Colusa Basin Drain Hydraulic Modeling
Final Technical Memorandum

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Date:	August 28, 2020
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Subject:	Colusa Basin Drain Hydraulic Modeling

Executive Summary

The proposed Sites Project (Project) will release water from Sites Reservoir, down the Tehama-Colusa Canal, into a new pipeline, from the Tehama-Colusa Canal to the Colusa Basin Drain (CBD) near Dunnigan, California. The pipeline will release up to 1,000 cubic feet per second (cfs) into the CBD near river mile (RM) 10.5. The reservoir release will then be conveyed down the CBD to the Sacramento River at Knight Landing, through the Knights Landing Outfall Gate (KLOG) structure on CBD. Sites releases are planned to be made primarily between June 1 and October 31, during dry and critical water years.

Jacobs conducted preliminary CBD hydraulic modeling to support the assessment of hydraulic effects caused by the Project and identify opportunities and constraints related to Sites Reservoir releases. Following are the objectives for this modeling task:

- Evaluate the changes in water surface elevation (WSE) in the CBD and Knights Landing Ridge Cut (Ridge Cut) caused by Sites Reservoir release of 1,000 cfs during April through October.
- Understand potential release constraints, timing (season), and operational effects on reservoir releases.

Jacobs collected historical gage records of flow and stage for CBD and Sacramento River from the publicly available data websites. Jacobs coordinated with several agencies to obtain as-built drawings for KLOG and Wallace Weir, KLOG gate operations information (including measured gate-opening records) and measured daily average flow and stage records at CBD at Davis Weir. Based on the availability of CBD at Davis Weir flow records, an analysis period was selected for modeling, which includes 4 water year types between 2013 and 2020. The selected water years include dry and critical water years during which the releases will be made. A wet water year was also selected to model the conditions when the Sacramento River stages are high and KLOG flap gates are closed. For each of these water years, the period between April 1 and October 31 was modeled using the daily flow historical records. This time window captures the full period of seasonal timing when Sites Reservoir releases will be made.

A hydraulic model was used to simulate existing conditions in the CBD and assess changes to the WSEs caused by the proposed Sites release of 1,000 cfs. A one-dimensional (1D) Hydrologic Engineering Center River Analysis System (HEC-RAS) model of the CBD and Sacramento River reaches was used to conduct this analysis. This model was based on the California Department of Water Resources' (DWR's) Central Valley

Floodplain Evaluation and Delineation (CVFED) Program Task Order 34 Sacramento River System Routing Model. The extents of the model were truncated to the study area to include CBD, Ridge Cut, and the Sacramento River reach, between below Wilkins Slough and Fremont Weir. The geometry of the channels, levees, and berms in the model are based on CVFED LiDAR and bathymetric cross-sectional surveys collected in 2009. All elevations in the model are referenced to North American Vertical Datum of 1988 (NAVD 88). The HEC-RAS 1D model was updated to include hydraulic structures that were not originally modeled in the CVFED HEC-RAS model. The KLOG was updated to improve model performance for low-flow existing conditions in the CBD.

The model validation was conducted for two periods (2012 and 2017) to assess the performance by comparing model results with the historically measured data. The validation was focused on KLOG gate operations to maintain upstream setpoint and convey flow through the gates to Sacramento River because of the major influence KLOG has on CBD stages upstream up to RM 25. Review of the validation results indicated that historically KLOG gate operations were not consistent with the standard operating rules, and the operations vary from event to event based on the existing conditions. Therefore, for the purpose of this analysis, the modeled stages were determined to be representative of the CBD WSEs for the selected water years, under standard operating conditions that assume all 10 gates to be operable to maintain setpoint of 23.73 feet, NAVD 88 (25.5 feet, United States Engineering Datum [USED]).

The model results shown in Figure E1 indicate that for a low-flow condition in CBD, KLOG causes backwater with a flat WSE (almost zero water surface slope) up to RM 25 near Balsdon Weir. The 1,000 cfs Sites Reservoir release during these conditions increases CBD WSEs by a maximum of 1.54 feet. The WSE increases are highest upstream of the Sites release location to Balsdon Weir; and the WSE dissipates upstream of the weir. The WSE increases taper off downstream of Sites release location to KLOG; and the WSE converges at the KLOG. The 1,000 cfs Sites Reservoir release during a high-flow condition of 1,700 cfs in CBD (as shown on Figure E2), still has a maximum WSE increase of 1.54 feet, but tapers off upstream at a faster rate because of the higher slope of the water surface. The lowest elevation along the toe of west berm profile at RM 8.9 was determined to be the lowest field elevation of 25.3 feet, NAVD 88. This elevation was considered critical in this analysis for assessing WSE effects because if the CBD WSE exceeds this elevation, flooding in this field can result because of seepage and backwater.

Using the simulated proposed conditions stage results, Jacobs identified the periods when WSEs exceed the critical elevation of 25.3 feet, NAVD 88 at RM 8.9, and computed the quantity and timing of when Sites Reservoir volumes can be conveyed to Sacramento River with a constant flow rate of 1,000 cfs. Figure E3 is an example plot, showing the flow and stage results that indicate the periods when reservoir releases can be made without effecting the RM8.9 field. The dashed yellow line shows the cumulative Sites release water volumes when there is no WSE effect. The figure illustrates that the 1,000 cfs Sites Reservoir release can be conveyed without causing WSE effects, primarily during the months of April through July, and October. In August and September, the CBD carries high flows, resulting from rice field agricultural drainage, and does not have capacity to convey reservoir releases of 1,000 cfs. Table E1 shows the summary of timing and Sites Reservoir volumes conveyed for all the water years modeled. The table and Figure E3 also indicate that Sites Reservoir can release less than 1,000 cfs many times during this period to prevent WSE effects and increase the overall volume of releases.

TABLE E1. SUMMARY OF WSE EFFECTS ON SITES VOLUME DELIVERY

Month	CBD Existing Conditions Monthly Average Flow (cfs)				# of Days without WSE Effects[a]				Sites Volume Conveyed to Sacramento River[b] (TAF)			
	2013 (D)	2014 (C)	2015 (C)	2017 (W)	2013 (D)	2014 (C)	2015 (C)	2017 (W)	2013 (D)	2014 (C)	2015 (C)	2017 (W)
Apr	332	161	307	307	1	19	28	0	2.0	37.7	55.5	0.0
May	451	85	229	229	4	26	29	0	7.9	51.6	57.5	0.0

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	2013 (D)	2014 (C)	2015 (C)	2017 (W)	2013 (D)	2014 (C)	2015 (C)	2017 (W)	2013 (D)	2014 (C)	2015 (C)	2017 (W)
Jun	435	158	376	376	5	16	30	10	9.9	31.7	59.5	19.8
Jul	555	148	387	387	0	22	31	0	0.0	43.6	61.5	0.0
Aug	1,319	509	1,022	1,022	0	4	5	0	0.0	7.9	9.9	0.0
Sep	636	633	940	940	8	4	10	4	15.9	7.9	19.8	7.9
Oct	137	43	60	60	26	31	31	31	51.6	61.5	61.5	61.5
Total					**44**	**122**	**164**	**45**	**87.3**	**241.9**	**325.2**	**89.2**

[a]Critical WSE of 25.3 feet, NAVD 88 was used to calculate the number of days without WSE effects.

[b]Sites volume was calculated using 1,000 cfs constant flow for the total number of days in the water year without WSE effects.

C = critical year
D = dry year
TAF = thousand acre-feet
W = wet year

The following tasks were identified for continuing the hydraulic analysis to inform Project planning and design:

- Verify with RD108 the lowest field elevation (RM 8.9) and the CBD operations for 2013 because they are not consistent with Jacobs' understanding for dry-year operations.
- Conduct field visit to collect geometric data for Balsdon and Davis Weirs, to improve model representation and evaluation.
- Improve the representation of CBD and Ridge Cut junction in the HEC-RAS model. Currently, the junction is modeled with reaches connecting to a storage area.
- Calibrate and validate CBD HEC-RAS model for additional events with historical gate operations.
- Model other Sites Reservoir release scenarios with variable release rates of less of 1,000 cfs.

