TOPOGRAPHIC SURVEY TECHNICAL MEMORANDUM

LA GRANGE HYDROELECTRIC PROJECT
FERC NO. 14581

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
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February 2017

1.0 INTRODUCTION

1.1 Background

The Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) own the La Grange Diversion Dam (LGDD) located on the Tuolumne River in Stanislaus County, California (Figures 1.1-1 and 1.1-2). LGDD is 131 feet high and is located at river mile (RM) 52.2 at the exit of a narrow canyon, the walls of which contain the pool formed by the diversion dam. Under normal river flows, the pool formed by the diversion dam extends for approximately one mile upstream. When not in spill mode, the water level upstream of the diversion dam is between elevation 294 feet and 296 feet approximately 90 percent of the time. Within this 2-foot range, the pool storage is estimated to be less than 100 acre-feet of water.

The drainage area of the Tuolumne River upstream of LGDD is approximately 1,550 square miles. Tuolumne River flows upstream of LGDD are regulated by four reservoirs: Hetch Hetchy, Lake Eleanor, Lake Lloyd (known as Cherry Lake), and Don Pedro. The Don Pedro Hydroelectric Project (Federal Energy Regulatory Commission [the Commission or FERC] No. 2299) is owned jointly by the Districts, and the other three dams are owned by the City and County of San Francisco (CCSF). Inflow to the La Grange pool is the sum of releases from the Don Pedro Project, located 2.3 miles upstream, and very minor contributions from two small intermittent streams downstream of Don Pedro Dam.

LGDD was constructed from 1891 to 1893 displacing Wheaton Dam, which was built by other parties in the early 1870s. LGDD raised the level of the Tuolumne River to permit the diversion and delivery of water by gravity to irrigation systems owned by TID and MID. The Districts' irrigation systems currently provide water to over 200,000 acres of prime Central Valley farmland and drinking water to the City of Modesto. Built in 1924, the La Grange hydroelectric plant is located approximately 0.2 miles downstream of LGDD on the east (left) bank of the Tuolumne River and is owned and operated by TID. The powerhouse has a capacity of slightly less than five megawatts. The La Grange Hydroelectric Project (La Grange Project or Project; FERC No. 14581) operates in a run-of-river mode. The LGDD provides no flood control benefits, and there are no recreation facilities associated with the Project or the La Grange pool.

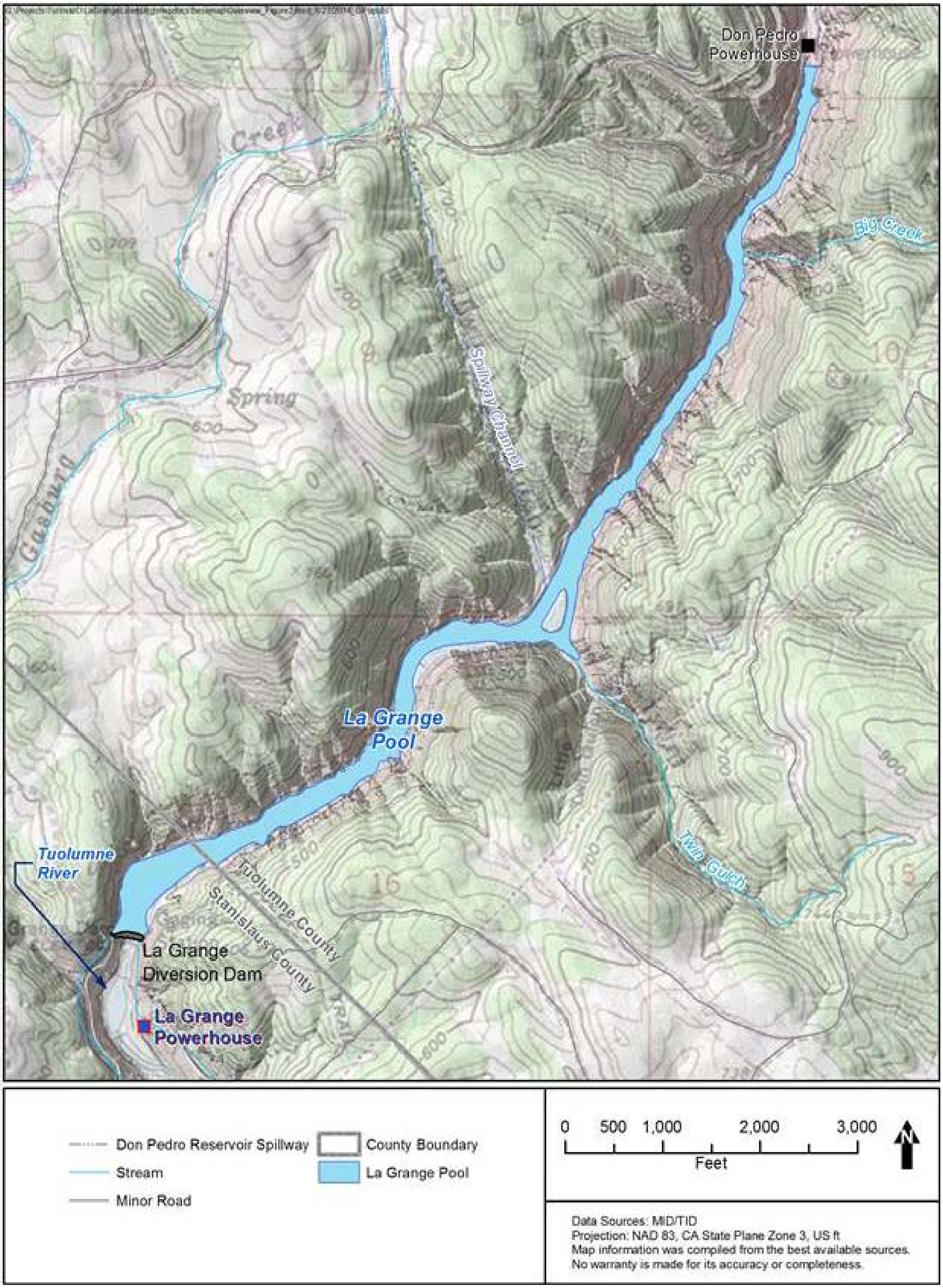

Figure 1.1-1. La Grange Hydroelectric Project location map.

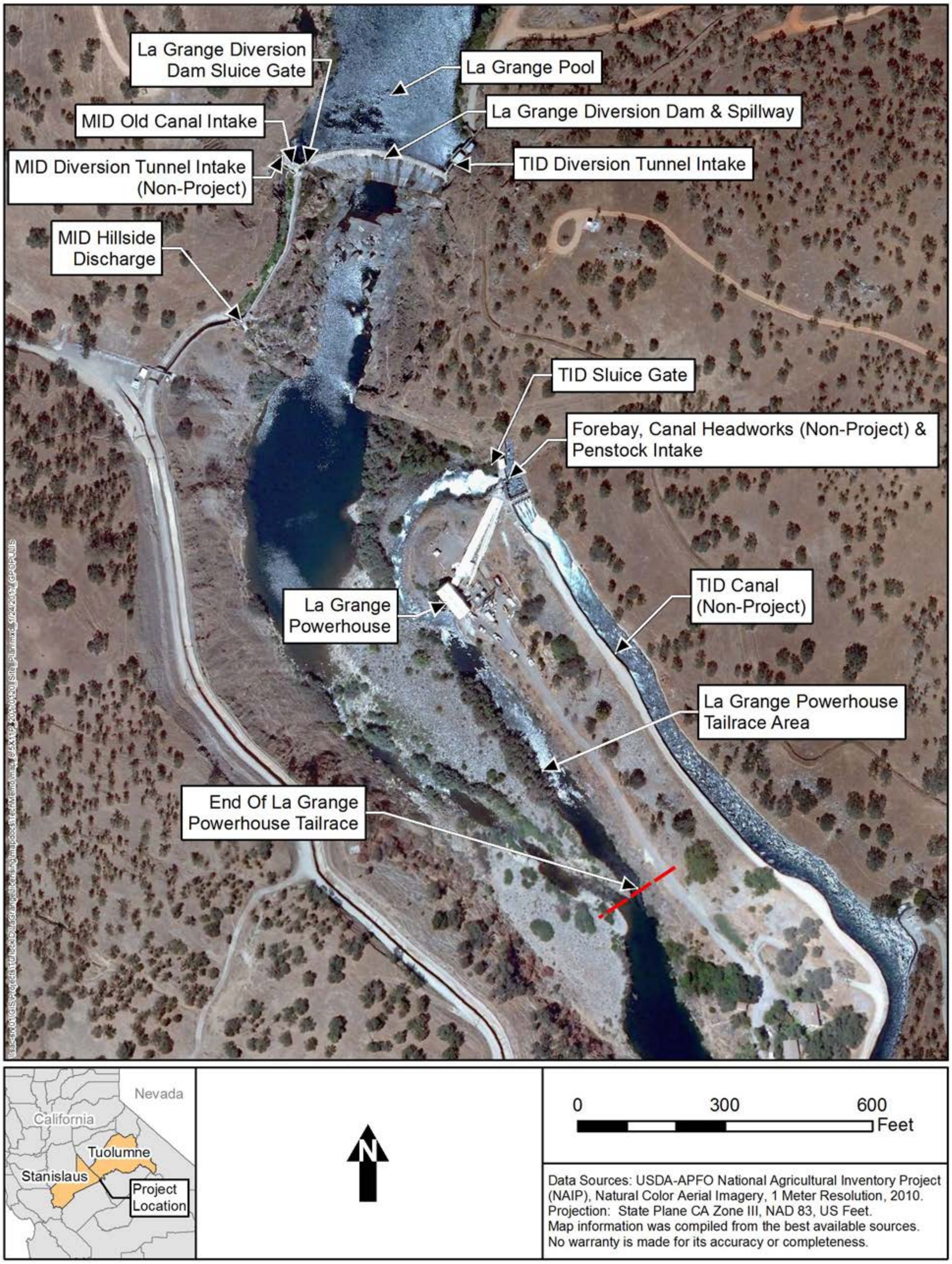

Figure 1.1-2. La Grange Hydroelectric Project site plan.

1.2 Licensing Process

In 2014, the Districts commenced the pre-filing process for the licensing of the La Grange Project by filing a Pre-Application Document with FERC[1]. On September 5, 2014, the Districts filed their Proposed Study Plan to assess Project effects on fish and aquatic resources, recreation, and cultural resources in support of their intent to license the Project. On January 5, 2015, in response to comments from licensing participants, the Districts filed their Revised Study Plan (RSP) containing three study plans: (1) Cultural Resources Study Plan; (2) Recreation Access and Safety Assessment Study Plan; and (3) Fish Passage Assessment Study Plan[2].

On February 2, 2015, FERC issued the Study Plan Determination (SPD), approving or approving with modifications six studies (Table 1.2-1). Of those six studies, five had been proposed by the Districts in the RSP. The Districts note that although FERC's SPD identified the Fish Passage Barrier Assessment, Fish Passage Facilities Alternatives Assessment, and Fish Habitat and Stranding Assessment below La Grange Diversion Dam as three separate studies, all three assessments are elements of the larger Fish Passage Assessment as described in the RSP. The sixth study approved by FERC, Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River, was requested by the National Marine Fisheries Service (NMFS) in its July 22, 2014 comment letter.

Table 1.2-1. Studies approved or approved with modifications in FERC's Study Plan Determination.

