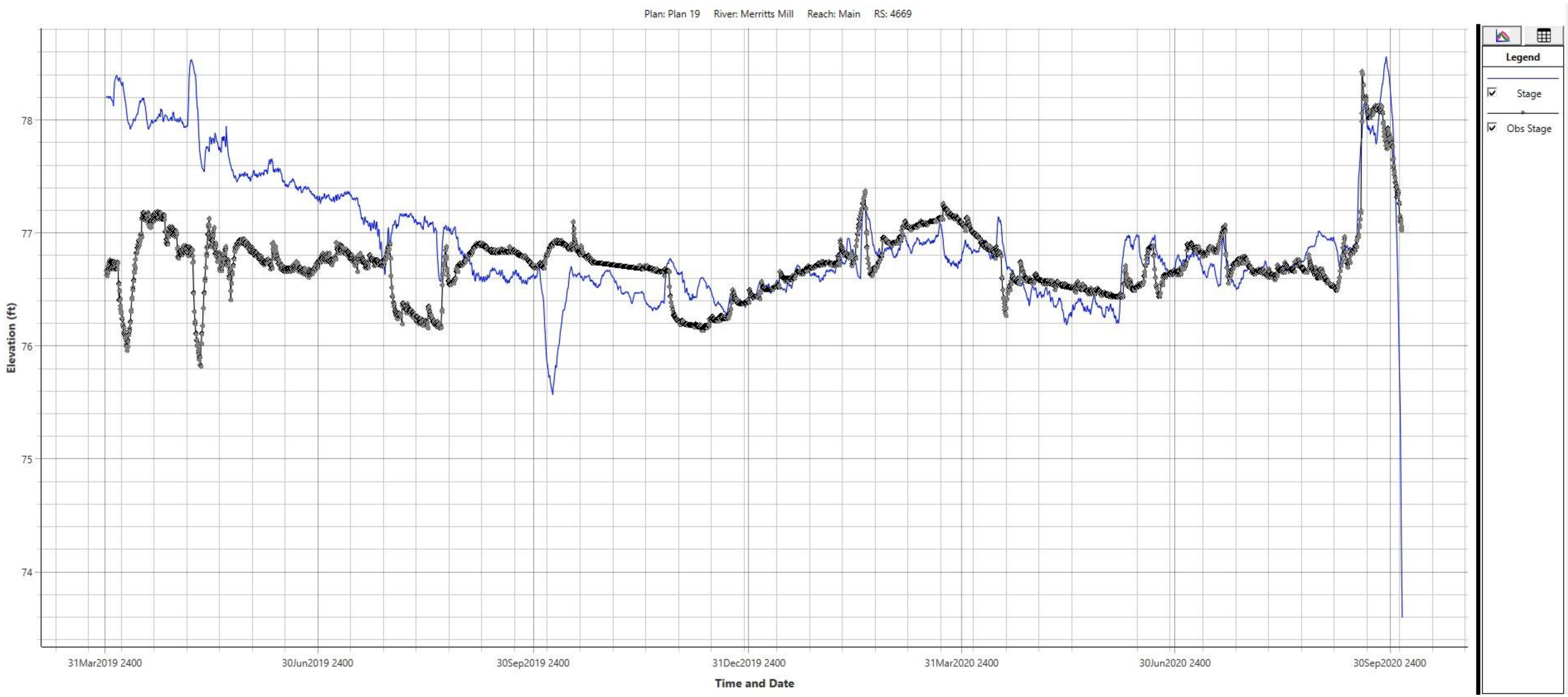

Figure 26: Measured Water Surface Elevations at the Merritts Mill Pond @ US 90 Gage (Station Number NWFWMD 11107) Compared with Model-Simulated Elevations from Plan 19 Test.

6. MODEL CALIBRATION AND VERIFICATION

The updated HEC-RAS unsteady-state model was calibrated to the best available water level data as provided by the NWFWMD. Based on the model set up and the available data, the model was calibrated to stage at two locations: Merritts Mill Pond @ US 90 gage (Station ID NWFWMD 011107) and Spring Creek at Spring Creek Park (Station ID NWFWMD 012744). The focus of this calibration effort was the parameterization of the Merritts Mill Pond control structure (weir and gate coefficients) and Manning's n values in Spring Creek. Model performance was assessed by evaluating stage residuals across a range of flows and graphical comparison of HEC-RAS simulated stage-frequency curves with those developed from provided stage data. Quantitative model goodness of fit values including mean error, coefficient of determination (R^2), root-mean-squared error (RMSE) and RMSE-observations standard deviation ratio (RSR) were also calculated and evaluated. It should be noted that uncertainties in the gate operation records may limit the utility of these quantitative measures for evaluating model performance.

6.1 Model Calibration

Review of the input data indicated limited time periods from which concurrent inflow, stage, and gate operations data were available. As described previously, the period from April 1, 2019, through October 4, 2020, was the longest time period available and was used to demonstrate that the constructed model would run successfully and was able to be calibrated. However, this period did not have complete gate operations records, which introduced an additional level of uncertainty into a calibration effort. Following review of the available data, the time periods shown in Table 4 were selected for calibration and verification.

Table 4: Model Calibration and Verification Periods

Start Date	End Date	Days	Simulation Type
11/4/2019	10/2/2020	336	Calibration
12/17/2020	3/30/2021	104	Verification
10/25/2021	2/23/2022	122	Verification

For the calibration period, a gate operation record was estimated for the periods in May 2020 and August 2020 when these records were missing. Note that, while the gate operations record did not indicate any changes for May through July 2020, the observed stage record indicates sudden slope changes in the hydrograph, which may indicate that not all changes in the gate level were documented.

The data available to calibrate the model was the stage record at Merritts Mill Pond Gage @ US 90 (Station ID NWFWMD 011107) and the stage record at Spring Creek @ Spring Creek Park (Station ID NWFWMD 012744). Due to the sensitivity of water levels in Merritts Mill Pond to the gate opening, the primary parameters for model calibration were the weir and sluice gate coefficients associated with the control structure at US 90. The weir coefficient was set to 3.2. The sluice discharge coefficient was set to 0.6 during model construction (typical range is 0.5 to

0.7, per HEC-RAS guidance). The sluice discharge coefficient was adjusted, and simulations were performed, after which graphical comparisons with simulated and observed stage time series were done. After a number of iterations, a sluice discharge coefficient of 0.57 was determined to provide the best fit. This value is in the lower range for this coefficient, which possibly reflects the additional flow resistance through the fish barrier. Figure 27 presents the result of the Model Calibration (HEC-RAS model plan "JBS_GateOps") at Merritts Mill Pond @ US 90 (Station ID 011107). Of note at the beginning of the calibration simulation (November 25-28, 2019) is where the model is showing a sudden increase in stage in Merritts Mill Pond, while the observed data shows a sudden decrease of approximately 0.5 ft. The gate operations records had no entries during these two months. Figure 28 presents the simulated and measured flows at Merritts Mill Pond @ US 90 (Station ID 011107).

Figure 29 compares the stage frequency curves for the observed and simulated Merritts Mill Pond stages at the US 90 bridge. The curves match very well for the calibration time period. This supports the conclusion that the model is responding to the boundary forcings appropriately.