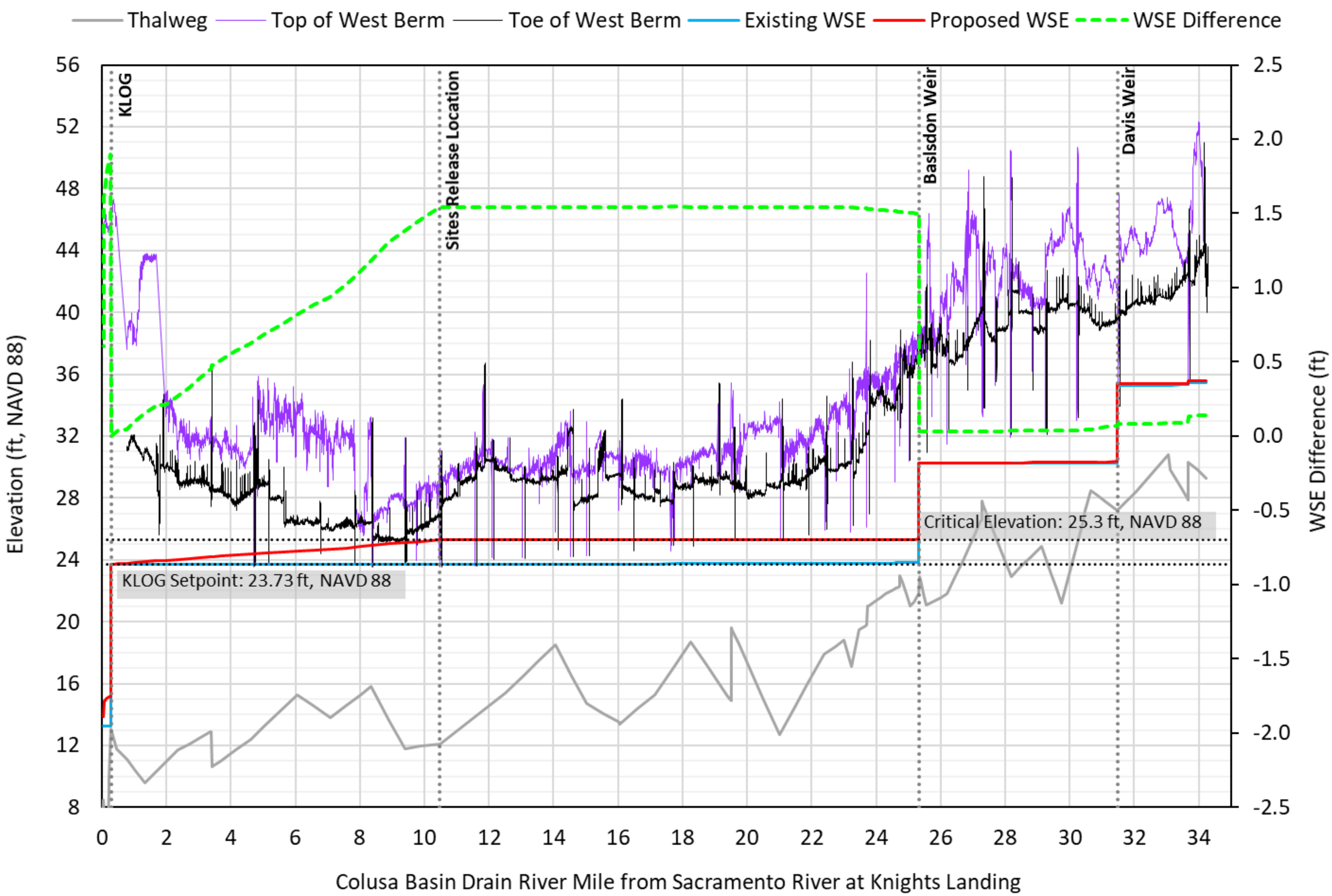


FIGURE E1. CBD WSE Profiles for Flow Profile 1 (Existing Flow: 50 cfs, Proposed Flow: 1,050 cfs)

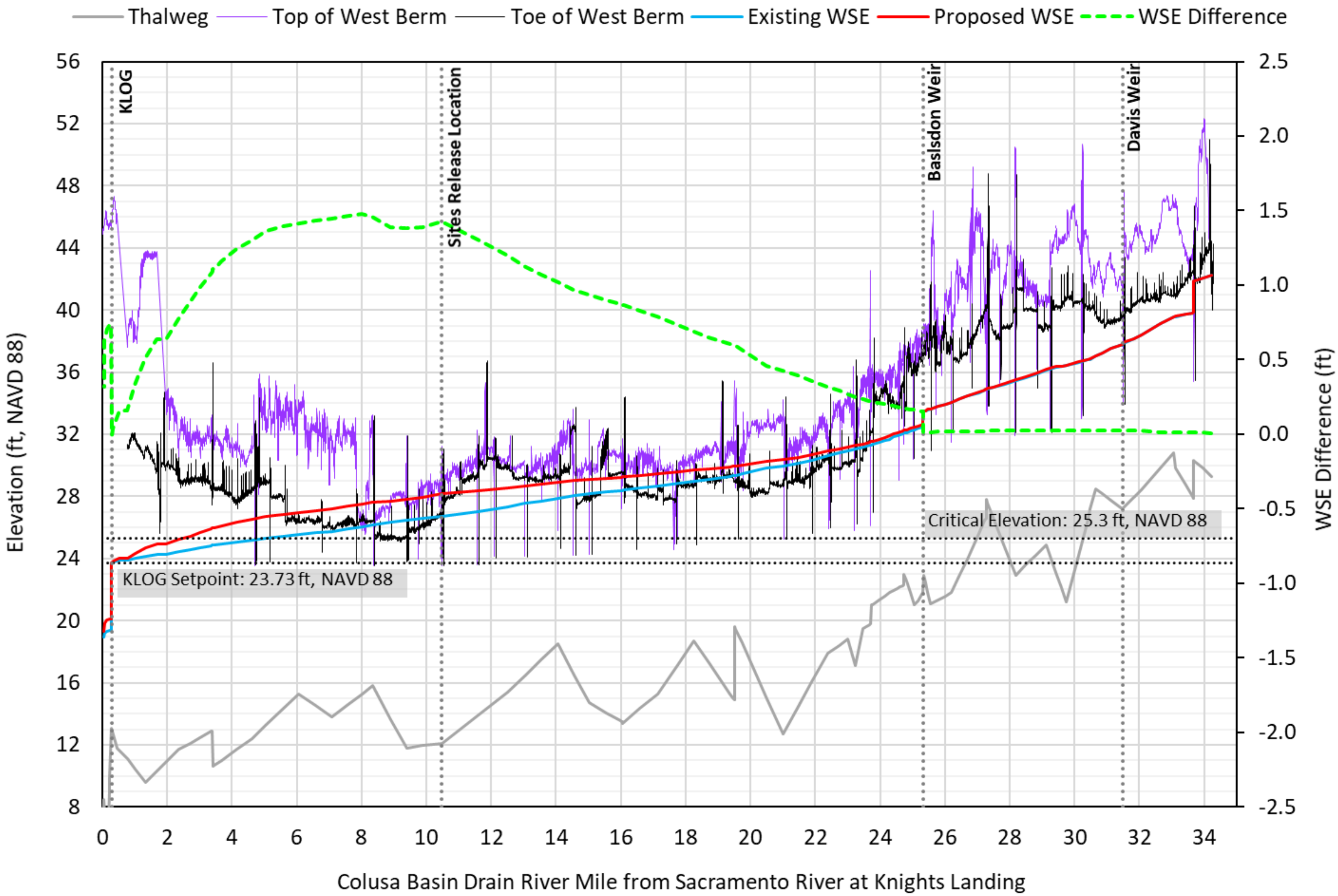


FIGURE E2. CBD WSE Profiles for Flow Profile 2 (Existing Flow: 1,700 cfs, Proposed Flow: 2,700 cfs)