No.	Study	Approved by FERC in SPD without Modifications	Approved by FERC in SPD with Modifications
1	Recreation Access and Safety Assessment		X
2	Cultural Resources Study		X
3	Fish Passage Barrier Assessment		X[1]
4	Fish Passage Facilities Alternatives Assessment		X
5	Fish Habitat and Stranding Assessment below La Grange Dam		X
6	Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River	X[2]	

[1] Page A-1 of Appendix A of FERC's SPD states that FERC approved with modifications the Fish Passage Barrier Assessment. However, the Districts found no modifications to this study plan in the SPD and page B-7 of the SPD states that "no modifications to the study plan are recommended."
[2] FERC directed the Districts to conduct the study plan as proposed by NMFS.

In the SPD, FERC recommended that, as part of the Fish Passage Facilities Alternatives Assessment, the Districts evaluate the technical and biological feasibility of the movement of anadromous salmonids through La Grange and Don Pedro project reservoirs if the results from

[1] On December 19, 2012, Commission staff issued an order finding that the La Grange Hydroelectric Project is required to be licensed under Section 23(b)(1) of the Federal Power Act. Turlock Irrigation District and Modesto Irrigation District, 141 FERC ¶ 62,211 (2012), aff'd Turlock Irrigation District and Modesto Irrigation District, 144 FERC ¶ 61,051 (2013). On May 15, 2015, the U.S. Court of Appeals for the District of Columbia Circuit denied the Districts' appeal and affirmed the Commission's finding that the La Grange Hydroelectric Project requires licensing. Turlock Irrigation District, et al., v. FERC, et al., No. 13-1250 (D.C. Cir. May 15, 2015).
[2] The Fish Passage Assessment Study Plan contained a number of individual, but related, study elements.

Phase 1 of that study indicate that the most feasible concept for fish passage would involve fish passage through Don Pedro Reservoir or La Grange pool. On September 16, 2016, the Districts filed the final study plan with FERC. On November 17, 2016, the Districts filed a letter with FERC after consulting with fish management agencies (i.e., NMFS and the California Department of Fish and Wildlife [CDFW]) regarding the availability of test fish and a determination that no fish would be available to support conducting this study in 2017. On January 12, 2017, the Districts filed a letter with FERC stating that with FERC's approval, they intend to conduct the study in 2018 if the results from the Fish Passage Facilities Alternatives Assessment indicate that upstream or downstream fish passage at La Grange and Don Pedro projects would require anadromous fish transit through one or both reservoirs.

In addition to the six studies noted in Table 1.2-1, the SPD required the Districts to develop a plan to monitor anadromous fish movement in the vicinity of the Project's powerhouse draft tubes to determine the potential for injury or mortality from contact with the turbine runners. The Districts filed the Investigation of Fish Attraction to La Grange Powerhouse Draft Tubes study plan with FERC on June 11, 2015, and on August 12, 2015, FERC approved the study plan as filed.

On February 2, 2016, the Districts filed the Initial Study Report (ISR) for the La Grange Project. The Districts held an ISR meeting on February 25, 2016, and on March 3, 2016, filed a meeting summary. Comments on the meeting summary and requests for new studies and study modifications were to be submitted to FERC by Monday, April 4. One new study request was submitted; NMFS requested a new study entitled Effects of La Grange Hydroelectric Project Under Changing Climate (Climate Change Study). On May 2, 2016, the Districts filed with FERC a response to comments received from licensing participants and proposed modifications to the Fish Passage Facilities Alternatives Assessment and the La Grange Project Fish Barrier Assessment. On May 27, 2016, FERC filed a determination on requests for study modifications and new study. The May 27, 2016 determination approved the Districts' proposed modifications and did not approve the NMFS Climate Change Study.

During the ISR meeting held on February 25, 2016, NMFS requested that the Districts provide a copy of the LiDAR report for the LiDAR data referenced in the Topographic Survey Technical Memorandum. NMFS requested additional data pertaining to the study in the agency's April 4, 2016, comments on the ISR. In particular, NMFS requested a copy of the survey data (x, y, z coordinate data) as well as the longitudinal profile and water surface data.

In response to these requests, the Districts provided the LiDAR report as an attachment to the Districts' May 2, 2016 response to licensing participant comments on the ISR. Additionally, the Districts prepared a data package that included: (1) a shapefile depicting point LiDAR measurements of the island area between the lower Tuolumne River main channel below the La Grange Diversion Dam and the powerhouse tailrace channel; (2) a shapefile with survey points; (3) a shapefile with longitudinal profile routed line features that represent the thalweg of each surveyed channel; (4) a shapefile with all survey points utilized to develop the profile graphic included in the technical memo; and (5) a table summarizing depths by habitat unit and profile charts that show the water depth data. The Districts provided this data package, via CD, to

NMFS on May 23, 2016. On May 31, 2016, the Districts mailed a copy of this CD to FERC. This data is available upon request to the Districts (Attachment A).

1.3 Study Plan

FERC's Scoping Document 2 (SD2) issued on September 5, 2014 identified the potential for Project effects on anadromous fish spawning habitat downstream of the LGDD. According to the SD2, such effects might possibly result from the retention of sediment in the La Grange pool, or if changes in Project outflows alter downstream spawning habitat suitability and thereby impact spawning due to stranding or displacement of fish or redds in either the main channel, the tailrace channel, or the sluice gate channel.

FERC's SPD approved with modifications the Districts' proposed Fish Habitat and Stranding Assessment below La Grange Diversion Dam. In its SPD, FERC ordered the Districts to: (1) continue monitoring existing flow conduits where flow monitoring is already occurring, conduct two years of flow monitoring at flow conduits not currently monitored (i.e., the Modesto hillside discharge and LGDD sluice gate), develop estimates of historical flows, data permitting, for each of the five flow conduits at the Project, and, based on existing information, to the extent available, characterize the magnitude and rate of flow and stage changes when Project conduits are shut down; (2) collect topographic, depth, and habitat data downstream of, and in the vicinity of, the Project; (3) assess fish presence and the potential for stranding; and (4) in consultation with NMFS and other interested parties, develop and implement a plan for monitoring anadromous fish movement into the powerhouse draft tubes.

The Topographic Survey reported herein describes the work associated with Item (2) above. Other components related to this study directive, including habitat typing, gravel mapping, and spawning habitat suitability in the reach immediately downstream of LGDD, are provided in a separate report entitled Salmonid Habitat Mapping Technical Memorandum (TID/MID 2016).

2.0 STUDY GOALS AND OBJECTIVES

The goal of the survey is to collect information to evaluate the effects of Project operation on stream flow and anadromous fish habitat in the Tuolumne River between LGDD and La Grange gage. Specific objectives of the survey include:

- surveying a longitudinal profile and transects along the channel thalweg in the La Grange powerhouse tailrace, TID sluice gate channel, and the mainstem river channel upstream of where it joins the tailrace channel, as depicted in Figure 1.1-2. Take survey measurements that characterize the large cobble and bedrock island that separates the La Grange powerhouse tailrace and the mainstem Tuolumne River below LGDD;
- taking survey measurements at geomorphic hydraulic control features in the channels below the LGDD and La Grange powerhouse. These include pool tailouts, rock outcroppings, ledges, and other immobile bed features that determine the stage-discharge relation. Note that this objective was added per FERC's SPD; and
- measuring water depths at a flow of approximately 25 cubic feet per second (cfs) in the mainstem river channel upstream of where it joins the tailrace channel and at approximately 75 to 100 cfs in the La Grange powerhouse tailrace channel and the TID sluice gate channel.

3.0 STUDY AREA

The study area is depicted in Figure 1.1-2 and includes the La Grange tailrace channel, the TID sluice gate channel, and the mainstem Tuolumne River from where it joins the tailrace channel upstream to the LGDD plunge pool. The total length of stream channel to be assessed is approximately 0.5 miles.

4.0 METHODOLOGY

4.1 2015 Topographic Data Collection

The survey was completed over two days. The first day was June 23, 2015 and the second day was July 15, 2015. A Real Time Kinematic (RTK) GPS system was used to record topographic information. RTK GPS is capable of recording centimeter level accuracy for both horizontal and vertical positions. A licensed TID surveyor and survey crew were present and completed the topographic surveys on both days.

The day before data collection commenced, TID surveyors set up the RTK GPS base station and verified that the RTK data loggers were recording data by surveying several known points and validating the results. On June 23, traditional ground-based surveys along the longitudinal profile of both the mainstem Tuolumne River and the La Grange powerhouse tailrace channel were conducted. Each topographic measurement included a water depth measurement approximately every 10 feet with additional points recorded in areas of hydraulic control. Figure 4.1-1 shows surveyors recording position and depth along the thalweg of the La Grange powerhouse tailrace.

Figure 4.1-1. Traditional ground-based data collection along La Grange powerhouse tailrace channel.

Because the large plunge pool below LGDD and several areas along both channels were too deep to survey safely using traditional ground-based survey methods, it was determined that a bathymetric survey at a later date would be required for these areas. The bathymetric survey was completed on July 15, 2015 using a remote control platform combined with RTK GPS and sonar. Surveyors used a Hydrone™ Remote Control Vessel (RCV), a HydroLite-TM™ sonar system, and RTK GPS for position and elevation to complete the survey (Figure 4.1-2).

The HydroLite-TM™ system utilizes a 200-KHz four degree sonar beam to accurately record depths to 1 cm. Because the plunge pool's depth did not allow for a visual evaluation of the thalweg, position and depth were measured along transects perpendicular to the longitudinal extent of the large pool. Each transect was spaced at approximately 15 feet. The longitudinal profile and thalweg was then derived from the transect data by connecting the lowest sounding from each transect. There were several in-channel pools that were measured using the RCV as well. At these pools, the water was shallow enough for a visual evaluation of the thalweg and the RCV was piloted along the thalweg, recording position, and depth. These measurements were combined with the previous surveyed profile data to produce a seamless longitudinal profile along the thalweg of both the mainstem Tuolumne River and La Grange powerhouse tailrace channels.

Figure 4.1-2. Bathymetric survey of plunge pool below La Grange Diversion Dam.

At the time of the survey in 2015, no depths were recorded because the TID sluice gate channel was not inundated by water[3]. The Districts provided a LiDAR dataset that was collected while the sluice gate was closed. The LiDAR data was used to complete the longitudinal profile of the sluice gate channel and the topographic survey of the large cobble and bedrock island that separates the La Grange powerhouse tailrace and the mainstem channel. The LiDAR data was flown on March 30, 2012 and meets Federal Emergency Management Agency specifications for the generation of two-foot contours.

[3] In general, an 18-inch pipe supplies water to the sluice gate channel at all time. However, during a portion of the summer of 2015, the 18-inch pipe was closed to support study activities. The pipe was reopened in the fall of 2015.

4.2 Hydraulic Control

In addition to collecting topographic data along the river profile, surveyors collected additional topographic points along areas of hydraulic control within the inundated channels of both the mainstem Tuolumne River and the La Grange powerhouse tailrace channel.

4.3 Discharge Measurements

To ensure depth measurements were being taken at discharges identified in the RSP (i.e., approximately 25 cfs in the mainstem river channel upstream of where it joins the tailrace channel and at approximately 75 to 100 cfs in the La Grange powerhouse tailrace channel and the TID sluice gate channel), manual flow measurements of both the La Grange powerhouse tailrace channel and the mainstem Tuolumne River channel were completed using a Swoffer® velocity meter on June 23 to verify flow conditions were consistent with the requirements of the RSP. The model of Swoffer® velocity meter used is accurate at velocities ranging from 0.1 to 25.0 feet per second (fps). A photo of the flow measurement transect within the La Grange powerhouse tailrace channel is shown in Figure 4.3-1.