The following observations are of note:

1. The model appears to be responding to the boundary condition forcings appropriately, and
2. The larger residuals (Computed – Observed) appear to be associated with periods when the gate operations record may have been missing an entry.

Calibration of the model in the Spring Creek reach involved adjustments to in-channel and floodplain Manning's n values. Initially in-channel and floodplain Manning's n values were 0.03 and 0.08, respectively. The final in-channel values along Spring Creek ranged from 0.055 near the control structure to 0.045 in the lower third of Spring Creek, values which are representative of main stream channels which are clean, winding, with some pools, shoals, weeds and stones (USACE, 2020). Floodplain values were set at 0.22, which is representative of a floodplain that is densely covered in trees (USACE, 2020) and reflects the large amount of debris observed along the reach. The final Manning's n values were similar to those used for the Middle Econfina Creek HEC-RAS model (Northwest Florida Water Management District, 2025). Figure 30 compares the simulated and observed stages in Spring Creek @ Spring Creek Park (Station ID 012744). Figure 31 compares simulated and observed flows at the same location. Figure 30 and Figure 31 demonstrate that the model is performing well up to June 18, 2020. When the station came back online approximately 2 months later, the modeled water surface elevations were approximately 0.5 ft higher than the observed elevations. A comparison of the measured flow at the Spring Creek Park station on August 19, 2020 with the concurrent discharge from the rating at the Merritts Mill Pond @ US 90 gage indicated a difference of approximately 33 cfs with the rating at the Merritts Mill Pond gage, indicating a flow of approximately 152 as compared to a measured flow at Spring Creek Park just downstream of the station of 119 cfs. These flows should be similar given their proximity and that no flow additions or reductions occur between these two locations. This would indicate the modeled residuals seen during the latter calibration period are largely due to measurement uncertainties and not model parameterization.

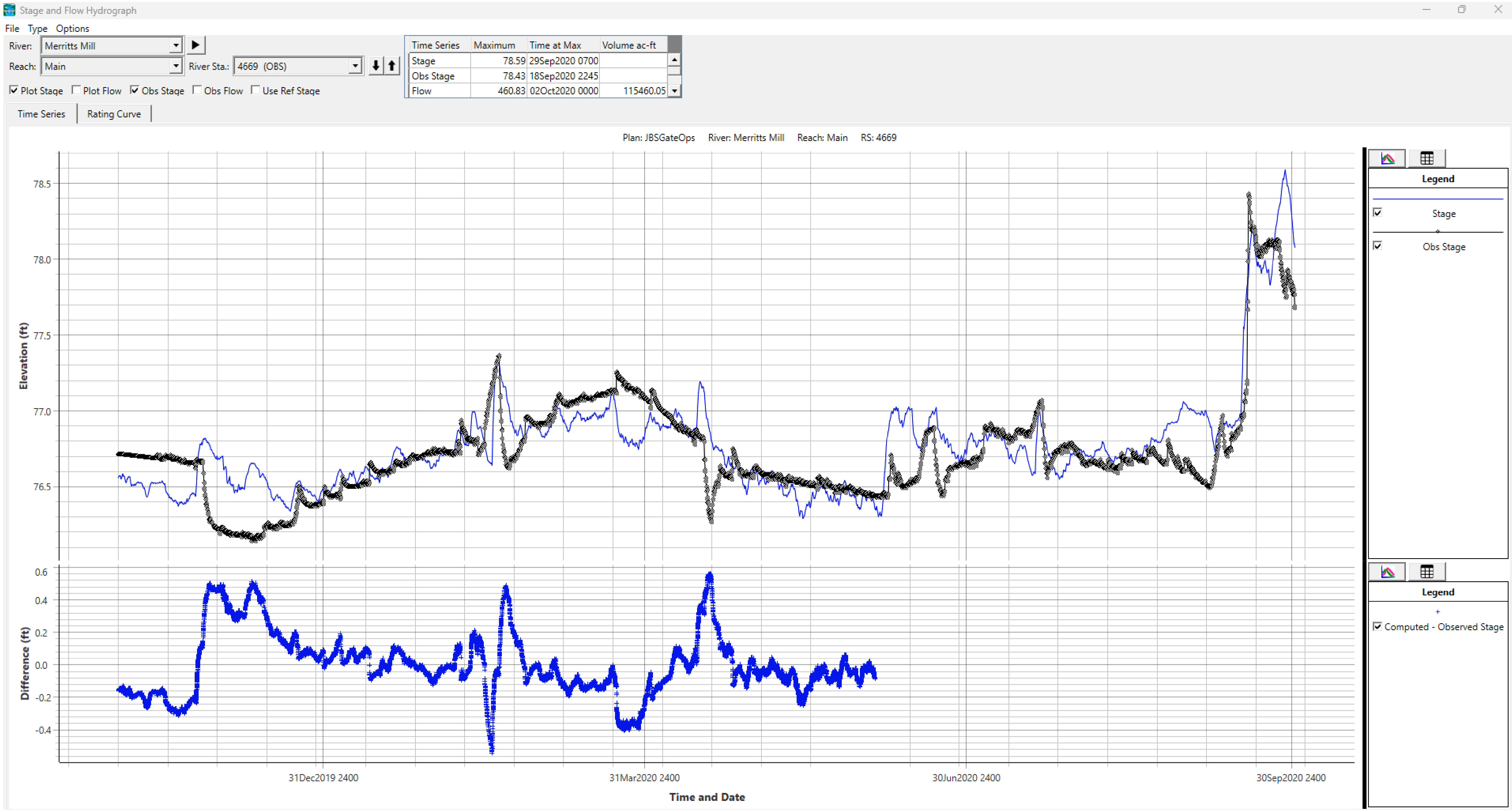

Figure 27: Jackson Blue Springs System HEC-RAS Model Calibration Showing Simulated vs. Observed Stage Time Series at the US 90 Bridge on Merritts Mill Pond