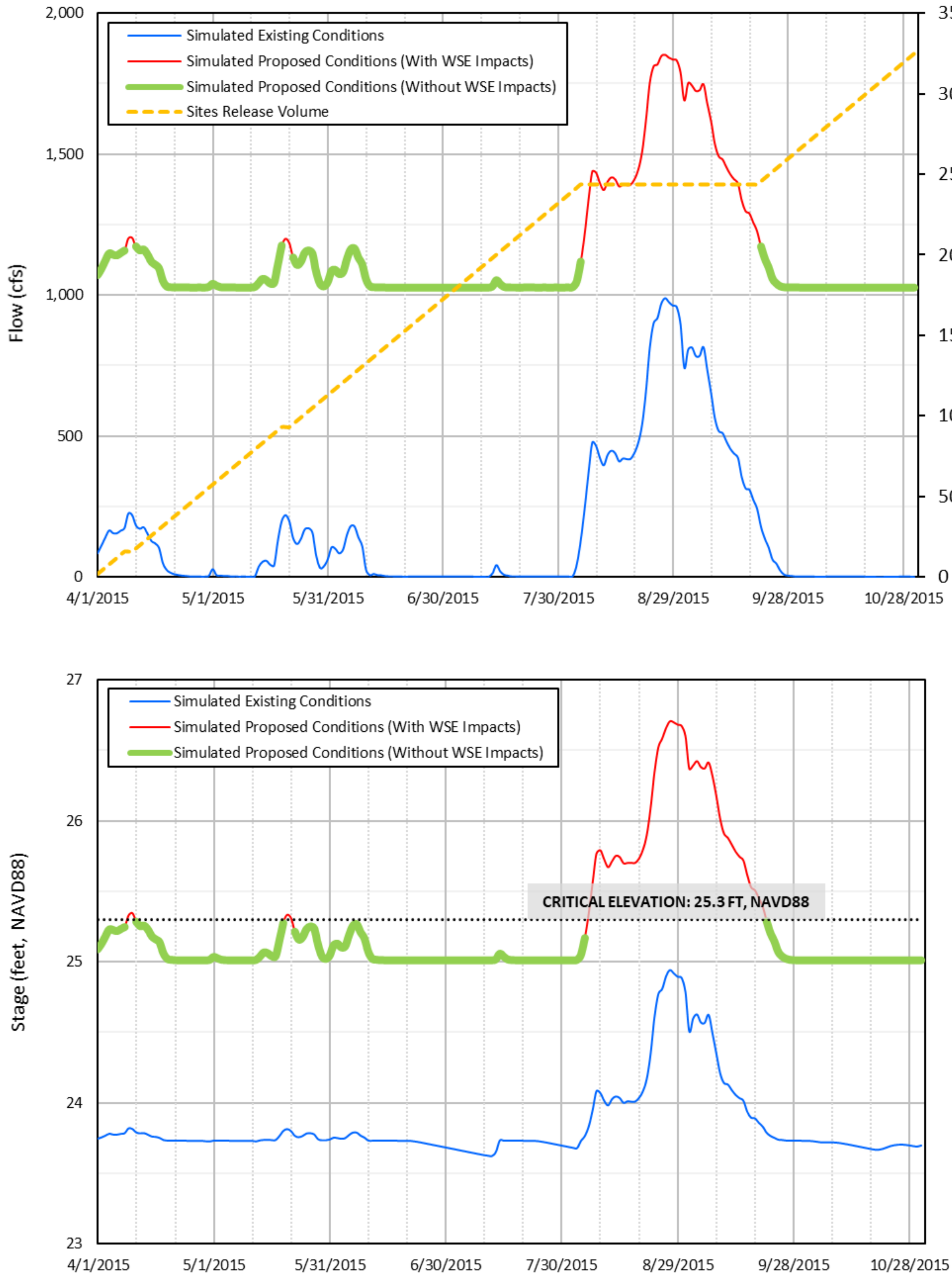


FIGURE E3. Water Year 2015 CBD at RM 8.9 Flow and Stage Data

1.0 Introduction

This technical memorandum describes the methodology and results of the CBD hydraulic modeling conducted to support the hydraulic effects assessment for the Sites Project. The proposed Project will release water from Sites Reservoir, down the Tehama-Colusa Canal, into a new pipeline, from the Tehama-Colusa Canal to the Colusa Basin Drain (CBD) near Dunnigan, California. The pipeline would release up to 1,000 cubic feet per second (cfs) into the CBD near river mile (RM) 10.5. The reservoir release will then be conveyed down the CBD to the Sacramento River at Knight Landing, through the Knights Landing Outfall Gate (KLOG) structure on CBD. Sites releases are planned to be made primarily between June 1 and October 31, during dry and critical water years.

1.1 Modeling Objectives

Following are the objectives for this modeling task:

- Evaluate the changes in water surface elevation (WSE) in the CBD and Knights Landing Ridge Cut (Ridge Cut) caused by Sites Reservoir release of 1,000 cfs during April through October.
- Understand potential release constraints, timing (season), and operational effects on reservoir releases.

2.0 Data Collection

Jacobs collected historical gage records of flow and stage for CBD and Sacramento River from the U.S. Geological Survey and Water Data Library (WDL) websites. In addition, Jacobs coordinated with Reclamation District No.108, Glenn-Colusa Irrigation District, and the California Department of Water Resources to obtain as-built drawings for KLOG and Wallace Weir, KLOG gate operations information (including measured gate-opening records) and measured daily average flow and stage records at CBD at Davis Weir. The summary of the data collected is in Table 1.

TABLE 1. SUMMARY OF DATA COLLECTED

Location	Data	Period of Record	Source
CBD at Davis Weir	Daily Flow and Stage	2013 to 2020	Glenn-Colusa Irrigation District (GCID)
CBD at KLOG	Daily and 15-min Flow Daily and 15-min Stage	1975 to 2012 1975 to 2018	WDL (Gage ID A02945)
Sacramento River below Wilkins Slough	Daily Flow	1940 to 2020	USGS (Gage ID 11390500)
Sacramento River at Knights Landing	Daily Flow and Stage	1982 to 2018	WDL (Gage ID A02200)
Sacramento River at Fremont Weir	Daily Stage	1982 to 2020	WDL (Gage ID A02170)
Ridge Cut Slough at Knights Landing	15-min Flow	2007 to 2020	WDL (Gage ID A02939)
KLOG	15-min Gate Opening	2011 to 2013 2015 to 2020	DWR, North Region Office (NRO)
KLOG	As-built Drawings	n/a	Reclamation District No.108 (RD 108)
Wallace Weir	As-built Drawings	n/a	Reclamation District No.108 (RD 108)

USGS = U.S. Geological Survey

3.0 Analysis Period

Based on the availability of CBD at Davis Weir flow records, Jacobs reviewed the historical flow and stage data summarized in Table 1 and selected an analysis period. Table 2 presents the 4 water years between 2013 and 2020 that were selected for modeling. The selected water years include dry and critical water years, typical of those during which the Sites Reservoir releases will be made. A wet water year was also selected to model the conditions when the Sacramento River stages are high and KLOG flap gates are closed. For each of these water years, the period between April 1 and October 31 was modeled using the daily flow historical records. This time window captures the full period of seasonal timing when reservoir releases will be made.

TABLE 2. SELECTED WATER YEARS FOR MODELING

Water Year	Water Year Type*
2013	Dry
2014	Critical
2015	Critical
2017	Wet

*Water Year Hydrologic Classification Index per Sacramento Valley 40/30/30 determined by DWR.

4.0 Model Development

A hydraulic model was used to simulate existing conditions in the CBD and assess effects to the WSEs caused by the proposed Sites Reservoir release of 1,000 cfs. A one-dimensional (1D) model of the CBD and Sacramento River reaches was used to conduct this analysis. This model was developed using U.S. Army Corps of Engineers' (USACE's) Hydrologic Engineering Center River Analysis System (HEC-RAS) version 5.0.7 software.

4.1 Geometry

The HEC-RAS 1D model used for this study was based on the California Department of Water Resources' (DWR's) Central Valley Floodplain Evaluation and Delineation (CVFED) Program Task Order 34 Sacramento River System Routing Model. The extents of the model were truncated to the study area to include CBD, Ridge Cut, and Sacramento River reach between below Wilkins Slough and Fremont Weir. The geometry of the channels, levees, and berms included in the model are based on CVFED LiDAR and bathymetric cross-sectional surveys collected in 2009. All elevations in the model are referenced to North American Vertical Datum of 1988 (NAVD 88). The model extents, HEC-RAS reaches, boundary conditions, and the hydraulic structures in the study areas are presented on Figure 1.

The HEC-RAS 1D model was updated to include hydraulic structures that were not originally modeled in the CVFED HEC-RAS model. The KLOG was updated to improve model performance for low-flow existing conditions in the CBD. The changes to the model are discussed below.