Figure 4.3-1. Velocity measurement transect on the La Grange powerhouse tailrace channel.

5.0 RESULTS

5.1 Topographic Data

The FERC-approved RSP states the results of the topographic study should include longitudinal profiles of the mainstem Tuolumne River, the TID sluice gate channel, and the La Grange powerhouse tailrace channel. These data are provided below (Figures 5.1-1, 5.1-2, and 5.1-3), along with a map showing the channel thalwegs (Figure 5.1-4). All elevations are reported in the North American Vertical Datum of 1988 (NAVD88).

The RSP additionally requires topographic points that characterize the large cobble and bedrock island that separates the La Grange powerhouse tailrace and the mainstem Tuolumne River below LGDD. These topographic points were available from the LiDAR data provided by the Districts and are characterized below in Figure 5.1-5. The elevations on the island at the time of the survey ranged from 176.9 to 193.0 feet. The average elevation was 186.9 feet and the average distance between points was approximately 1.4 feet.

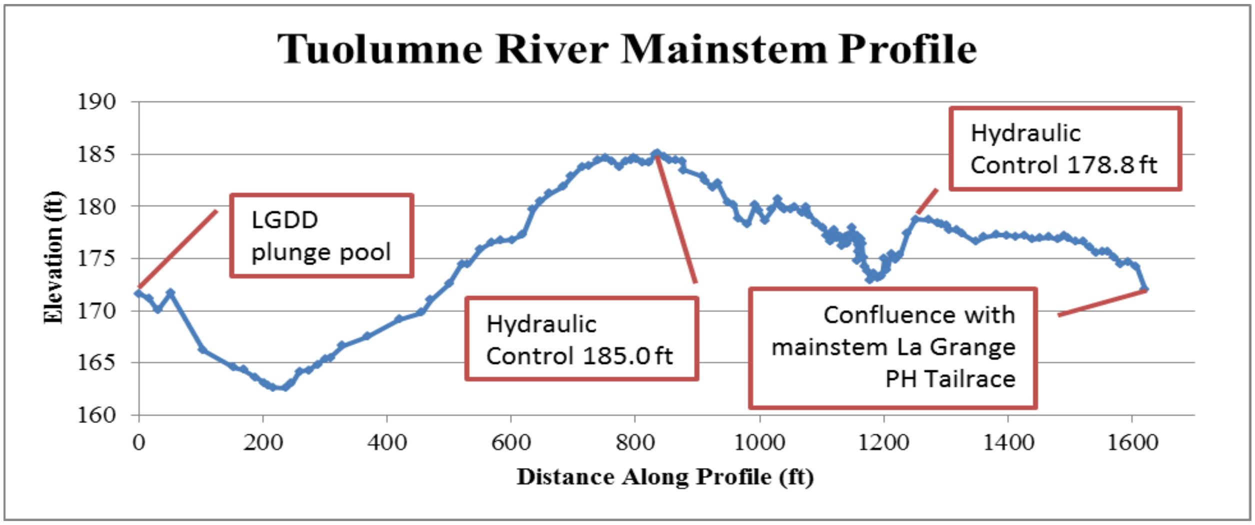

Figure 5.1-1. Longitudinal profile of the Tuolumne River mainstem channel.

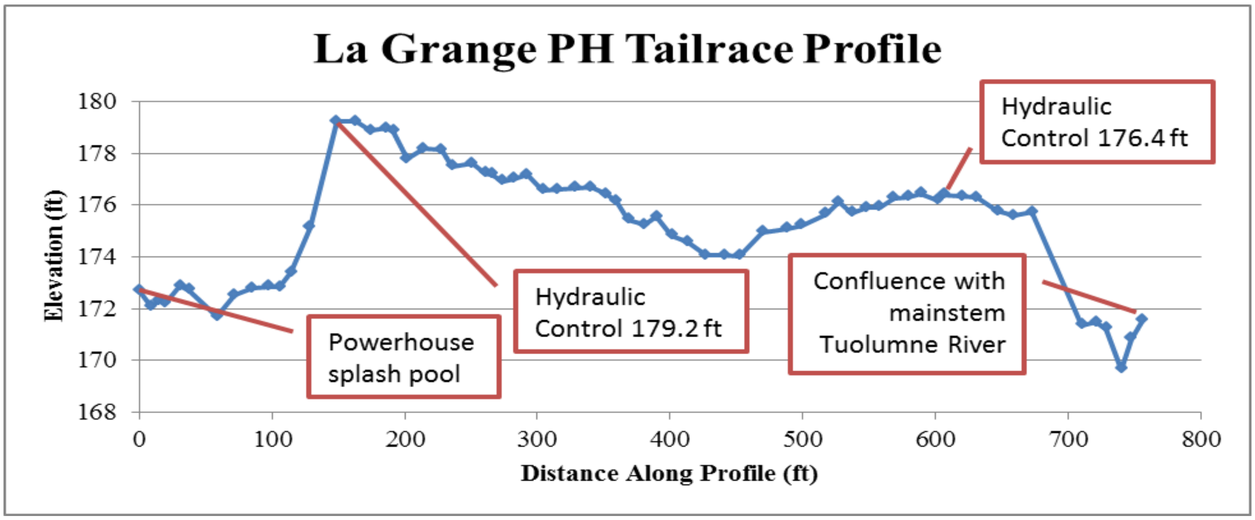

Figure 5.1-2. Longitudinal profile of the La Grange powerhouse tailrace channel.

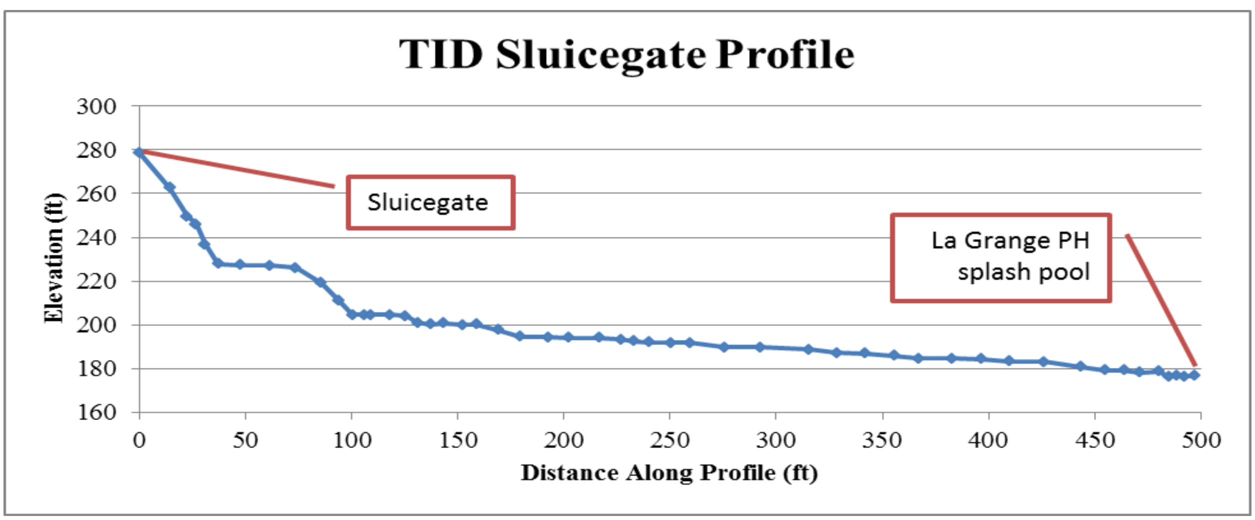

Figure 5.1-3. Longitudinal profile of the TID sluice gate channel.

Figure 5.1-4. Channel thalwegs and hydraulic control locations with distances along profile identified.

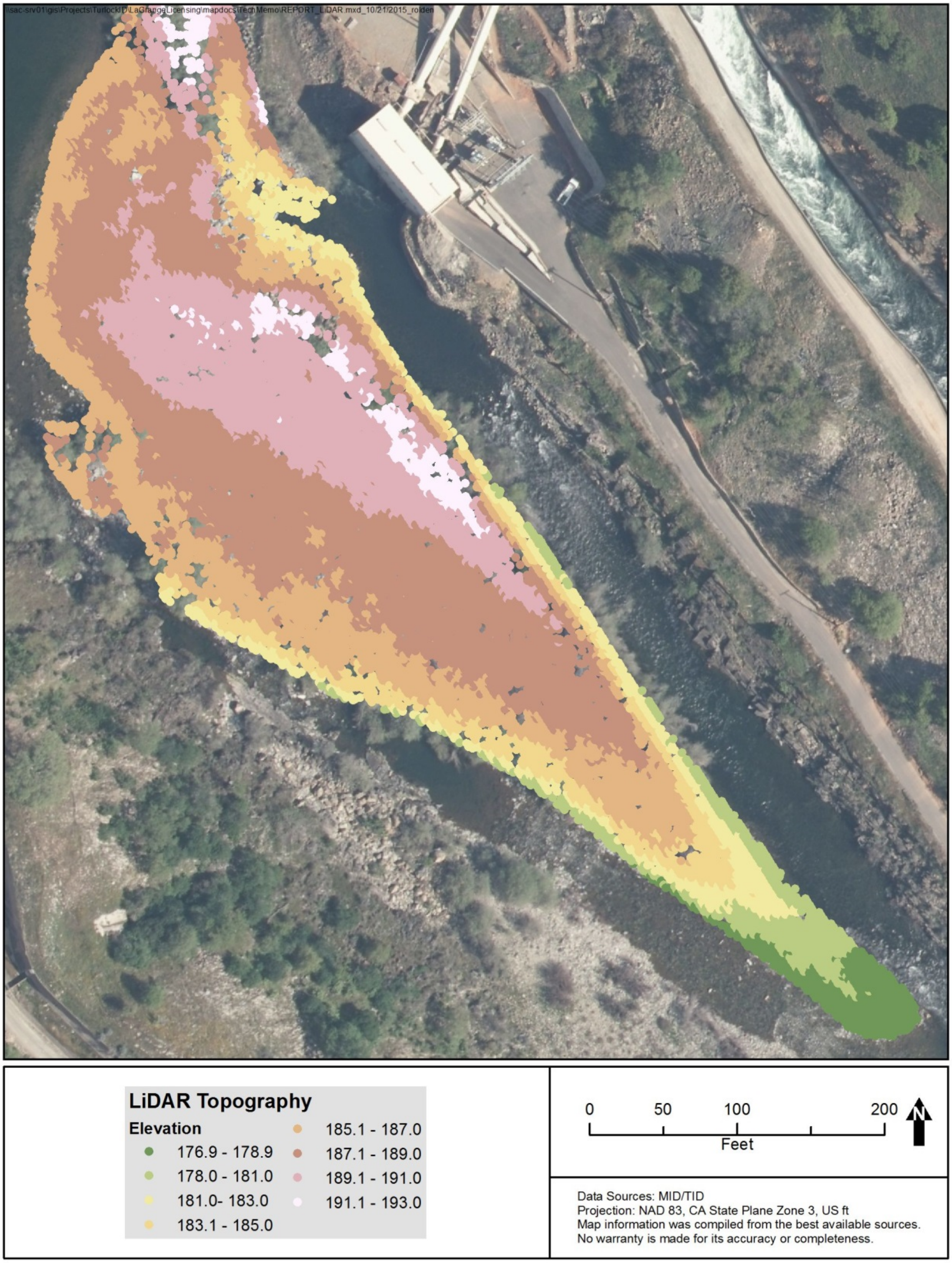

Figure 5.1-5. Mid-channel island LiDAR topography.