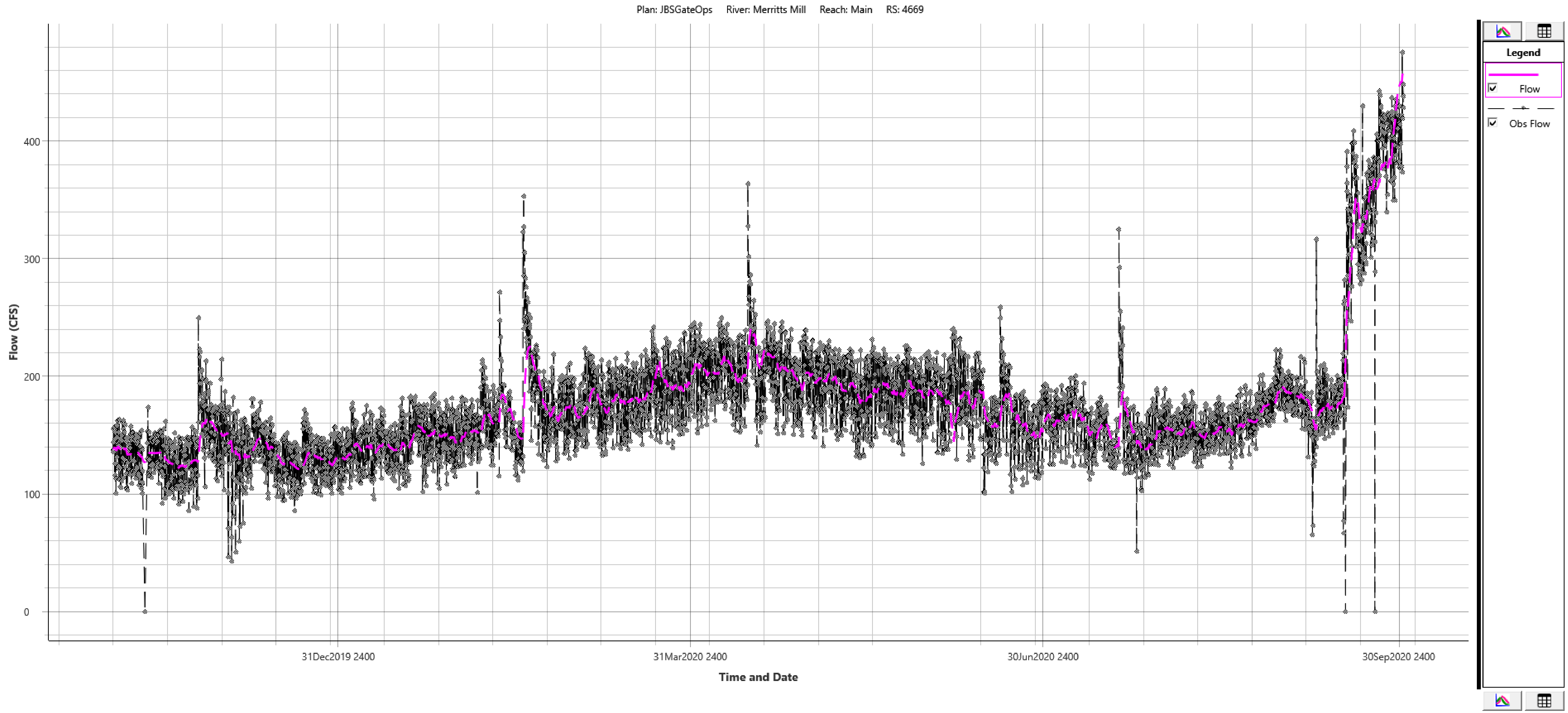

Figure 28: Jackson Blue Springs System HEC-RAS Model Calibration Showing Simulated vs. Observed Flow Time Series at the US 90 Bridge on Merritts Mill Pond

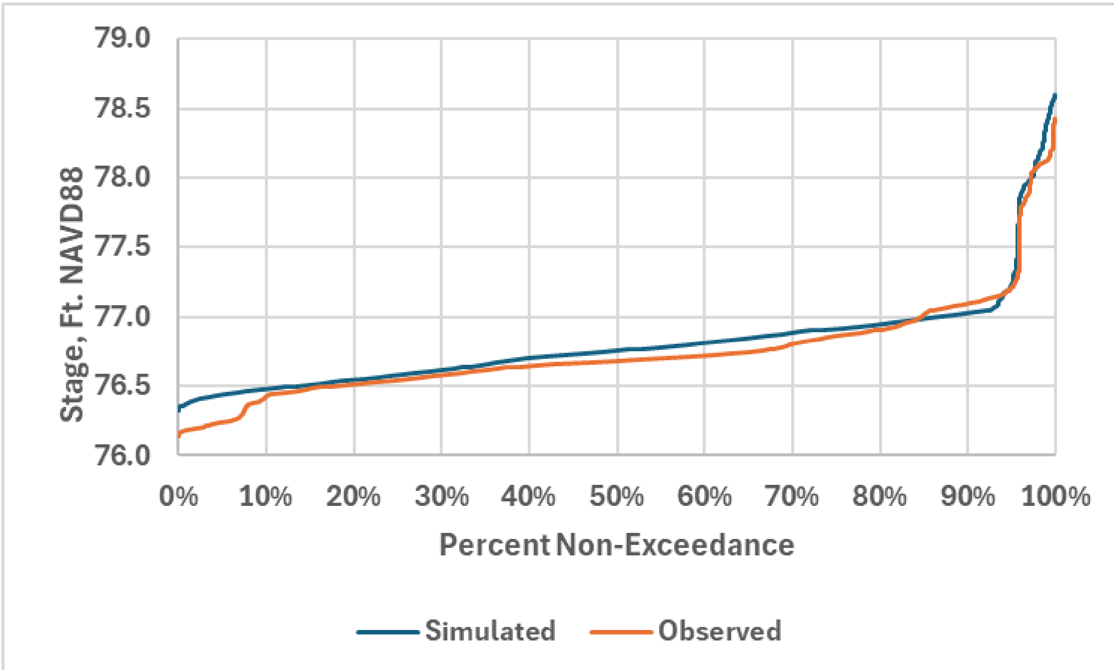

Figure 29: Stage Frequency Curves for the Calibration Simulation Comparing Observed and Simulated Stages at the US 90 Bridge on Merritts Mill Pond

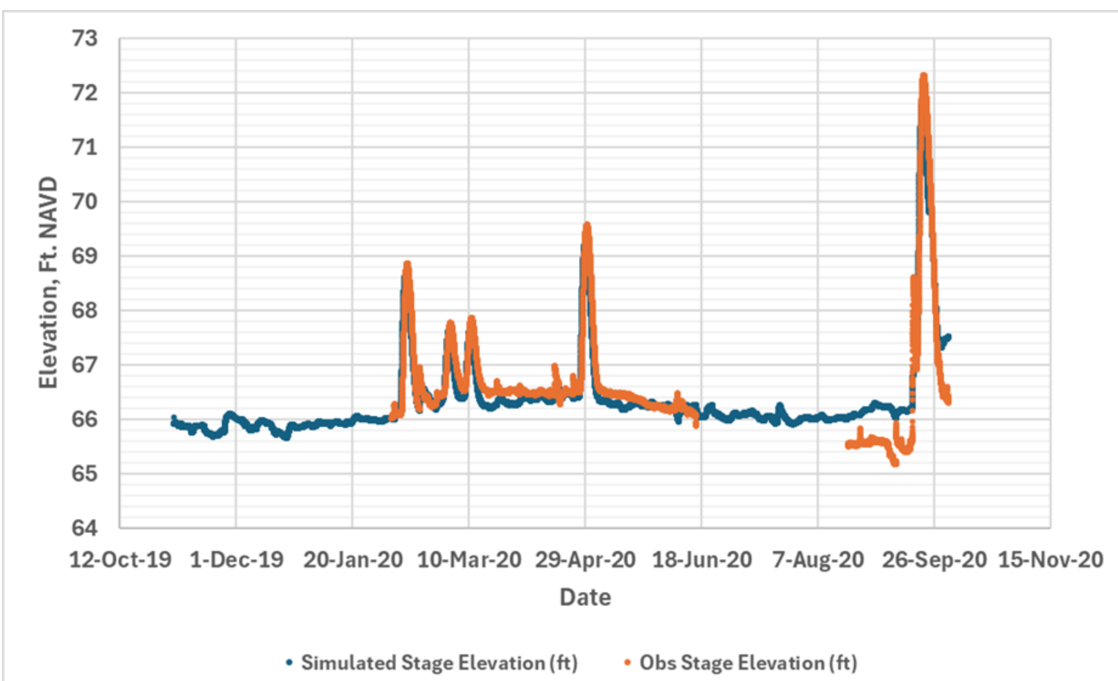

Figure 30: Stage Time Series for the Calibration Simulation Comparing Observed and Simulated Stages at the Spring Creek @ Spring Creek Park Gage