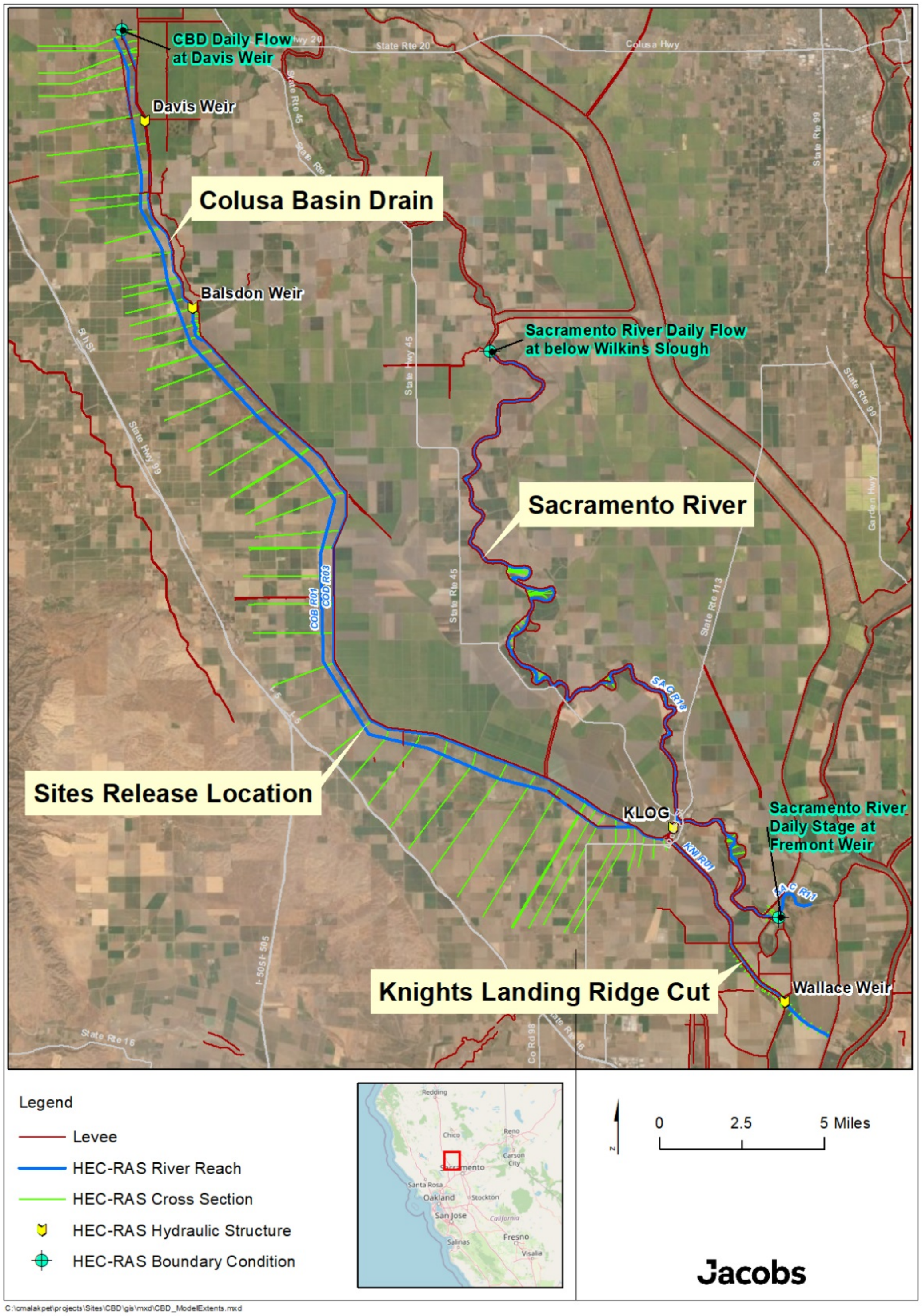


FIGURE 1. CBD HEC-RAS Model Extents

4.1.1 KLOG

The CVFED HEC-RAS model included KLOG as an inline structure with gates. Rectangular gates were used with an equivalent cross-sectional area for 42-inch-diameter (Gate 1 and 10) and 66-inch-diameter (Gates 2 through 9) gates. Because the CVFED HEC-RAS model was developed for modeling flood conditions, it only included simplified gate operations to close all KLOG gates when the Sacramento River stage is higher than gate sill elevation; the model did not include gate operations to maintain water level upstream of KLOG.

The KLOG gate dimensions and invert elevations were updated based on the as-built drawings. Equivalent area rectangular gates were used for 42-inch-diameter-and 66-inch-diameter gates with heights equal to the diameters of the gates. This approach was taken because HEC-RAS does not provide an option to model circular gates. Figure 2 shows the configuration of KLOG HEC-RAS inline structure.

The KLOG gate operations were updated using “Rules” in HEC-RAS unsteady-state flow module. The descriptive information and measured gate-opening records received from DWR North Region Office (NRO) were reviewed to develop logic for opening and closing of KLOG gates, as discussed below. The gates operate to a setpoint elevation upstream of KLOG. Based on the information received from DWR, this setpoint was determined to be 23.73 feet, NAVD 88 (25.5 feet, USED). When the upstream WSE exceeds the setpoint, the gates open sequentially (from Gate 1 to Gate 10) every 10 minutes by 5% of the gate height. When the upstream WSE falls below setpoint, gates close in the reverse direction (Gate 10 to Gate 1) every 10 minutes by 5% of the gate height. In addition, the flap gates on the downstream side of KLOG close when the WSE exceeds gate sill elevation.

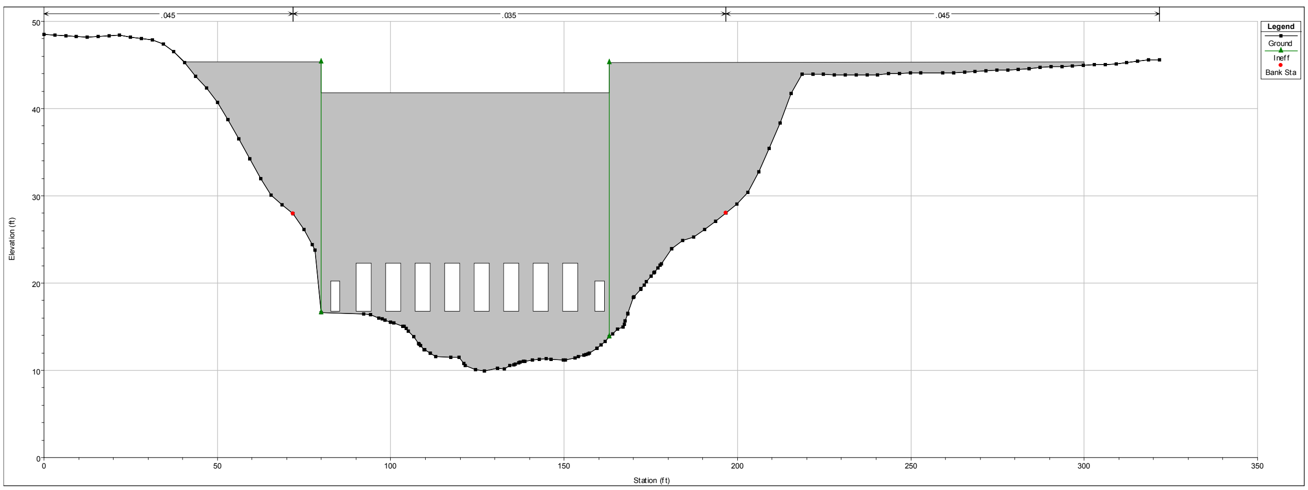


FIGURE 2. KLOG HEC-RAS Inline Structure

4.1.2 Wallace Weir

The CVFED HEC-RAS model did not include Wallace Weir in the Ridge Cut channel reach (HEC-RAS reach: KNI R01). Therefore, the Ridge Cut channel reach was extended to include the Ridge Cut from Yolo Bypass west levee to Tule Canal (Yolo Bypass east levee) and a Wallace Weir inline structure was added. The geometry of the weir and the Obermeyer gate dimensions were based on the Wallace Weir as-built drawings, provided by RD108. Figure 3 shows the configuration of Wallace Weir HEC-RAS inline structure.