5.2 Hydraulic Control

Surveyors identified two points of hydraulic control on each of the both the mainstem Tuolumne River and the La Grange powerhouse tailrace channel. The topographic measurements at areas of hydraulic control are identified in Figures 5.1-1, 5.1-2, and 5.1-4.

5.3 Discharge and Depth Measurements

Mainstem Tuolumne River channel flow measurements were difficult to complete due to the low flow conditions and the lack of a suitable flow measurement location. However, the combined flow for both channels is captured by the U.S. Geological Survey (USGS) gage just downstream of the study area, thus mainstem channel flow measurements can be inferred by subtracting the flow measurement within the La Grange powerhouse tailrace channel.

Flow measurements for each of the channels were not measured on July 15, 2015 as they were similar to June 23, 2015 according to both the USGS gage immediately downstream of the study area and a visual assessment by survey staff. The RSP states that flows should be approximately 75 to 100 cfs in the La Grange tailrace channel and approximately 25 cfs in the main channel. As shown below in Table 5.3-1, the flow measurement results are consistent with this requirement.

Table 5.3-1. Flow measurements below La Grange Diversion Dam and powerhouse.

Date	Manual – La Grange PH Tailrace (cfs)	USGS 11289650 (cfs)	Inferred – Main Channel (cfs)
6-23-2015	81	~100	19
7-15-2015	NA	~90	NA

Depth measurements along the surveyed longitudinal profiles were recorded under discharges identified in the RSP. A summary of these data is provided below (Table 5.3-2). A range of depths is provided along with the average and median depths for each of the channel profiles. The median depth may be more representative of the most common depths by length as the deep pool depths are an order of magnitude larger than the most prolifically observed depths. The complete dataset of depth measurements is available upon request to the Districts.

As noted above, depths in the TID sluice gate channel were not available during the time of the 2015 survey as the sluice gate was closed and no water was in the channel. Additionally, existing LiDAR data of the sluice gate channel provided by the Districts was conducted when the TID sluice gate was closed. In 2016, a hydraulic study of the TID sluice gate channel was completed, the data from which is available upon request (Attachments A and B).

Table 5.3-2. Summary of depth measurements collected in 2015 for each channel below LGDD.

Channel	Depth Range (ft)	Average Depth (ft)[1]	Median Depth (ft)
Tuolumne River Mainstem	0.3-23.1	6.2	2.9
La Grange PH Tailrace	0.7-9.1	3.4	2.2
TID Sluice Gate[2]	NA	NA	NA

1 Average and median depth calculated along the longitudinal profile measurements.
2 The TID sluice gate was closed during the survey.

6.0 STUDY VARIANCES AND MODIFICATIONS

There was one variance and no modifications to the study plan. At the time of the survey in 2015, there were no flows in the TID sluice gate and thus no depth measurements were taken. The Districts collected this information in 2016 (Attachment B).

7.0 REFERENCES

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 2016. Salmonid Habitat Mapping Technical Memorandum. Prepared by Stillwater Sciences. Attachment to La Grange Hydroelectric Project Initial Study Report. February 2016.

TOPOGRAPHIC SURVEY
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ATTACHMENT A

LIDAR AND SPATIAL DATA AVAILABLE UPON REQUEST

A CD containing LiDAR data and spatial data used by or developed during the Topographic Survey is available upon request. The CD contains: (1) a shapefile depicting point LiDAR measurements of the island area between the lower Tuolumne River main channel below the La Grange Diversion Dam and the powerhouse tailrace channel; (2) a shapefile with survey points; (3) a shapefile with longitudinal profile routed line features that represent the thalweg of each surveyed channel; (4) a shapefile with all survey points utilized to develop the profile graphic included in the technical memo; (5) a table summarizing depths by habitat unit and profile charts that show the water depth data; and (6) a LandXML file containing data from the 2016 sluice gate channel survey. The CD is available upon request to Jenna Borovansky (jenna.borovansky@hdrinc.com).

TOPOGRAPHIC SURVEY
TECHNICAL MEMORANDUM

ATTACHMENT B

2016 SLUICE GATE CHANNEL SURVEY

1.0 INTRODUCTION

As part of the La Grange Hydroelectric Project (La Grange Project or Project; FERC No. 14581) Topographic Survey, Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) were required to conduct a survey of the sluice gate channel. At the time of the Topographic Survey fieldwork in 2015, there were no sluice gate flows and thus no water depth measurements were taken. In January 2016, the Districts filed with the Federal Energy Regulatory Commission (the Commission or FERC) the Topographic Survey Technical Memorandum, which stated that the Districts would collect water depth data in the sluice gate channel in 2016. FERC staff approved this modification per the May 27, 2016 Determination on Requests for Study Modifications and New Study for the La Grange Project. This technical memorandum presents the results of the 2016 hydraulic study of the sluice gate channel.

If the La Grange powerhouse trips off line, the sluice gate(s) located adjacent to the penstock intakes (see Figure B-1) is immediately opened to maintain discharge in the tailrace channel. When powerhouse operation is restored, the sluice gate(s) closes. An 18-inch pipe delivers approximately 5 to 10 cfs from the forebay structure to the sluice gate channel continuously, maintaining flowing water to the sluice gate channel at all times [1].

Figure B-1. Aerial photo of sluice gate channel area, forebay, penstock intakes, powerhouse and upper end of tailrace channel.

[1] In general, an 18-inch pipe supplies water to the sluice gate channel at all time. However, during a portion of the summer of 2015, the 18-inch pipe was closed to support study activities. The pipe was reopened in the fall of 2015.

The Districts performed field survey measurements of topography and water surface elevation in the channel below the sluice gate at the constant flow from the 18-inch pipe which was measured to be approximately 8 cfs and at a sluice gate flow of 80 cfs. This field survey information and water surface elevation data were used to develop a hydraulic model and plot cross-section and longitudinal depth profiles as well as to quantify the stage changes associated with flow changes during operation of the sluice gates to enable the evaluation of the potential for fish stranding.

2.0 SITE DATA

Site data for the study was provided in the form of a detailed 1-foot contour interval topographic survey performed in October 2016. The topographic survey covered the area of the sluice gate channel between the discharge gates and the powerhouse tailrace, as shown in Figure B-2 and provided in Attachment 1. Figure B-2 shows the shaded area of the survey with the individual survey points overlaid on the aerial image of the study area.

Figure B-2. Topographic survey coverage.

3.0 HEC-RAS MODEL

HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels. The Hydrologic Engineering Center (HEC) in Davis, California, developed the River Analysis System (RAS) to aid hydraulic engineers in channel flow analysis and floodplain determination. HEC-RAS is capable of simulating steady and unsteady flows, including calculations for cross-sections, bridges, culverts, dams, gates, and other hydraulic structures.

HEC-RAS version 5.0.3 was used to evaluate the hydraulic characteristics of the sluice gate channel.

3.1 Setup

The HEC-RAS model is based on the field survey data compiled into HEC-GeoRAS and ArcGIS, then processed into a HEC-RAS model geometry. Figure B-3 presents the HEC-RAS model cross-section locations along the bypass channel.

Figure B-3. HEC-RAS model geometry superimposed on aerial photo.

Normal depth was set for the downstream boundary condition with a 1.7 percent slope approximated using the furthest downstream sections provided in the channel geometry. The calibration region was selected to be sufficiently upstream of the normal depth condition, ensuring that the channel's water surface was not affected by the boundary condition.

3.2 Geometry

Figure B-4 shows the generalized channel profile, illustrating the steep pitch directly below the gates, the shallow pool at the base of the steep pitch, and the run leading from the pool to the powerhouse tailwater. Representative cross sections are provided in Figures B-5 through B-7 for the pool, run, and a location just upstream of the powerhouse tailwater. The locations of these representative cross sections are shown in Figure B-4.

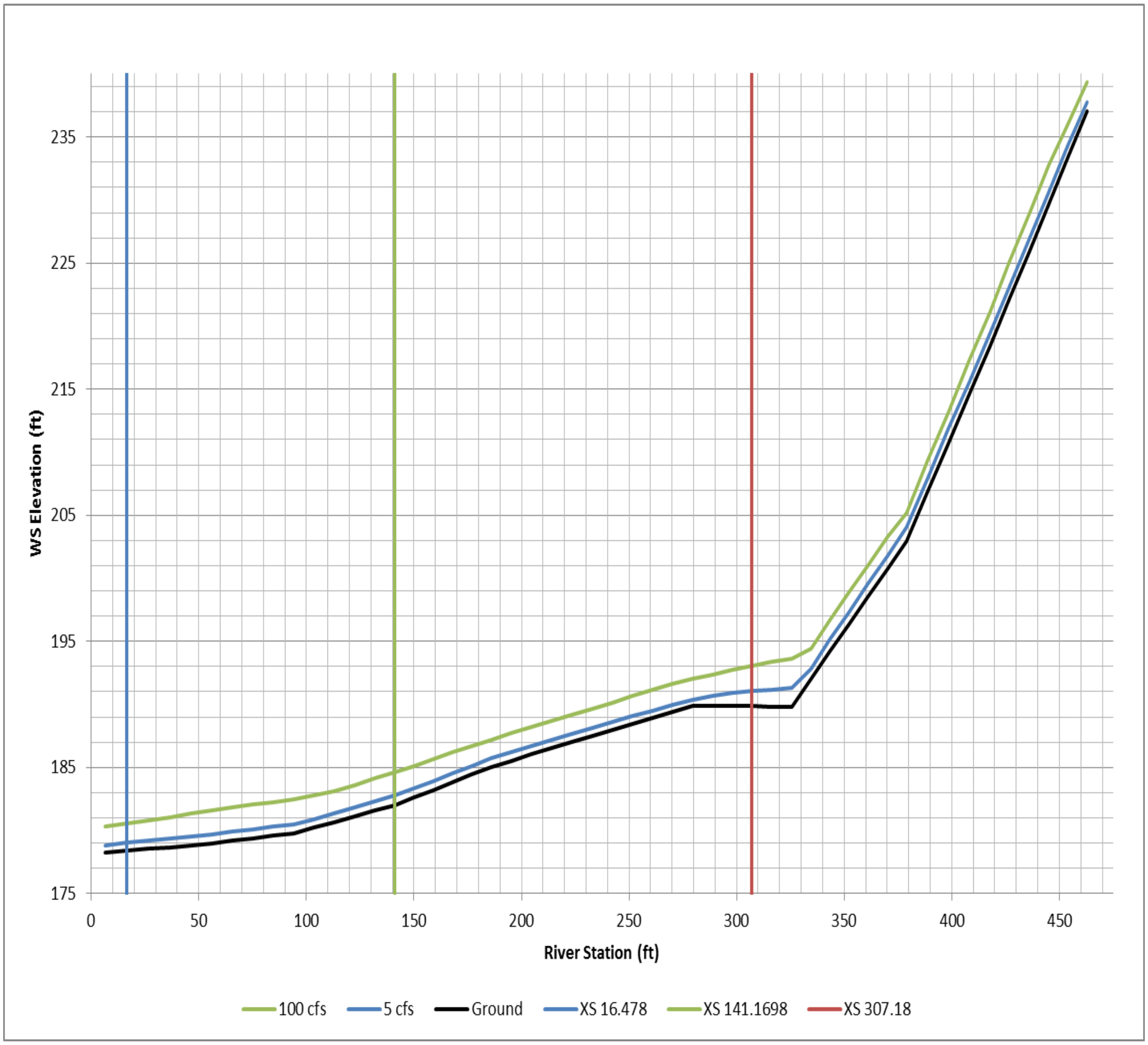


Figure B-4. Generalized channel profile with representative cross sections. Note the difference in the horizontal and vertical scales.