Figure 31: Flow Time Series for the Calibration Simulation Comparing Observed and Simulated Flows at the Spring Creek @ Spring Creek Park Gage

6.1.1 Model Performance Evaluation

General statistics for mean, maximum, and minimum for the simulated and observed stage time series were calculated at the Merritts Mill Pond @ US 90 gage and at River Station 4669. Also, model performance statistics were calculated for the residuals (computed – observed stage). In this study, the stage data measured at the Merritts Mill Pond @ US 90 gage were used to calculate model performance statistics and assess the model performance. Model performance statistics were not calculated at the Spring Creek @ Spring Creek gage due to the short continuous record available. These HEC-RAS model results were evaluated with the statistical measures of R^2, RMSE, and RSR, as well as visual comparison of observed and simulated stage time series and stage duration curves.

The RMSE (Equation 1) indicates a perfect match between observed and predicted values when it equals 0 (zero), with increasing RMSE values indicating an increasingly poor match. Singh et al. (2004) stated that RMSE values less than half the standard deviation of the observed (measured) data might be considered low and indicative of a good model prediction.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \qquad \text{Equation 1}$$

The R^2 (Equation 2) describes the fraction of the variance in an observed value that is explained by a model, and ranges from 0 to 1. In Equation 2, *n* is the total number of observed stages; O_i is observed stage at time step *i*; P_i is simulated or predicted stage at time step *i*; and the over bar denotes the mean for the entire evaluation time period. An R^2 with a value of 1 indicates a perfect linear relationship between two variables, whereas an R^2 of zero represents no linear relationship.

$$R^2 = \left[\frac{\sum_{i=1}^{n} (O_i - \overline{O})(P_i - \overline{P})}{\sqrt{\sum_{i=1}^{n} (O_i - \overline{O})^2} \sqrt{\sum_{i=1}^{n} (P_i - \overline{P})^2}} \right] \qquad 0 \le R^2 \le 1$$

Equation 2

The *RSR* (Equation 3) is calculated as the ratio of the RMSE and the standard deviation of measured data ($STDEV_{obs}$). *RSR* varies from the minimum value of 0, to a large positive value. The lower the *RSR* and the lower the *RMSE*, the better the model simulation performance.

$$RSR = \frac{RMSE}{STDEV_{obs}} = \left[\frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sqrt{\sum_{i=1}^{n} (O_i - \overline{O})^2}} \right]$$

Equation 3

In this equation, *n* is the number of observations in the period under consideration, O_i is the i-th observed value, *O* is the mean observed value, P_i is the i-th model-predicted value.

Table 5 presents the model statistics for the model calibration based on 15-minute observed and simulated time series. Approximately half of the variability in the MMP stage was explained by the model (indicated by a R^2 of 0.48), and the model was unbiased (indicated by a difference of 0.06 ft between the simulated mean and the observed mean), represented the overall variability in water level with reasonable accuracy (indicated by an RMSE of 0.30 ft or 13% of the observed range), and represented the extreme stages with reasonable accuracy (indicated by differences of 0.17 ft and 0.18 ft between the simulated and observed maximum and minimum stages, respectively). The model performance was reasonable considering the high level of variation in the stage-discharge relationship observed at the MMP US 90 gage (Geosyntec Consultants, 2026, Figure 6), which was likely caused by gate adjustments of unknown timing and magnitude, periodic vegetation removal directly upstream of the structure, and periodic cleaning of the fish barrier.

Table 5: Model Performance Statistics for 15 Minute Time Series at the Merritts Mill Pond @ US 90 Gage (Station ID NWFWMD 11107)

Location	River Station	Statistics	Mean Stage (ft-NAVD88)	Max Stage (ft-NAVD88)	Min Stage (ft-NAVD88)	R^2	RMSE	RMSE/ Range	RSR
Merritts Mill Pond @ US 90	4669	Obs	76.73	78.43	76.14				
		Sim	76.79	78.60	76.32	0.48	0.30	13.1%	0.785
		Diff	0.06	0.17	0.18				

6.2 Model Verification

Figure 32 presents the results of the first verification simulation, which spanned the time period from December 2020 to March 2021 (HEC-RAS model plan "Verification_1220-0321") at Merritts Mill Pond @ US 90 (Station ID 011107 and RS 4669) The verification period began following the drawdown event. In unsteady HEC-RAS simulations, initial conditions can be set for flow but not stage. This is done in the Unsteady Flow file. If the river system is dendritic (no loops anywhere in the system) such as the Jackson Blue Springs/Merritts Mill Pond system, the user can leave all of the flow data fields blank. When this is done, the software gets flow data from the first value of all of the boundary condition hydrographs (upstream and lateral inflows). Flows are set from upstream to downstream by adding flows together at junctions as appropriate. This option also requires the user to enter a starting elevation for any storage areas that are part of the system. There are no storage areas in the model setup, so this step was not able to be taken. Initial simulations produced higher elevations but did not capture the beginning of the refilling of Merritts Mill Pond. To capture this, an adjustment was made to the gate operations record in the form of setting a smaller gate opening than the record showed during the first week of this verification simulation that better captured the initial water elevations. The following observations are of note.

1. The larger residuals (Computed – Observed) not associated with the drawdown in the beginning of the simulation appear to be associated with periods when the gate operations record may have been missing an entry or possibly the available entries were misinterpreted.
2. The model consistently overpredicted stage during this verification period. It is not clear why this occurred because no changes to structure parameters were performed, and the simulated stages following verification period were consistent with observed data. One possibility is that after the drawdown, less vegetation was present, causing less friction in the system than what was calibrated to during the pre-drawdown timeframe. Therefore, the model may overpredict since the Manning's n is too high

Figure 33 compares the simulated and observed stages in Spring Creek @ Spring Creek Park (Station ID 12744) for the verification simulation for December 2020 to March 2021 The model generally overpredicted stage based on the measured stage 0.2 to 0.4 ft. Figure 34 compares simulated and observed flows at the same location and show good agreement.

Figure 35 presents the results of the second verification simulation, which spanned the time period from October 2021 to February 2022 (HEC-RAS model plan "Verification_1021-0222"), showing simulated versus observed stages at the US 90 Bridge on Merritts Mill Pond. Gate operations records data were missing in November and December 2021. Based on the pattern of the stage hydrograph (sudden decrease in observed water levels but for which no record was available), adjustments to the gate opening were made to the November 2021 gate operations record in the DSS in which the main gate opening was increased slightly to better match the observed record.