The Wallace Weir gate operations were set in conjunction with KLOG gate operations. The Wallace Weir gates operate to maintain setpoint elevation of 25.5 feet, USED with a ± 0.01-foot range (that is, between 23.74 and 23.72 feet, NAVD 88).

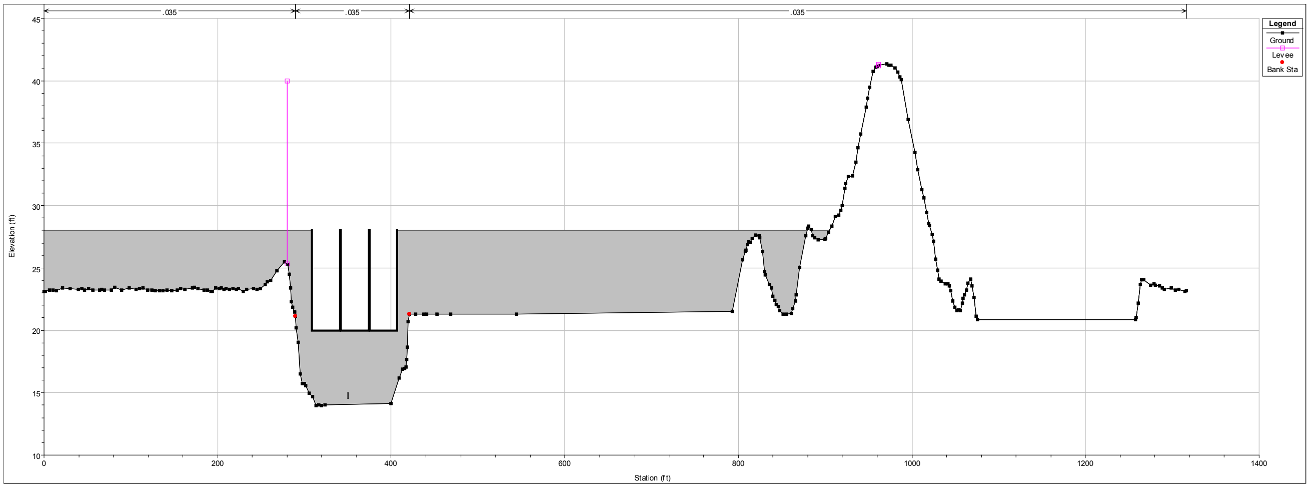


FIGURE 3. Wallace Weir HEC-RAS Inline Structure

4.1.3 Davis Weir

Similarly, the CVFED HEC-RAS model did not include Davis Weir in the CBD channel reach (HEC-RAS reach: COD R03). Therefore, the Davis Weir inline structure was added to the CBD reach. The geometry of the weir and the Obermeyer gate dimensions were estimated based on the CVFED LiDAR because no as-built drawings or survey data were available. Figure 4 shows the configuration of Davis Weir HEC-RAS inline structure.

The Davis Weir gate operations were set based on the information provided by GCID. The Davis Weir gates operate to a setpoint elevation of 34.5 feet, National Geodetic Vertical Datum of 1929 (NGVD 29). The gates open and close to maintain this setpoint by deflating and inflating the bladder dam. The setpoint elevation was converted to NAVD 88 datum using a correction of +2.43 feet computed using VERTCON (https://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl).

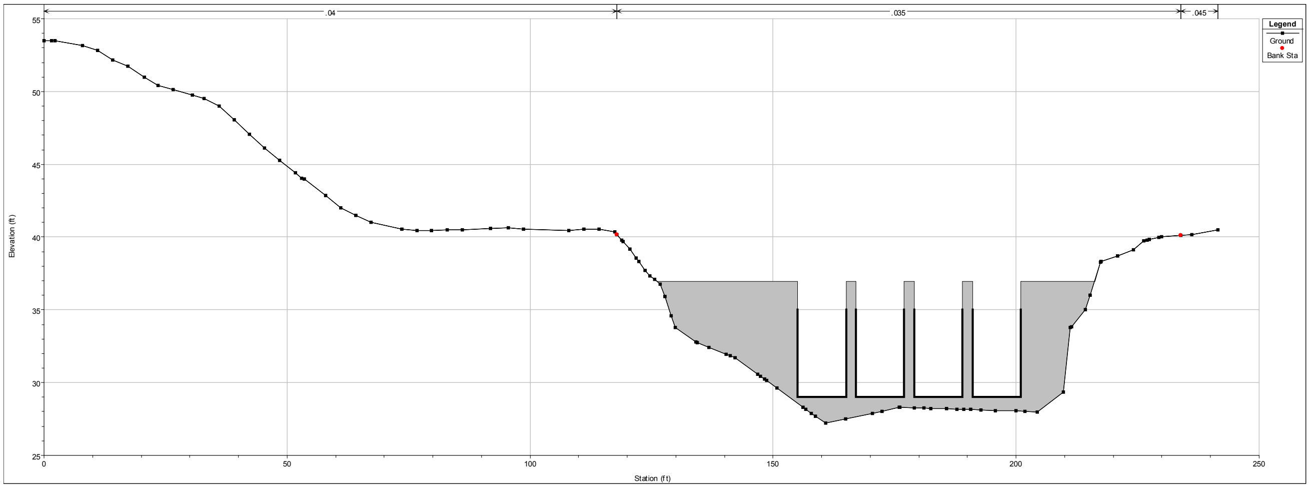


FIGURE 4. Davis Weir HEC-RAS Inline Structure

4.1.4 Balsdon Weir

Similarly, to Davis Weir, the CVFED HEC-RAS model did not include Balsdon Weir in the CBD channel reach *(HEC-RAS reach: COD R03).* Therefore, the Balsdon Weir inline structure was added to the CBD reach. The geometry of the weir was estimated based on the CVFED LiDAR because no as-built drawings or survey data were available. Figure 5 shows the configuration of Balsdon Weir HEC-RAS inline structure.

The Balsdon Weir is a flow-through inline weir and does not have operable gates. It was modeled as a broad-crested weir, with a weir coefficient of 2.6.

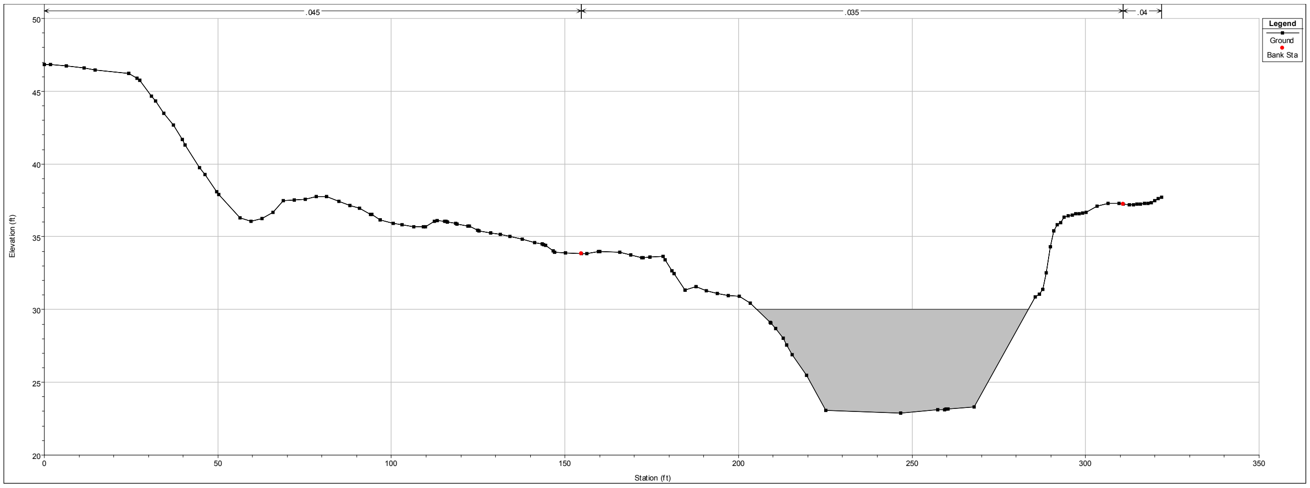


FIGURE 5. Balsdon Weir HEC-RAS Inline Structure

4.2 Boundary Conditions

The HEC-RAS model was simulated as an unsteady-state model with time-varying flow and stage conditions. The boundary conditions for the existing conditions model were applied using the historical flow and stage records summarized in Table 1. CBD at Davis Weir, and Sacramento River below Wilkins Slough, daily flow timeseries data were applied as upstream flow hydrograph boundary conditions for CBD and Sacramento River channels. Sacramento River at Fremont Weir daily stage timeseries data were applied as a downstream-stage-hydrograph boundary condition for Sacramento River channel. A normal depth boundary condition, with a friction slope of 0.0001, was applied to Ridge Cut channel. Internal boundary conditions for weirs with gates were applied using elevation-controlled gates and rules, as described in Section 4.1. Although daily average flow and stage timeseries data were used as boundary conditions (constant flow and stage conditions applied at the model boundary for a given day), the simulations were run on a 1-minute timestep. This means that the model is able to hydraulically route the flows through the channels and operate weirs/gates on a 1-minute timestep.