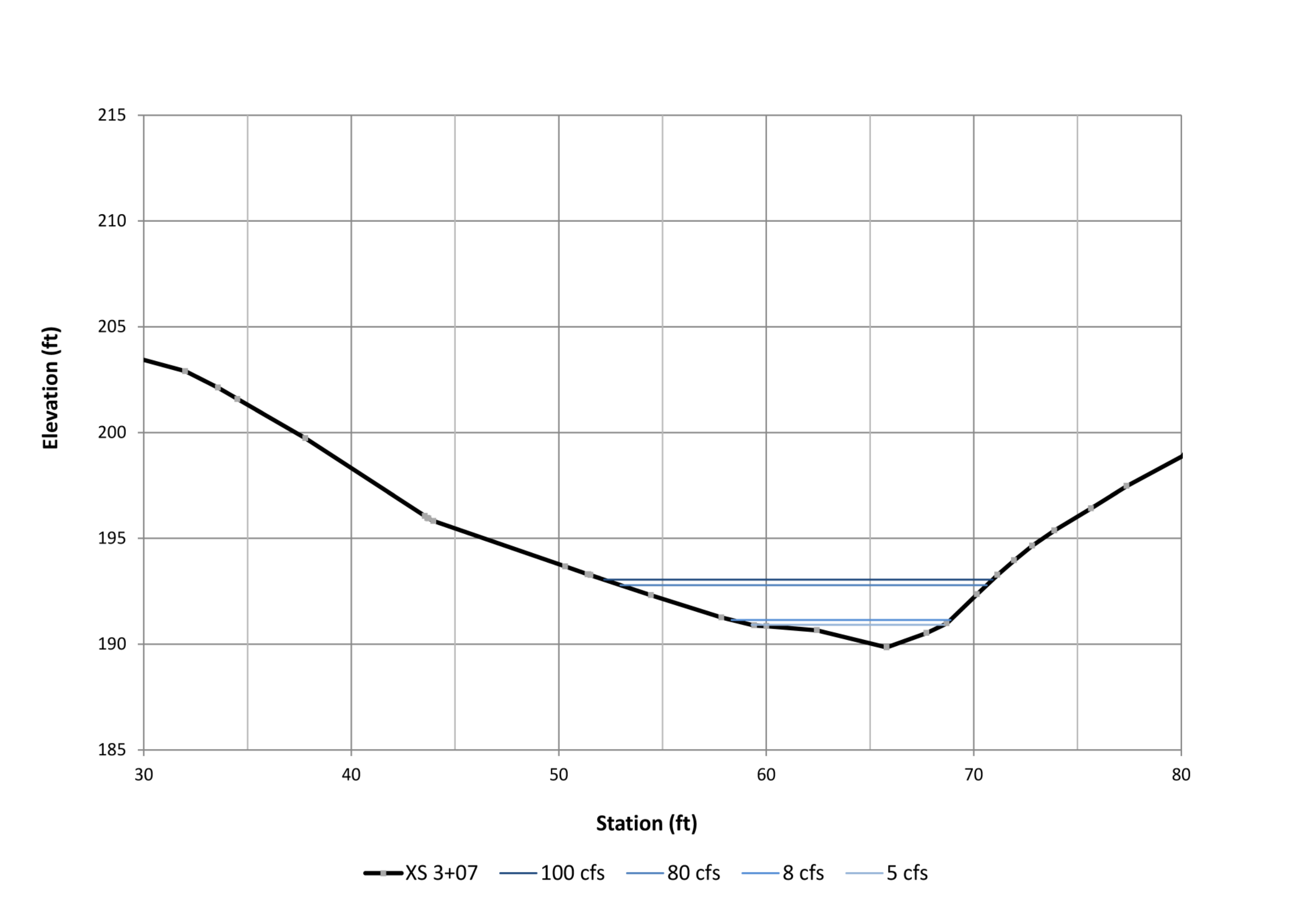


Figure B-5. **Cross section at Station 3+07 in shallow pool area.**

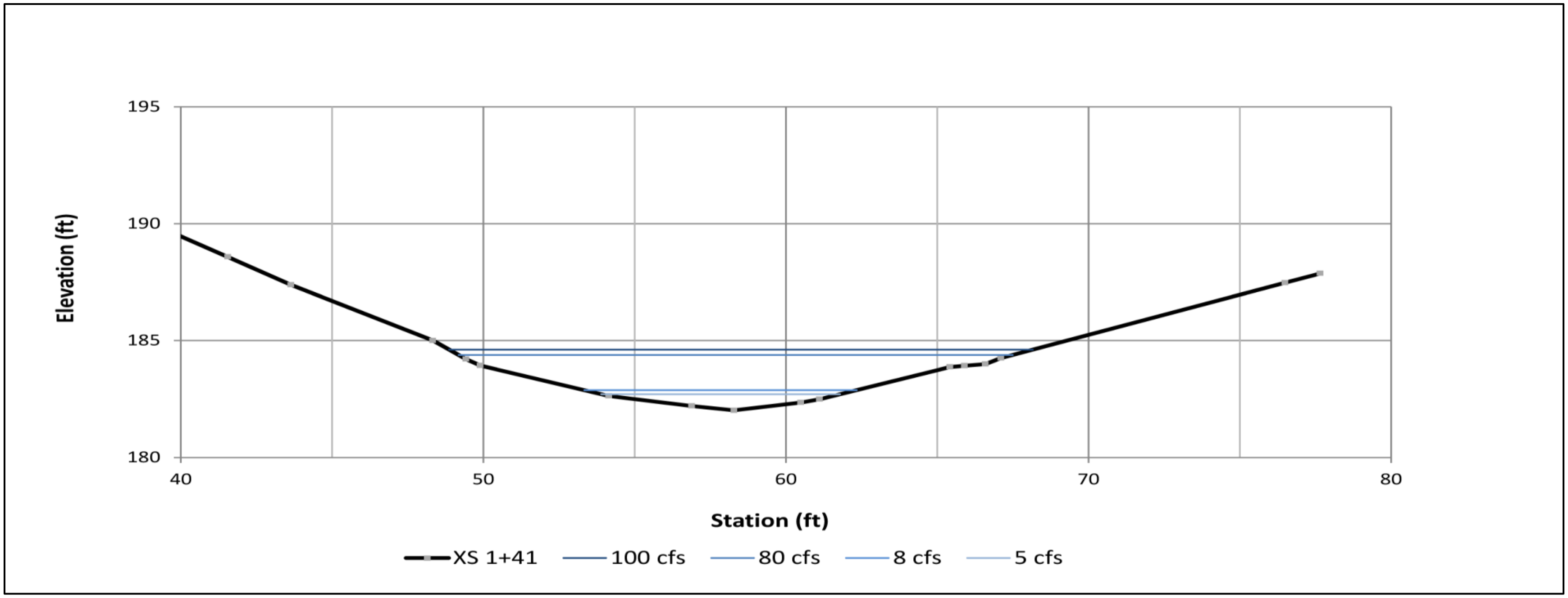


Figure B-6. **Cross section at Station 1+41 in run area.**

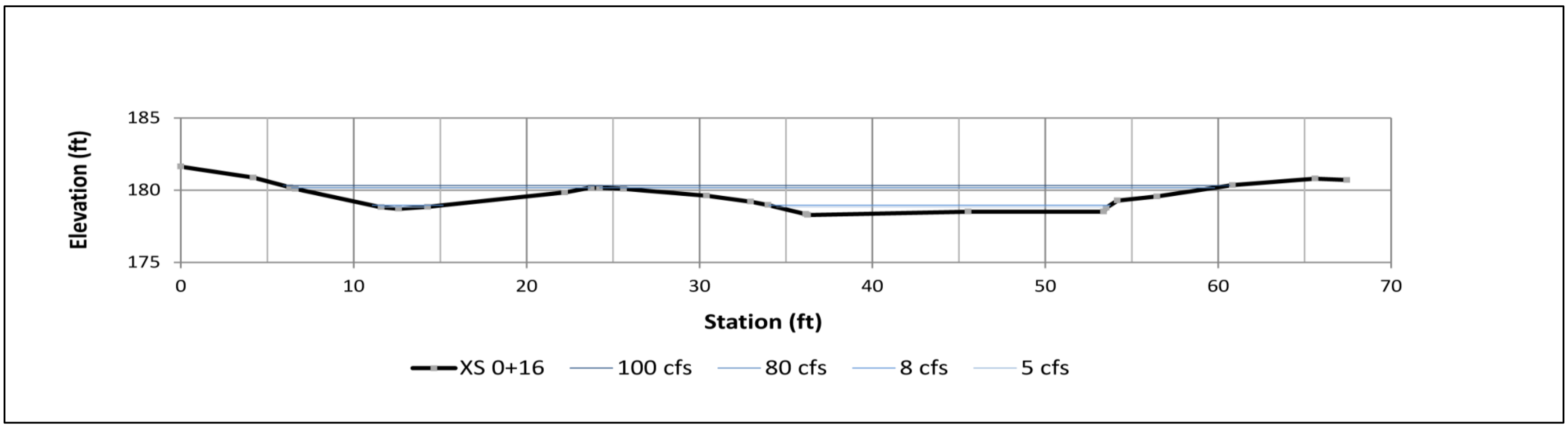


Figure B-7. **Cross section at Station 0+16 upstream of tailwater.**

3.3 Calibration

Calibration was performed using the field survey data obtained during the 2016 field survey, where flows of 8 and 80 cfs were released, and survey data was obtained along the channel edge of water for the two flows. TID estimated the flow rates in the sluiceway channel during the survey based on standard hydraulic formulae for submerged gates and orifices.

The HEC-RAS model was calibrated by varying the channel roughness, Manning's "*n*", in HEC-RAS to best match the surveyed 8 cfs and 80 cfs water surface elevations. For calibration, a range of *n* values of 0.08 to 0.20 were considered with calibration values of 0.15 and 0.12 determined for 8 and 80 cfs respectively.

A mean section roughness *n* value of 0.135 was selected to represent the general roughness in the stream reach, with resulting water surface profiles compared to survey data as shown in Figure B-8 and Figure B-9. The reach between model station 0+75 and station 3+25 was used in the calibration. For the mean *n* value of 0.135, the computed water surface elevation for 8 cfs was compared to the 8 cfs field survey elevation data, and the computed elevations were generally within 0.03 feet of the field survey water surface elevation data along the area of calibration. For the flow of 80 cfs, the modeled water surface was generally within 0.15 feet of the field survey elevation data, which is within 6 percent of the average depth for the measured 80 cfs water surface. HDR considers this to be reasonable fit for the model to the observed data.