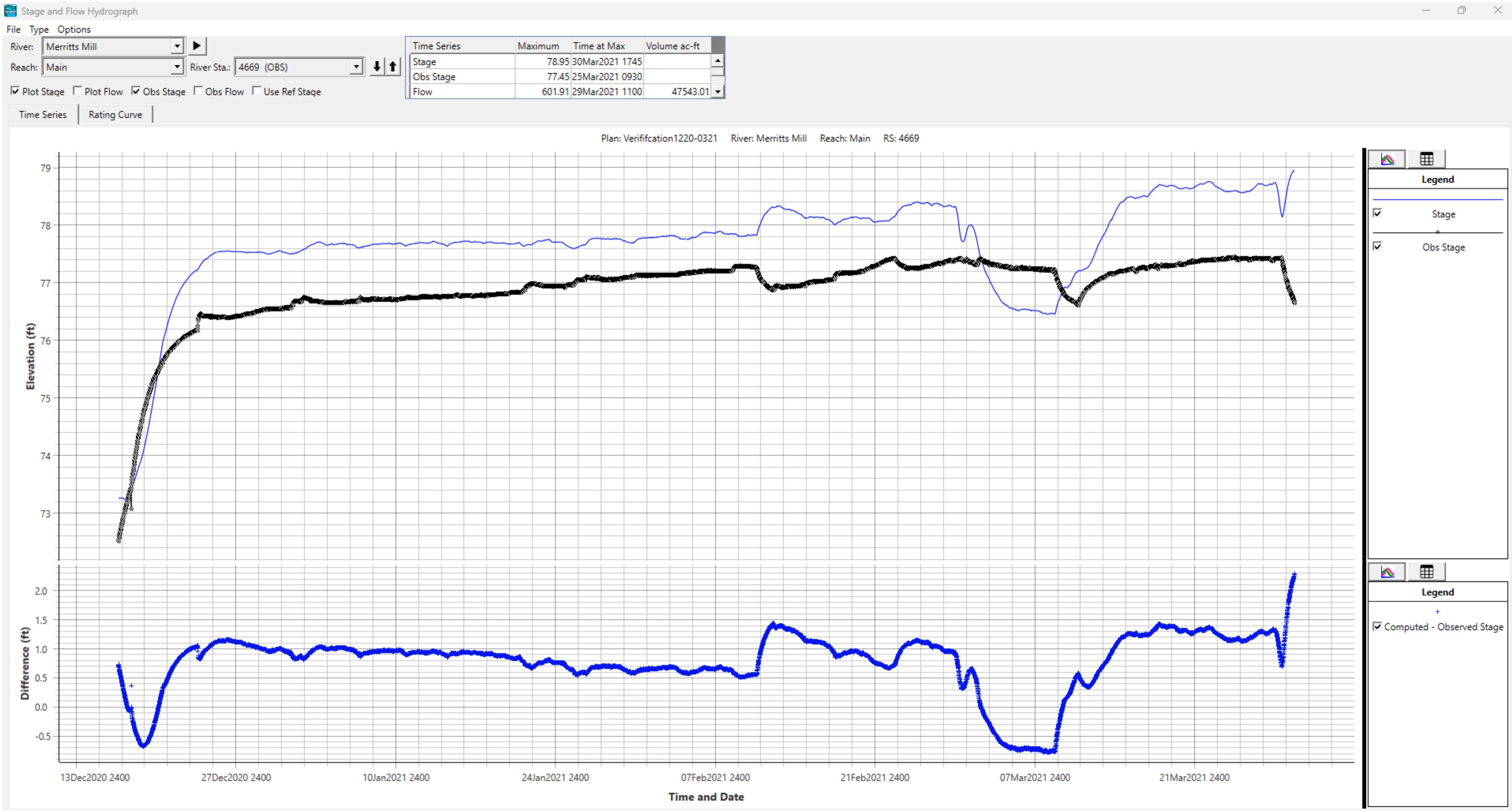

Figure 32: Jackson Blue Springs System HEC-RAS Model Verification (12/20-03/21) Showing Simulated vs. Observed Stages at the US 90 Bridge on Merritts Mill Pond

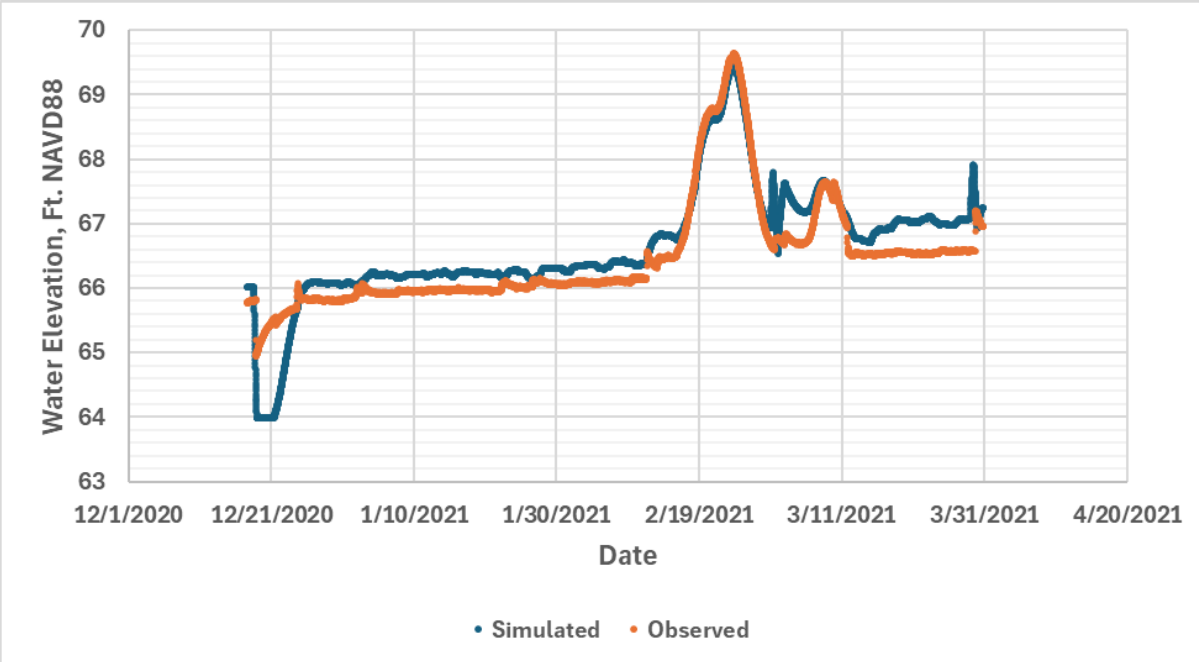

Figure 33: Jackson Blue Springs System HEC-RAS Model Verification (12/20-03/21) Showing Simulated vs. Observed Stages in Spring Creek @ Spring Creek Park