For the proposed conditions model, a timeseries of constant inflow of 1,000 cfs for the entire simulation time window was added as a lateral inflow hydrograph boundary condition at RM 10.5, which represents a Sites Reservoir release at the outfall location on CBD.

4.3 Roughness

The roughness values for CBD in the CVFED HEC-RAS model were reviewed. Manning's "n" value of 0.035 was used for the main channel; for overbank areas, values of 0.045 to 0.075 were used. These values were considered appropriate for the current analysis; therefore, no changes were made.

4.4 Pilot Channels

Pilot channels were added to CBD (HEC-RAS reaches COD R03, R02, and R01), Ridge Cut (HEC-RAS reach KNI R01) and CBD west overbank (HEC-RAS reach COB R01) channels to stabilize the HEC-RAS model for low flows. During certain days of the simulation time period, the historical CBD flows are zero. However, HEC-RAS 1D model cannot simulate a zero-flow condition, so a minimum flow of 1 cfs was added to the CBD channel, with pilot channels used to stabilize the model for low-flow conditions.

4.5 Model Validation

The model validation was conducted to assess the performance by comparing model results with the historically measured data. The validation was focused on KLOG gate operations to maintain upstream setpoint and convey flow through the gates to Sacramento River. Because KLOG has a major influence on CBD stages upstream up to RM 25, modeling hydraulics at KLOG accurately is important. Two time periods were selected for validation. These periods represent historical conditions before and after KLOG rehabilitation project, which was completed in 2015, and the new Wallace Weir construction, which was completed in 2016. The periods are as follows:

- July 1 to Sep 30, 2012 – For this period, KLOG flow, stage, and gate-opening data are available.
- July 1 to Sep 30, 2017 – For this period, KLOG flow data are unavailable, but stage and gate-opening data are available.

For the 2012 validation period, KLOG-measured flow at the WDL gage A02945 was applied as a boundary condition for the CBD at Davis Weir because the flow records at Davis Weir were not available for this timeframe. Figure 6 compares simulated KLOG flow and stage hydrograph with the measured data. The modeled flow closely follows measured data, with similar magnitudes, but a lag of about 24 hours. This lag is attributed to the CBD routing time; it is expected because of the boundary condition applied about 34 RMs upstream of the measured location along CBD. The modeled stage stays constant at the setpoint (23.73 feet, NAVD 88) throughout the period, while the measured stage has a variability of 2 feet during August to September. To understand the differences between modeled and measured stages, gate-opening heights were compared, as shown in Figure 7. The figure indicates that during 2012, only half of the gates were operated to convey the flow through KLOG. Gates 1 to 6 remain closed for most of the period, and gates 7 to 10 were open to full height. The model follows standard operating rules, as described in section 4.1.1; these rules use all 10 gates to convey the flow through KLOG.

Similarly, the 2017 validation results are shown in Figures 8 and 9. KLOG-measured flow data were not available for 2017 to compare. The stage comparison shows less variability for this period, with a difference in stage of 0.23 between modeled and measured stages. The gate-opening height comparison indicates a close correlation of gate-opening and -closing patterns. However, the differences in gate-opening height exist at the peak of the hydrograph.

Reviewing the validation results led to the conclusion that historically KLOG gate operations were not consistent with the standard operating rules; operations vary from event to event based on the conditions that existed. Therefore, for the purpose of this analysis, the modeled stages were determined to be representative of the CBD WSEs for the selected water years under standard operating conditions that assume all 10 gates to be operable, to maintain setpoint of 23.73 feet, NAVD 88 (25.5 feet, USED).