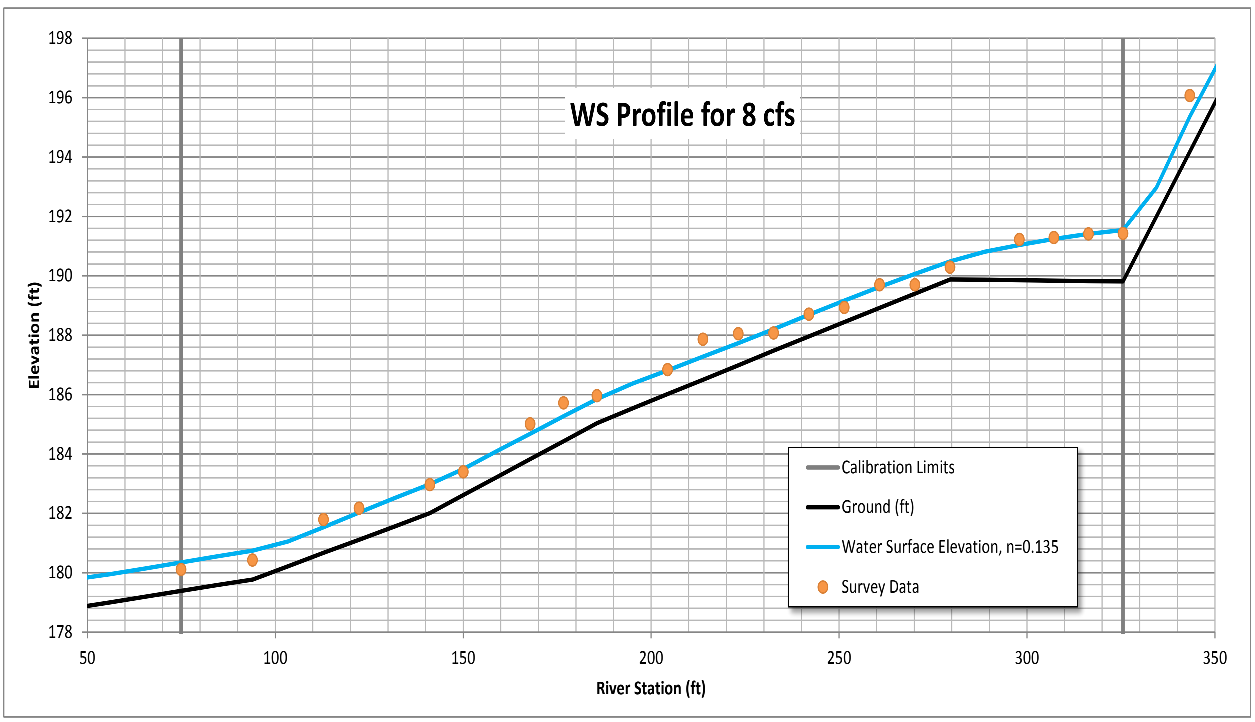


Figure B-8. Water surface profile for 8 cfs showing field survey calibration data.

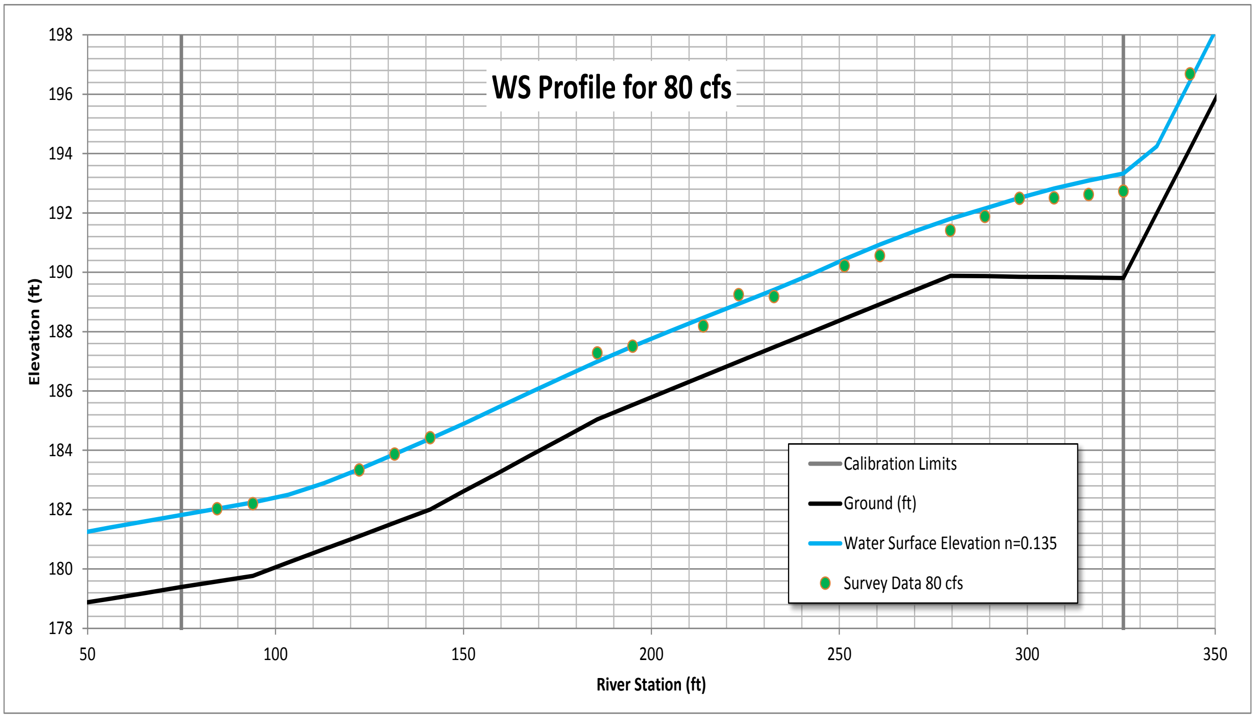


Figure B-9. Water surface profile for 80 cfs showing field survey calibration data.

3.4 Model Runs

Following calibration of the water surface profile for the surveyed 8 cfs and 80 cfs water surface profiles, the model was executed to simulate a gate closure event in which the inflow to the model was transitioned from a constant gate discharge of 100 cfs to a flow of 5 cfs, simulating a gate closure over a closure time of two minutes. The model was run at a 10-second time interval and ran 10 minutes past the end of the gate closure event to capture the attenuation of flow at the downstream end of the model.

4.0 RESULTS AND CONCLUSIONS

Within the sluice gate channel, there is a shallow watered pool located below the gates at model station 2+80 to 3+20. As shown in the profile on Figure B-3, a minimum flow of 5 cfs provides an average modeled channel depth of 0.7 feet (8 ¼ inches) with a minimum depth of 0.5 feet (6 inches) at the downstream end of the pool. From the pool downstream to the tailrace, the average depth for the channel is 0.65 feet (7 ¾ inches). It is important to note that the substrate composition for this channel is mainly large cobble with boulders, which provide localized flow resistance and localized irregular variation in water surface elevations. The HEC-RAS model utilizes the roughness value (Manning's "*n*") to uniformly approximate channel roughness and does account for the localized three-dimensional turbulence, although it is likely that these local effects create local variations in depths and velocity.

The HEC-RAS unsteady flow model runs demonstrated that a change in water surface, during a gate closure event from 100 cfs gate discharge to 5 cfs, would result in an average water surface drop along the flow channel of 1.7 feet starting within 6 minutes of the beginning of gate closure. The drop is relatively uniform across the lower reach length, demonstrating flow connectivity between the upstream pool area and the downstream tailrace as shown in Figure B-10.

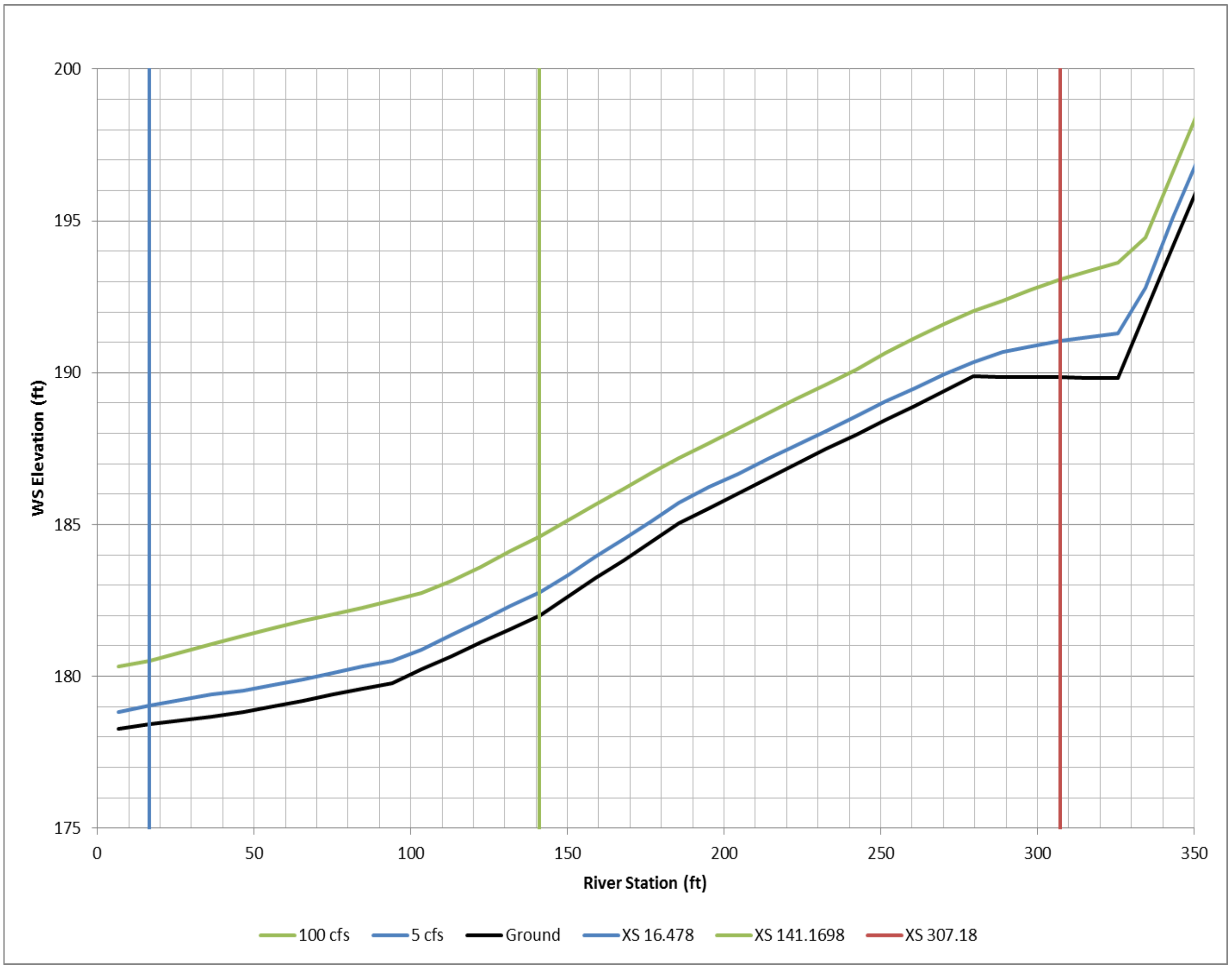


Figure B-10. Modeled water surface profiles under flows of 100 cfs and 5 cfs.

For the representative cross-section locations identified in Figure B-10, stage and discharge hydrographs are provided to demonstrate the modeled variation in water surface with discharge in Figures B-11, B-12 and B-13. Note the modeled two-minute gate closure begins on the second minute of modeling and the modeled lag between gate closure and change in downstream hydrograph is approximately one minute as shown in Figure B-13.