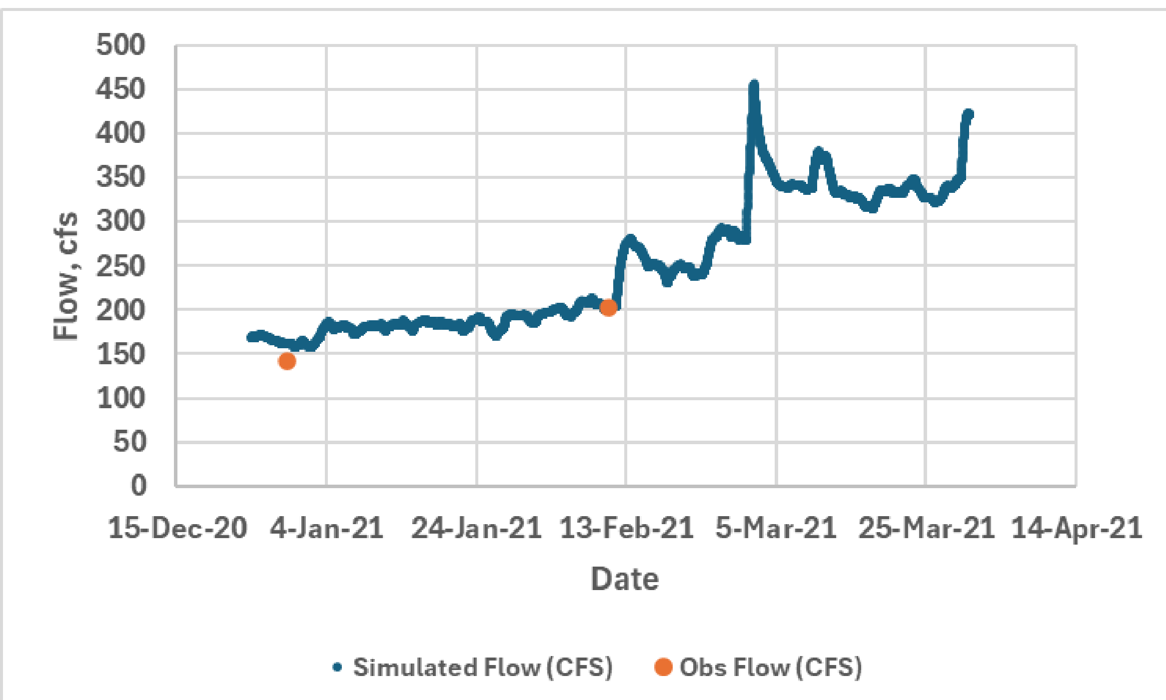

Figure 34: Jackson Blue Springs System HEC-RAS Model Verification (12/20-03/21) Showing Simulated vs. Observed Flows in Spring Creek @ Spring Creek Park

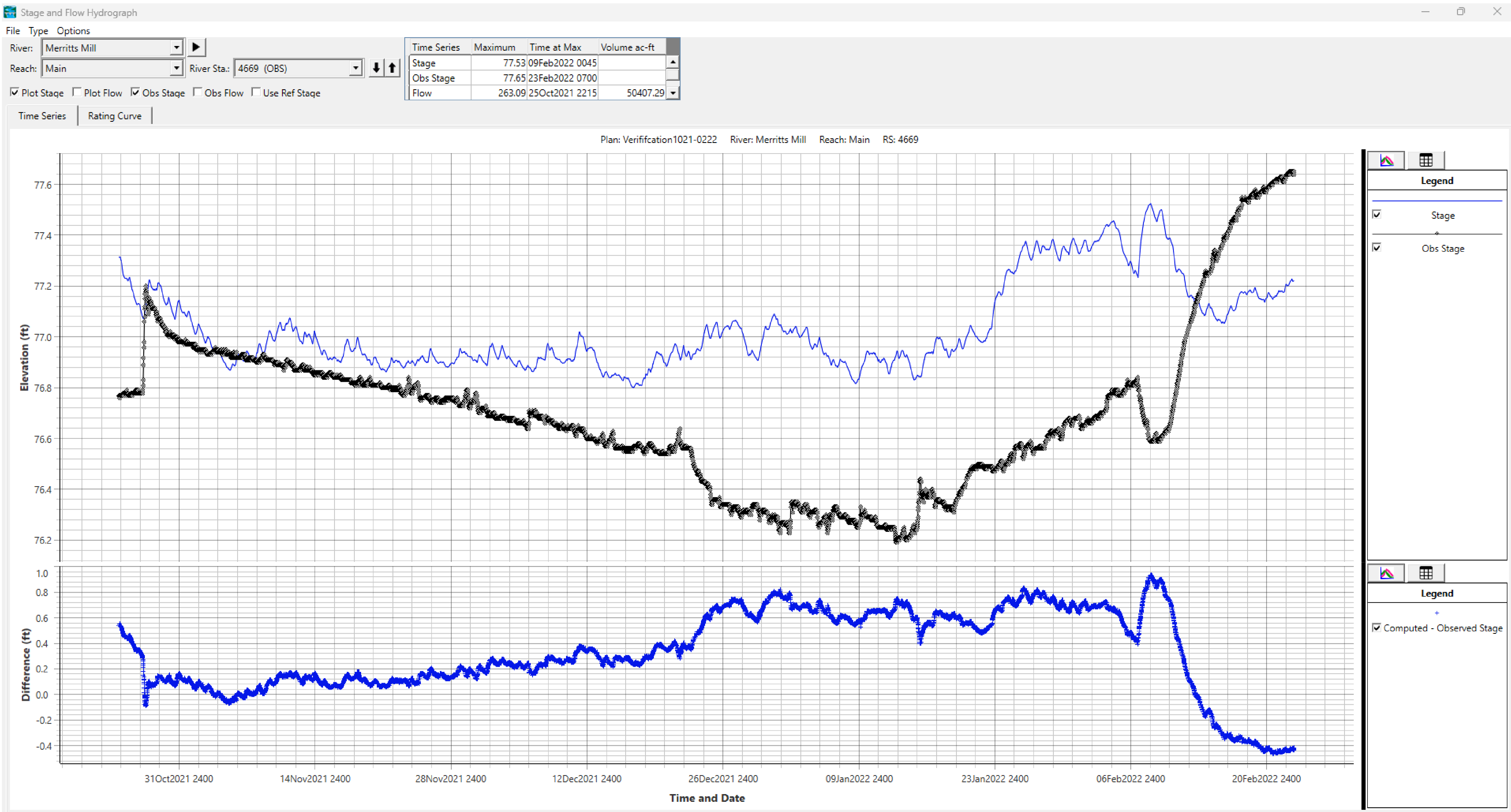

Figure 35: Jackson Blue Springs System HEC-RAS Model Verification (10/21-02/22) Showing Simulated vs. Observed Stages at the US 90 Bridge on Merritts Mill Pond.