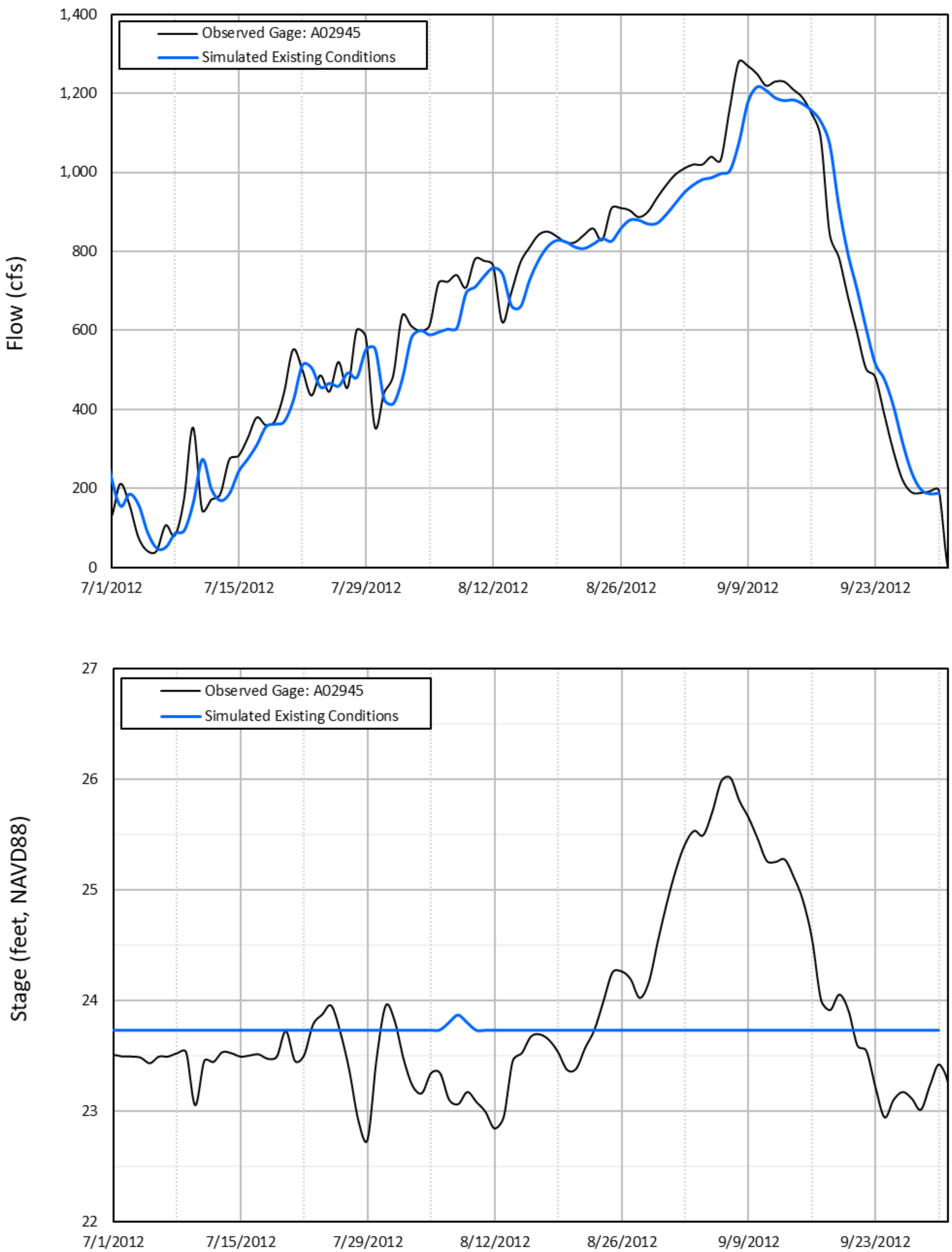


FIGURE 6. KLOG Flow and Stage Data for 2012 Validation

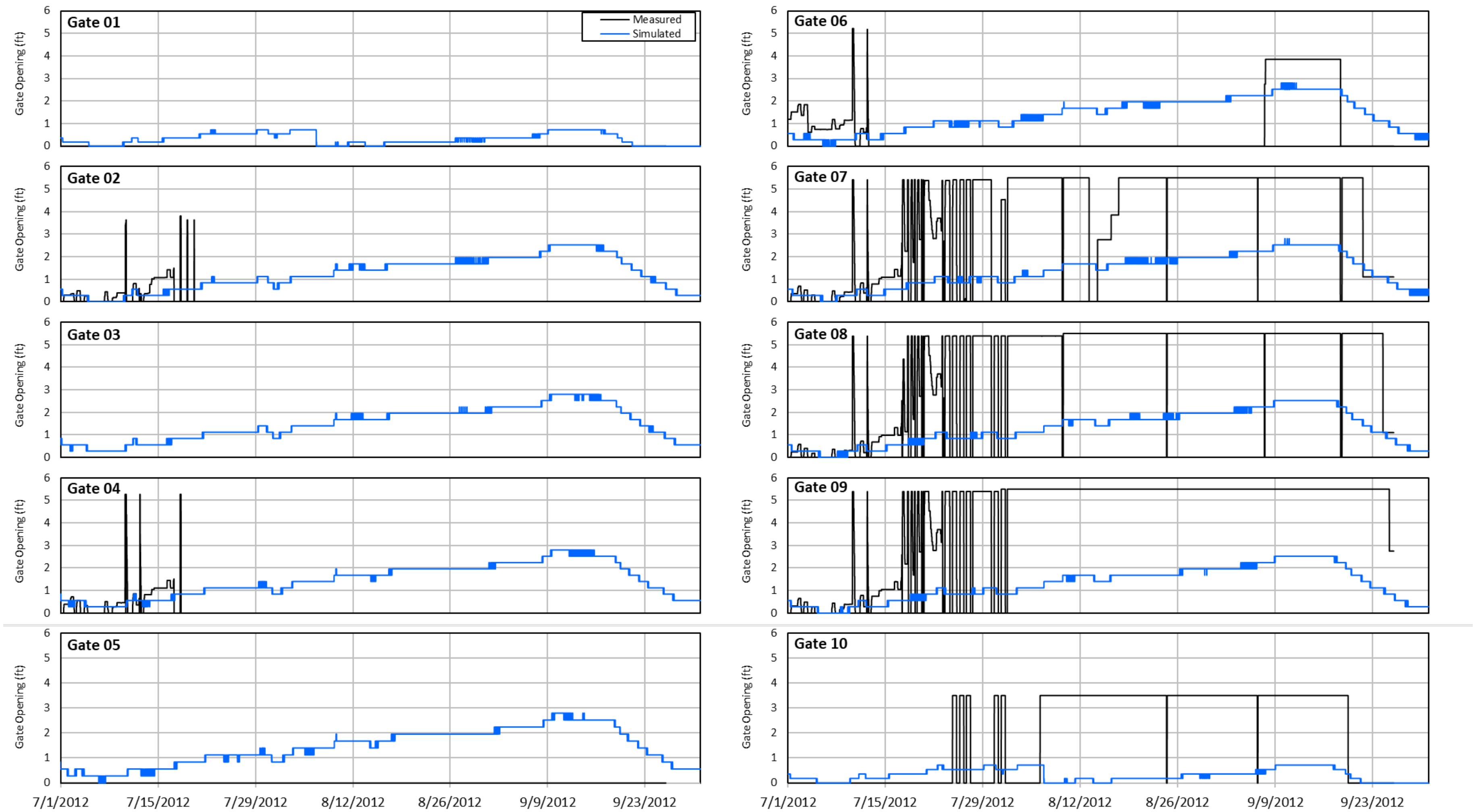


FIGURE 7. KLOG Gate Opening for 2012 Validation

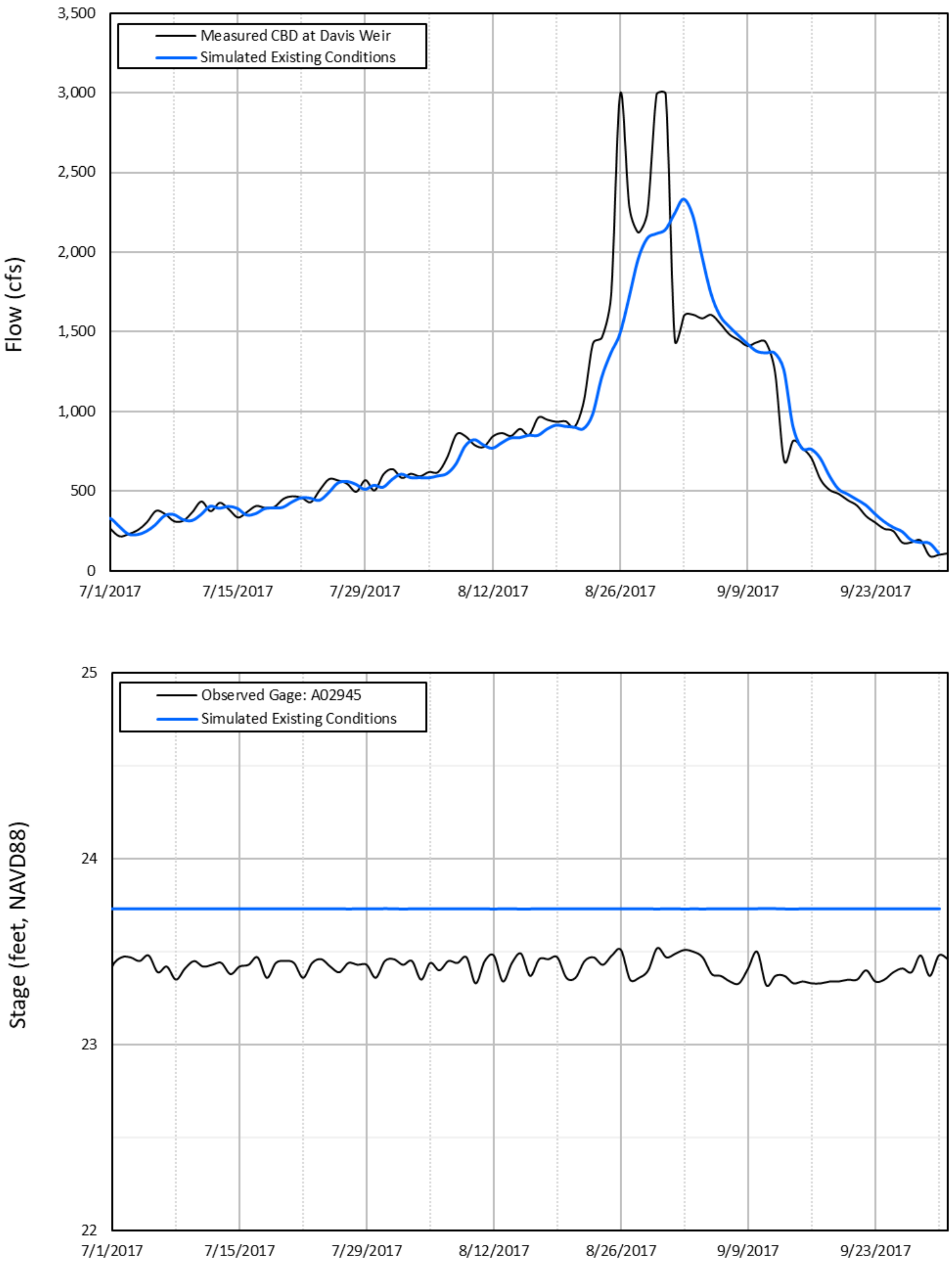


FIGURE 8. KLOG Flow and Stage Data for 2017 Validation

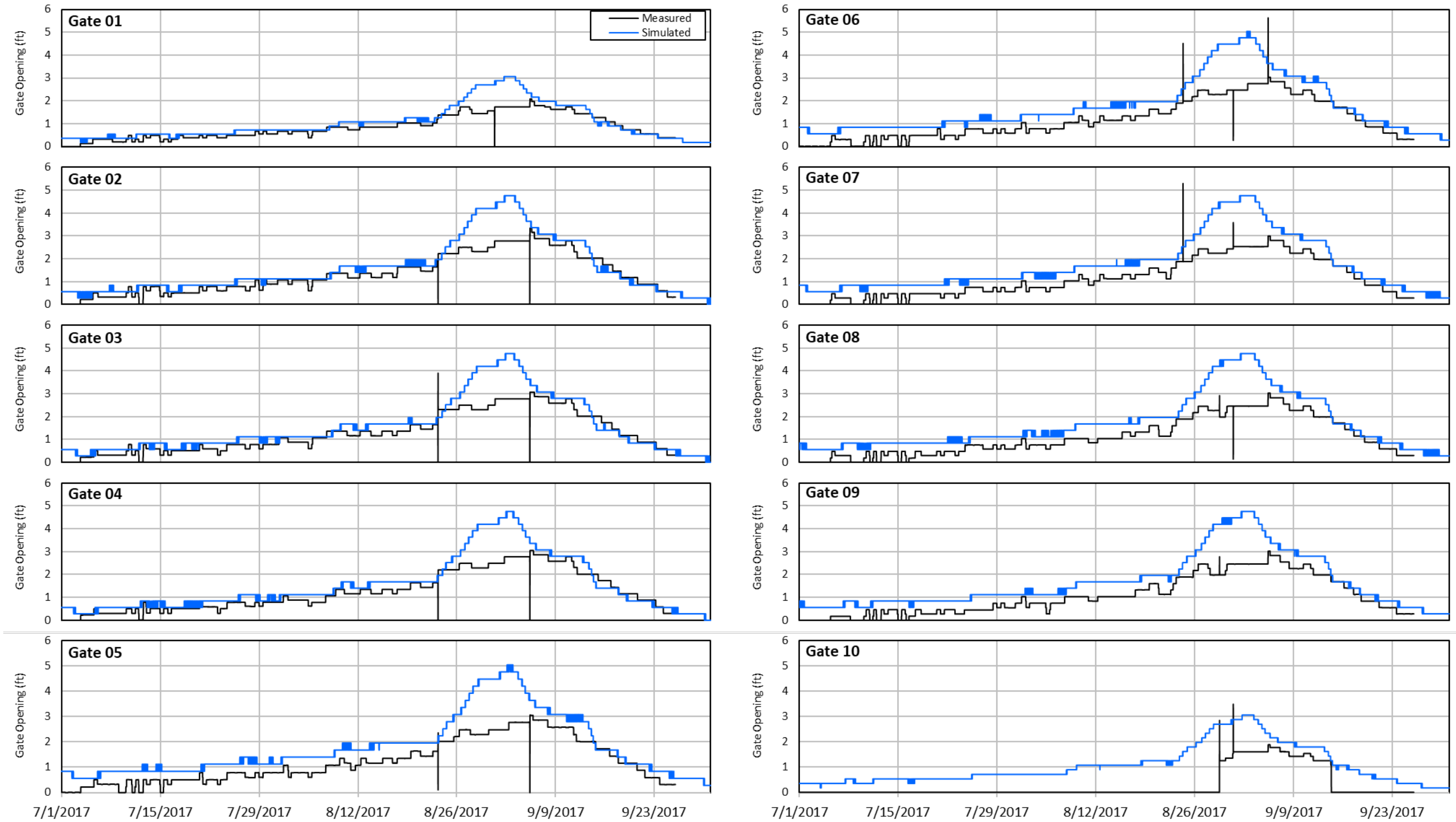


FIGURE 9. KLOG Gate Opening for 2017 Validation

4.6 Assumptions

The following assumptions were made for this hydraulic analysis:

- The KLOG circular gate dimensions were approximated using rectangular gates with equivalent cross-sectional area.
- The KLOG gate operations were assumed to follow standard operating rules, with all 10 gates operating to maintain setpoint of 23.73 feet, NAVD88 (25.5 feet USED) for the historical events and proposed conditions.
- The historical daily flow records for CBD at Davis Weir were assumed to be routed though the CBD channel to KLOG without seepage or loss.

5.0 Results

5.1 KLOG Flow, Stage, and Gate Openings

Figures 10 to 13 show KLOG flow and stage comparisons between measured, simulated existing, and proposed conditions results. The figures indicate that the 1,000 cfs Sites release can be conveyed to Sacramento River through KLOG for dry and critical years (2013, 2014 and 2015). For wet years, the Sacramento River stages are high and the KLOG flap gates are closed (from April to June). This causes CBD flow, including Sites Reservoir releases, to be diverted to Yolo Bypass via Ridge Cut.

Figures show that the measured stages at KLOG have a variability between 19 and 27 feet, NAVD 88 for different water years. Based on the discussion with RD108, it is anticipated that the drop in stage during April to July results from local pumping by agricultural users along CBD and Ridge Cut, and because the earthen embankment at Wallace Weir (prior to construction of Wallace Weir structure) was not put back in place after the flood season. The increase in stage during August and September results from change in KLOG operation setpoint to increase pool elevation and pulse flows down the Ridge Cut to Yolo Bypass, as part of the Delta Smelt Food Action Program administered from 2017.

The simulated stage results stay constant for majority of the simulation period when Sacramento River stage is low. For the water year 2017, the KLOG simulated stages are higher than setpoint until mid-June because of KLOG flap gates being closed. The reason for this difference in simulated stages compared to measured stages is the assumed KLOG gate operations in the model as discussed in model validation, Section 4.5. Although the proposed conditions model has additional 1,000 cfs Sites Reservoir release, the stage results at KLOG for the dry and critical years are similar between the simulated existing and proposed conditions. Comparison of gate openings indicated that simulated proposed conditions model has all 10 gates open at a higher height and longer duration than simulated existing conditions, to convey higher flow. Figure 14 is an example comparison of simulated gate openings for water year 2015.