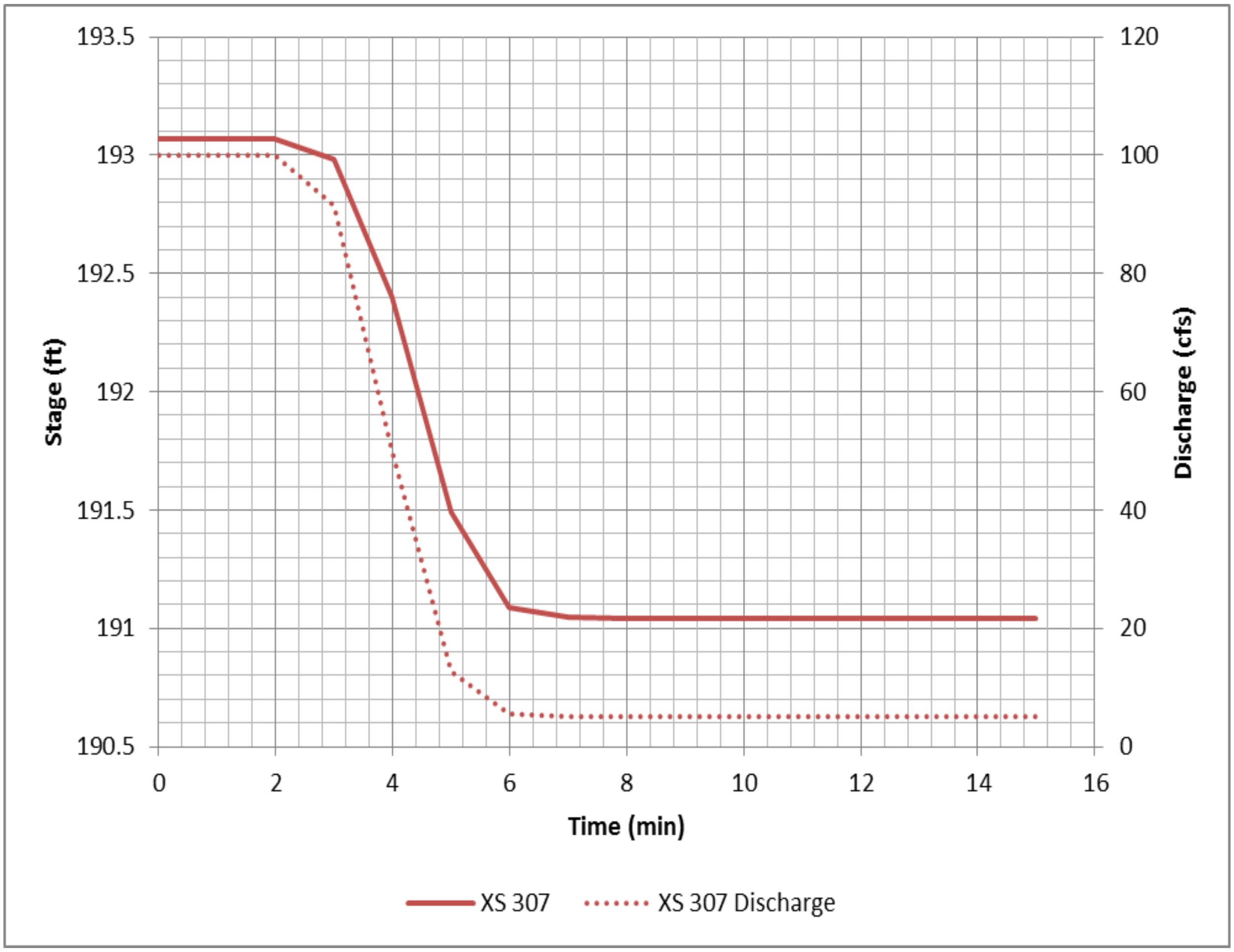


Figure B-11. Modeled stage-discharge hydrograph for representative pool cross section.

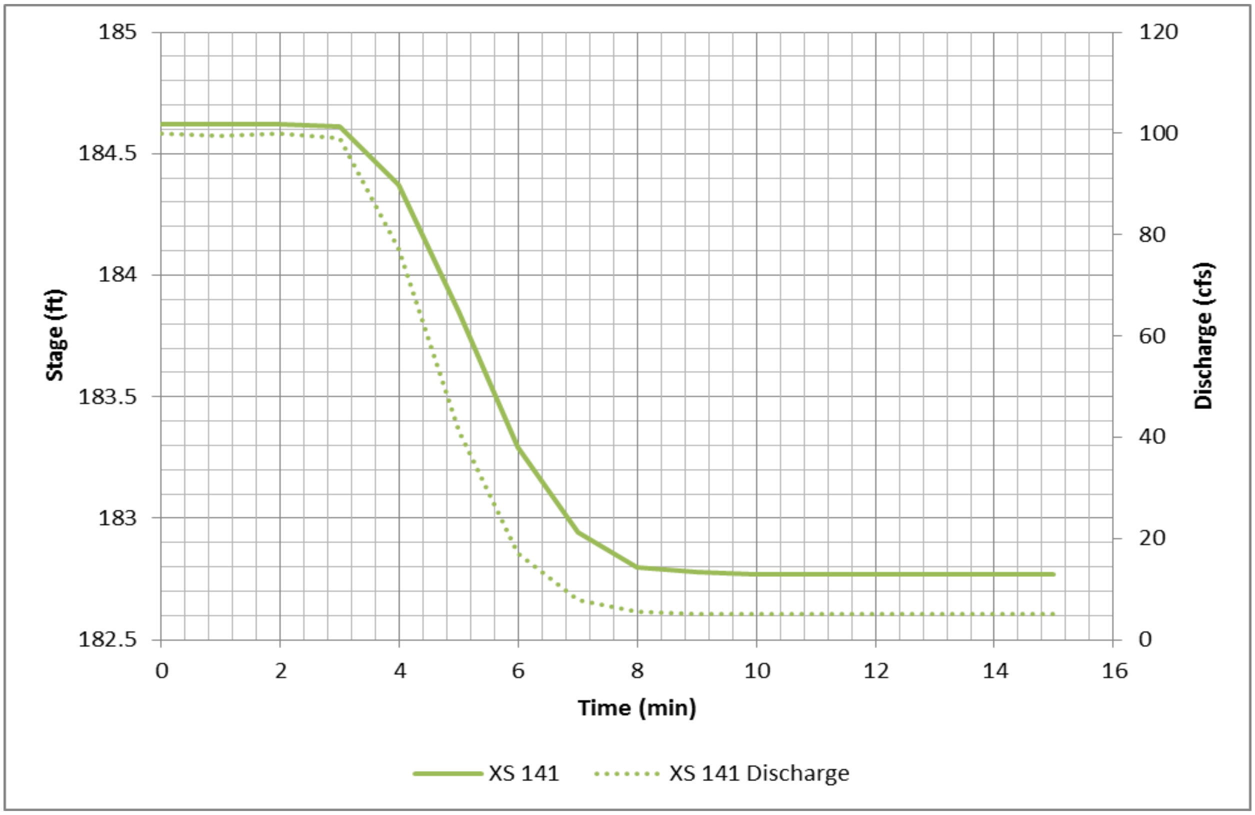


Figure B-12. **Modeled stage-discharge hydrograph for representative run cross section.**

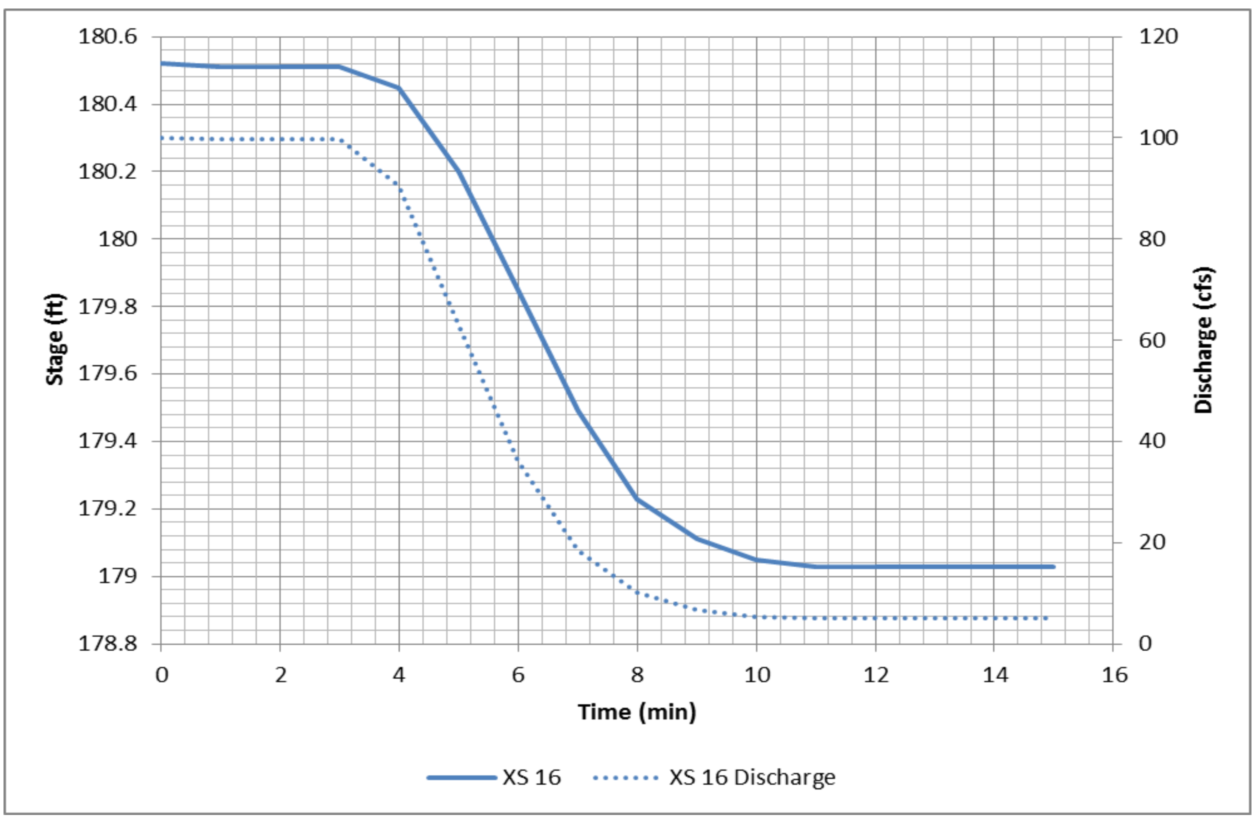


Figure B-13. **Modeled stage-discharge hydrograph for representative terminal cross section.**

Modeled HEC-RAS output was exported to GIS to provide a plan view of the modeled water surfaces and to examine the channel reach at various flow changes in the flow rates. Figure B-14 provides a plan view of modeled 80, 50, 25, and 8 cfs (colored polygons). For the section of the channel leading up from the tailrace to station 3+25.6, the modeled 8 and 80 cfs water surfaces match well with surveyed extents. Above station 3+25.6, topographic analysis shows that the average channel slope is 36 percent, demonstrating an extremely steep section. Note that the field survey did not locate edge of water surface in this steep reach.

Examination of Figure B-14 indicates zones of continuous water connectivity and absence of isolated pools during the changing flows upon gate closure. This matches field observations made during the La Grange study program after gate closure. Unsteady flow analysis of a two-minute gate closure event (in which the flow rate changes from 100 to 5 cfs) indicates the existence of a continuous flow channel as flow is reduced to the approximate minimum flow of 5 cfs.