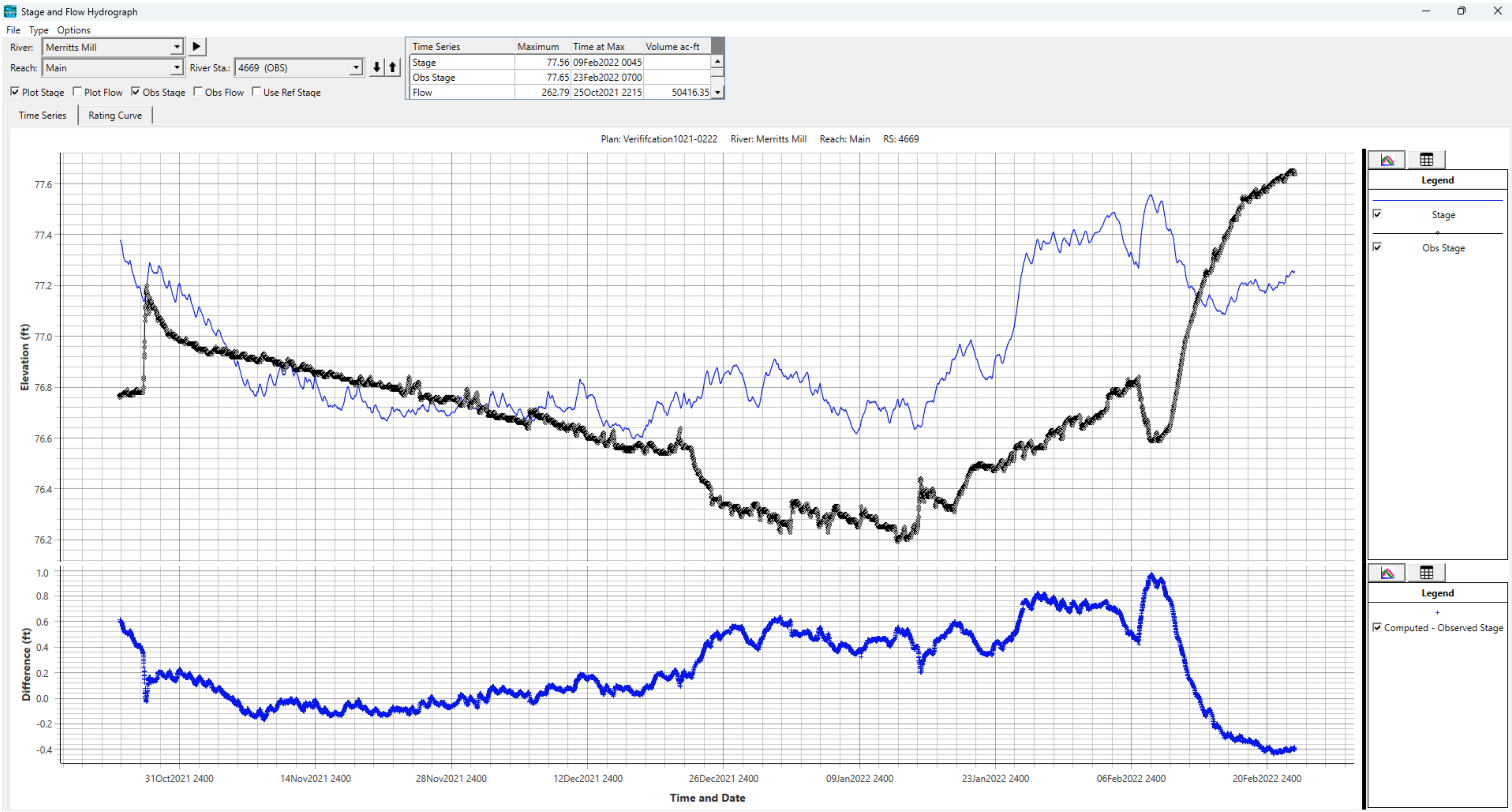

Figure 36: Jackson Blue Springs System HEC-RAS Model Verification (10/21-02/22) Showing Simulated vs. Observed Stages at the US 90 Bridge on Merritts Mill Pond Following Adjustments to the Gate Opening.

The result of this simulation is presented in Figure 36 and indicates a good match up to the middle of December 2021, during which the main gate opening was increased by 2 inches. Once gate operations records became available in January 2022, the model simulates the observed rise in water levels, albeit approximately 0.5 ft higher. One possible explanation may be that the actual stop log configuration in the Merritts Mill Pond control structure (Figure 10) immediately following the rehabilitation work and subsequent pond refill was different than that during the calibration period. No documentation was found to confirm this.

The following observations are of note:

1. For the beginning of the December 2020 to March 2021 verification simulation for Merritts Mill Pond (Figure 32), residuals were 0.6 to 0.7 ft and show a consistent over-prediction of stage. This is likely due to a change in the control structure configuration that was not captured in the model.
2. For the October 2021 to February 2022 verification period before the gap in the gate operations record was filled (Figure 35), the model overpredicted stage with the residuals increasing to 0.4 ft. up to December 22, 2021. Following the sudden observed drop in stage, the model simulated stages followed the observed trends but were 0.6 to 0.7 ft higher.
3. For the October 2021 to February 2022 verification period after the data gap in the gate operations record was filled (Figure 36), except for the initial 2 days, the model predicted stage with the residuals increasing to ±0.2 ft up to December 22, 2021. Following the sudden observed drop in stage, the model simulated stages followed the observed trend but were 0.4 to 0.5 ft higher.
4. The larger residuals (Computed – Observed) period begins in December 22 2021, when the gate was apparently raised, creating a larger gate opening, but there is no entry in the gate operations record.

In addition to the operation of the control structure gate, there is also a fish barrier that is periodically raised and cleaned. It has been noted that the water level in Merritts Mill Pond just upstream of the structure tends to drop approximately 0.25 to 0.4 ft following the removal of the accumulated vegetated matter and algae. As vegetative debris accumulates, flow resistance through the fish barrier gradually increases, gradually raising water levels. This activity involved in maintaining the fish barrier is not directly accounted for in the current model configuration. It could be more directly modeled through a modification to the inline structure, possibly through the addition of a small gate that would allow for incorporation of the fish barrier maintenance record as an irregular time series of gate openings that mimics the varying hydraulic effect of the fish barrier.

Model performance statistics for mean error, R^2, RMSE and RSR were not calculated for the verification runs given the magnitude of the residuals seen.

Figure 37 compares the simulated and observed stages in Spring Creek @ Spring Creek Park (Station ID 12744) for the verification simulation for October 2021 to February 2022 and shows that the model is overpredicting stage by 0.2 to 0.4 ft. Figure 38 compares simulated and observed flows at the same location.