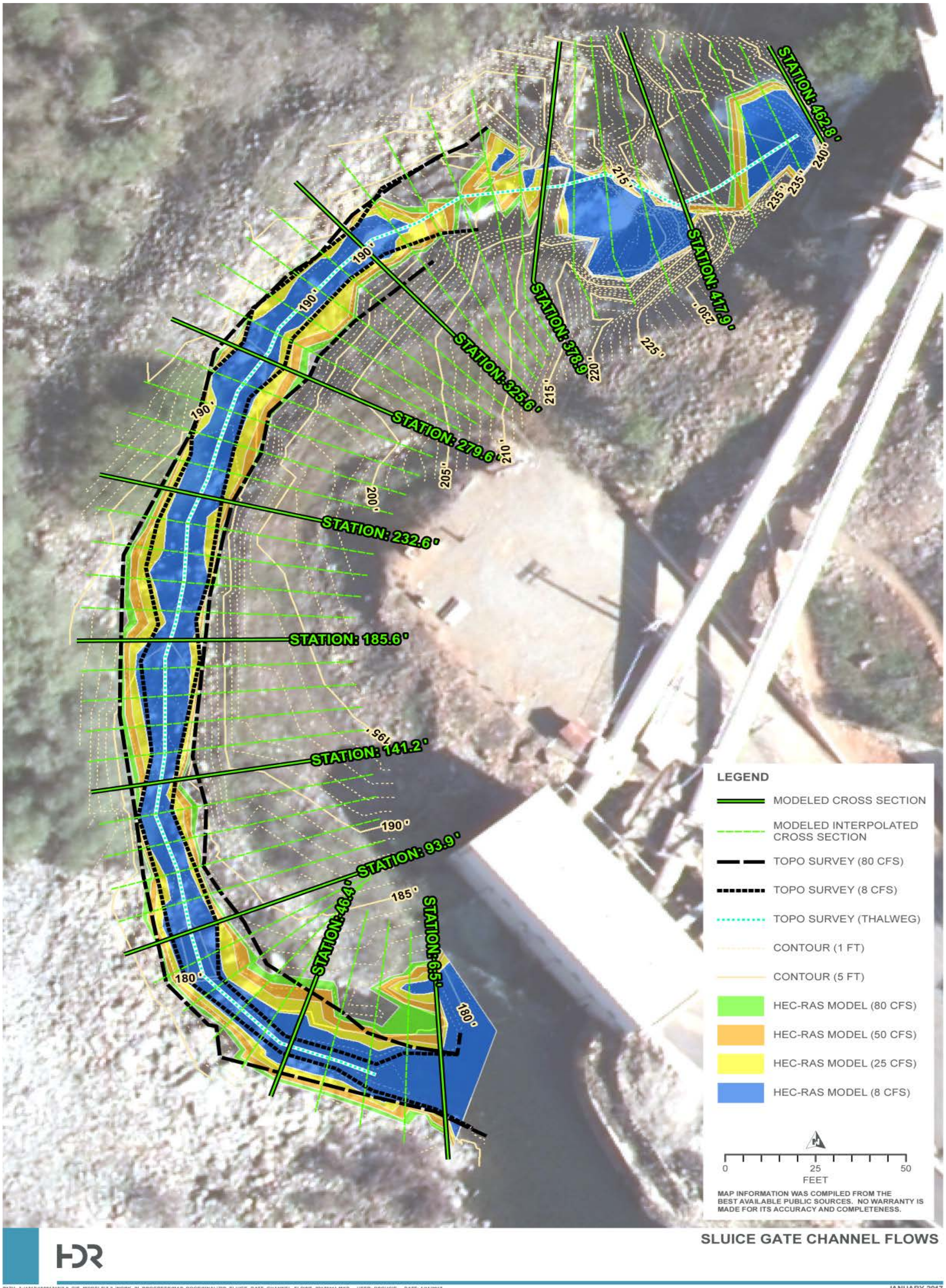


Figure B-14. **Modeled water surfaces during flow changes from 80 to 8 cfs.**

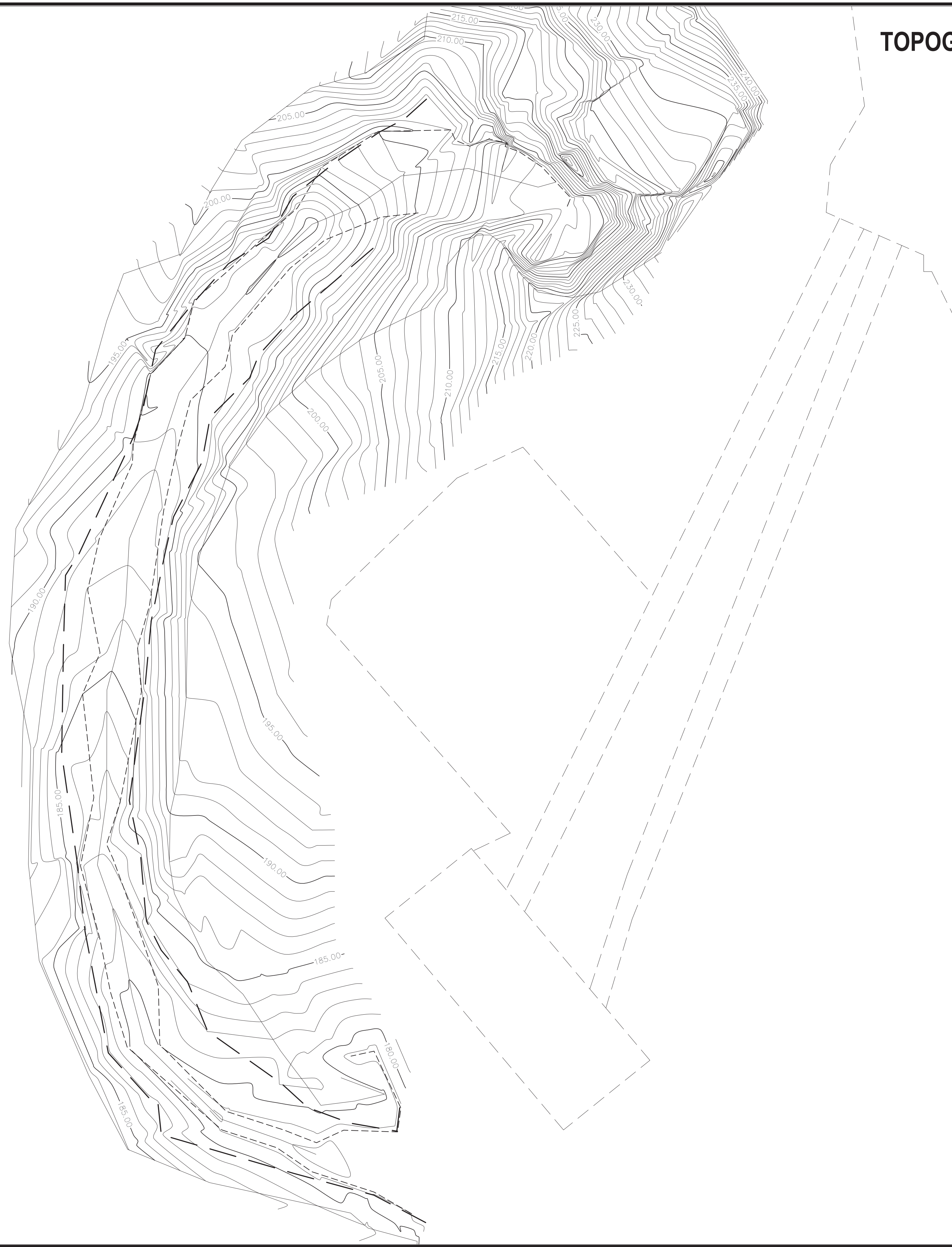
2016 SLUICE GATE CHANNEL SURVEY

ATTACHMENT 1

HDC-05 (2016 TID FIELD SURVEY)
REDUCED FROM 36X24

TOPOGRAPHIC SURVEY

BEING A TOPOGRAPHIC SURVEY OF A
PORTION OF THE
LA GRANGE SLUICE GATE CHANNEL AT
VARIOUS DISCHARGE LEVELS



LEGEND

—— ——	APPROXIMATE WATER LEVEL @ 80 CFS
— — — — — —	APPROXIMATE WATER LEVEL @ 8 CFS
———	APPROXIMATE THALWEG
— — —	APPROXIMATE IMPROVEMENT LOCATIONS DERIVED FROM AERIAL PHOTOGRAPHS

ABBREVIATIONS

RW	RIGHT-OF-WAY
PL	PROPERTY LINE
CL	CENTER LINE
TL	TOP OF LINING
FL	FLOWLINE
EP	EDGE OF PAVEMENT
TC	TOP OF CURB
BSW	BACK OF SIDEWALK
EX	EXISTING
PROP	PROPOSED
GB	GRADE BREAK
AP	ANGLE POINT
PP	POWER POLE
UP	UTILITY POLE
GUY	GUY WIRE
ANC	ANCHOR
CB	CATCH BASIN
SD	STORM DRAIN
SS	SANITARY SEWER
W	WATER
ELEC	ELECTRICAL
OHE	OVERHEAD ELECTRICAL LINE
UGE	UNDERGROUND ELECTRICAL LINE
INV	INVERT
VT	VENT
CBX	CONCRETE IRRIGATION BOX
SSMH	SANITARY SEWER MANHOLE
SDMH	STORM DRAIN MANHOLE
SSCO	SANITARY SEWER CLEANOUT

REVISIONS

NO.	DATE	REVISION

REDUCED

SURVEYORS STATEMENT

THIS TOPOGRAPHIC SURVEY WAS PERFORMED BY ME AND OR UNDER MY DIRECTION IN OCTOBER OF 2016 AT THE REQUEST OF THE TURLOCK IRRIGATION DISTRICT.

TRISTAN S. HIGGINS, PLS #9048
(ONLY AN ORIGINAL SIGNATURE CONSTITUTES THIS SURVEY)

ADDITIONAL NOTES:

1. TREES HAVE NOT BEEN SHOWN ON THIS PLAN, AND LOCATIONS OF SUCH TREES SHOULD BE FIELD VERIFIED. TREE DIAMETERS IF ANY ARE APPROXIMATE AND ARE BASED ON MEASUREMENT TAKEN AT BREAST HEIGHT.

2. UTILITY INFORMATION AS SHOWN ON THIS PLAN, IF ANY, IS TAKEN FROM VISIBLE PHYSICAL EVIDENCE AND/OR RECORD INFORMATION AVAILABLE TO THE SURVEYOR DURING THE CREATION OF THIS SURVEY. NO ATTEMPT HAS BEEN MADE TO FURTHER LOCATE UNDERGROUND FACILITIES. LOCATION AND DEPTH OF ALL EXISTING UNDERGROUND UTILITIES TO BE VERIFIED BY CALLING 811 FOR UNDERGROUND SERVICE ALERT 72 HOURS PRIOR TO ANY EXCAVATION OR CONSTRUCTION.

3. SITE INFORMATION IS VALID AS OF OCTOBER 2016. PHYSICAL CHANGES MADE AFTER THIS DATE ARE NOT SHOWN AND ADDITIONAL SURVEY DATA SHOULD BE OBTAINED PRIOR TO ANY EXCAVATION OR CONSTRUCTION.

4. ELEVATION DATA IS BASED ON CURRENT TID DATUM, AND IS INTERPOLATED FROM GROUND ELEVATIONS OBSERVED DURING THE COURSE OF THIS SURVEY. INDIVIDUAL SPOT ELEVATIONS MEET NMAS STANDARDS FOR 5' CONTOURS. ADDITIONAL 1' CONTOURS ARE INTERPOLATED, DO NOT MEET NMAS STANDARD, AND ARE INTENDED FOR INFORMATIONAL PURPOSES ONLY.

N

SCALE: 1"= 15'

0' 15' 30'

ALL DISTANCES ARE IN FEET OR DECIMALS THEREOF

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