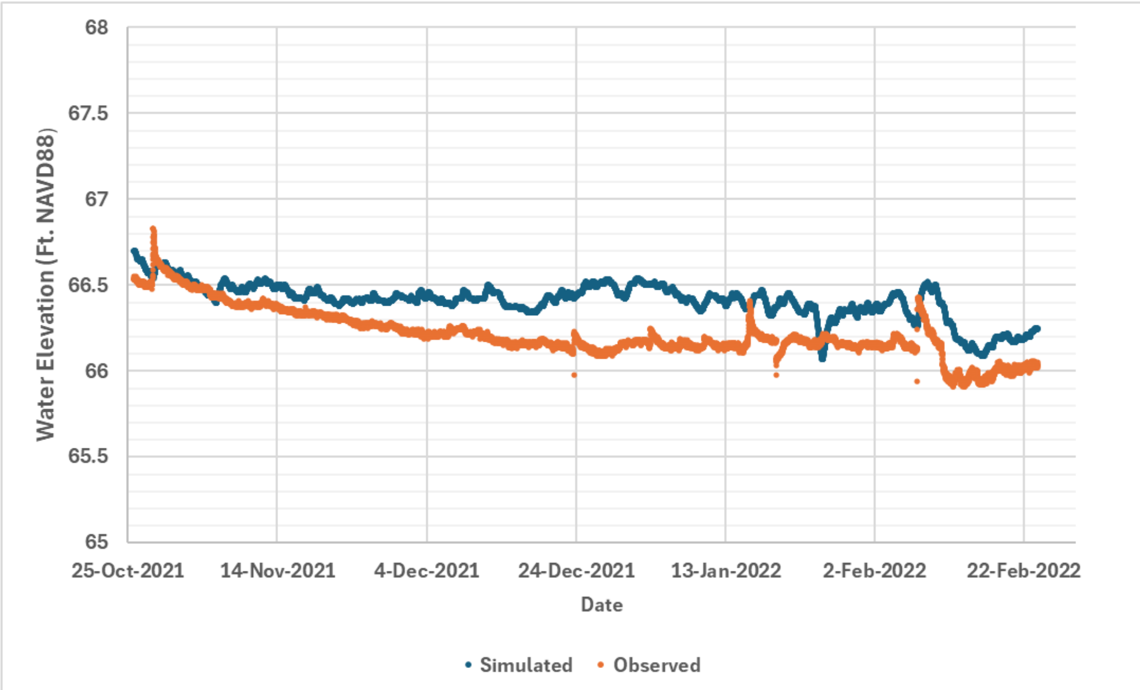

Figure 37: Jackson Blue Springs System HEC-RAS Model Verification (10/21-02/22) Showing Simulated vs. Observed Stages at Spring Creek @ Spring Park

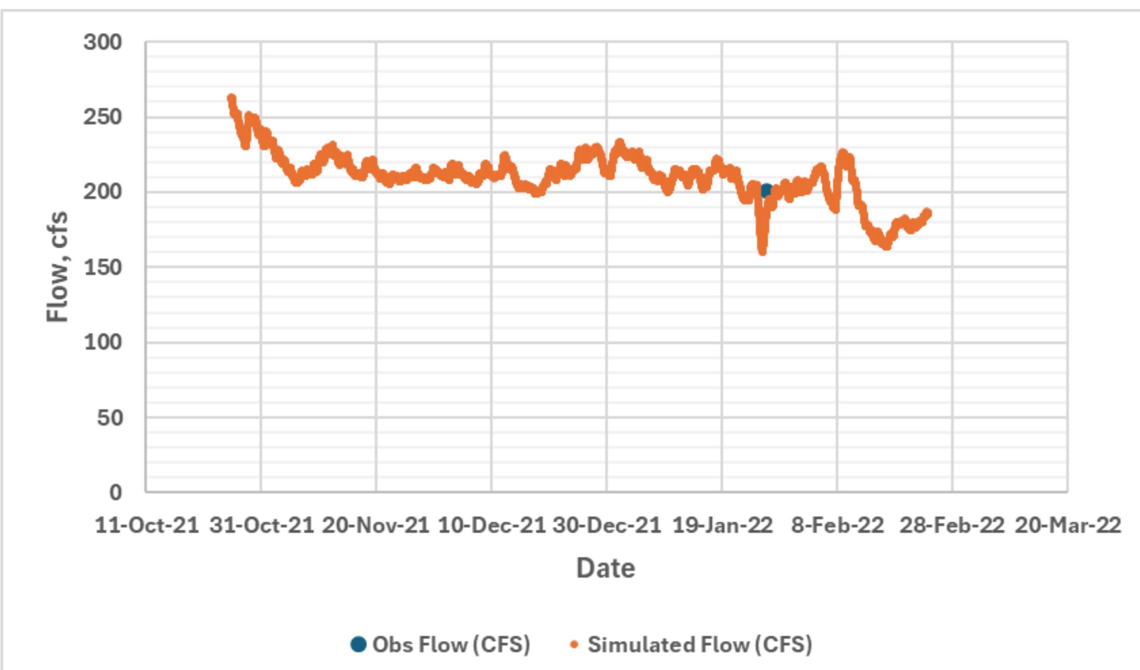

Figure 38: Jackson Blue Springs System HEC-RAS Model Verification (10/21-02/22) Showing Simulated vs. Observed Flows at Spring Creek @ Spring Park

The results of the two verification simulations indicate that the model is not predicting water levels in Merritts Mill Pond nearly as well as in the calibration period. Some decrease in prediction accuracy is expected during a verification run. However, large residuals occurred in a number of instances. Hydrograph patterns during rising and receding periods would seem to indicate that some of the large residuals seen are the result of missing entries in the gate operations record.

The results of the two verification runs (Figure 33 and Figure 37) also indicate that the model does a reasonable job of predicting water levels in Spring Creek, with residuals of approximately 0.25 ft or less throughout the simulation periods. There was a consistent overprediction of stages during both verification periods. It is noted that vegetation was different after the conclusion of the drawdown event, although the model was tested and calibrated using pre-drawdown event flows and post-drawdown event channel geometry obtained from field survey. This is a possible source of uncertainty.

7. CONCLUSIONS AND RECOMMENDATIONS

An unsteady-state HEC-RAS model was constructed and calibrated for the Jackson Blue Spring/Merritts Mill Pond/Spring Creek system. Graphical comparisons and quantitative metrics of the simulation results and the observed stage data at the Merritts Mill Pond @ US 90 gage indicate that the model is responding in a reasonable manner to the boundary forcings. All of the simulations had instances in which the model trends were noticeably different and did not exhibit the same immediate response in water levels as seen in the stage record. This would imply that the gate operations records may have had missing entries or, due to non-standard nomenclature, the entries could not be interpreted correctly. This adds some uncertainty to model predictions.

Given these limitations, the model does have utility for future MFL evaluations and can reasonably predict water levels in Merritts Mill Pond, particularly when gate operations records are known with certainty. Also, the model provided reliable predictions of Spring Creek water levels and flows.

The following recommendations are offered.

1. Coordinate further with Jackson County staff to improve gate operations records. There needs to be standard nomenclature in the Gate Operations record keeping. The records are probably quite adequate for the purposes of simply keeping track of the adjustments and maintenance that has been performed but are not of sufficient detail and clear enough for use in the modeling, especially given the effect the structure's settings have on flows and stages. The missing entries and sometimes confusing terminology used makes it difficult to interpret after the fact.
2. Although the landowner requested that the District discontinue monitoring of stage and flow at the Spring Creek station located on the downstream side of the structure, if site access can be obtained in the future, Spring Creek should be monitored in at least one location for stage and flow and possibly a second location for stage. If continuous measurements cannot be implemented, manual measurements of stage and flow should be performed, particularly in locations between Spring Creek Park and the Chipola River. This would allow for further calibration of the model in the Spring Creek portion of the model and possibly improve accuracy of the flow and stage predictions in this reach, particularly in the middle portion of the creek. It would make it possible to run scenarios in which the effects in Spring Creek from changes in the gate operations and water levels in the Chipola River can be better assessed.
3. If access can be obtained, re-establish monitoring for stage and flow at the Merritts Mill Pond @ US 90 gage. It is desirable to have longer data records for use in MFL evaluations so the full range of hydrologic/hydraulic patterns can be captured, either through unsteady-state or steady-state analysis tools.

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