5.2 CBD Water Surface Profiles

Figures 15 and 16 show CBD hypothetical WSE profiles for existing and proposed conditions for the following flow conditions:

- Flow Profile 1 (Figure 15) – existing condition flow of 50 cfs and proposed condition flow of 1,050 cfs
- Flow Profile 2 (Figure 16) – existing condition flow of 1,700 cfs and proposed condition flow of 2,700 cfs

These flow profiles were selected to illustrate the range of the potential changes in CBD WSEs caused by Sites Reservoir release of 1,000 cfs. Figure 15 indicates that for a low-flow condition in CBD, KLOG causes backwater with a flat WSE (almost zero water surface slope) up to RM 25 near Balsdon Weir. The 1,000 cfs Sites release during these conditions increases CBD WSEs by a maximum of 1.54 feet. The WSE increases are highest upstream of Sites release location to Balsdon Weir; and the WSE dissipates upstream of the weir. The WSE increases taper off downstream of Sites release location to KLOG, and converge at the KLOG.

Figure 16 indicates that for a high-flow condition in CBD, steeper water surface slope exists in the CBD, up to RM 34. The 1,000 cfs Sites Reservoir release during high flow in CBD increases CBD WSEs by a maximum of 1.5 feet. However, because of the steeper slope of the CBD water surface upstream of Sites outfall, the WSE differences taper off at a rapid rate to become zero at Balsdon Weir. The WSE increases taper off downstream of Sites outfall location to KLOG, and converge at the KLOG.

During the discussion with RD108 to review preliminary results of this hydraulic modeling, it was determined that increase in CBD WSEs resulting from Sites Reservoir releases need to be assessed with respect to the lowest agricultural field elevation along the western berm (RM 8.9). If the CBD WSE exceeds this elevation, it can cause flooding in this field from seepage and backwater. To evaluate this criteria, elevation profiles of top of the western berm and toe of the western berm along CBD were generated using the CVFED LiDAR. These profiles are shown on Figures 15 and 16. The lowest elevation along the toe of western berm profile at RM 8.9 was determined to be the lowest field elevation of 25.3 feet, NAVD 88. This elevation was considered as critical elevation in this analysis for assessing WSE effects.

Table 3 presents WSE differences at select locations on CBD for the flow profiles.

TABLE 3. CBD WATER SURFACE ELEVATIONS AT SELECT LOCATIONS

	Flow Profile 1 WSEs[a]			Flow Profile 2 WSEs[b]		
CBD location	Existing (ft, NAVD 88)	Proposed (ft, NAVD 88)	Difference (ft)	Existing (ft, NAVD 88)	Proposed (ft, NAVD 88)	Difference (ft)
KLOG (RM 0.287)	23.73	23.73	-0.01	23.74	23.73	-0.01
RM 4	23.73	24.30	0.57	25.09	26.33	1.24
Lowest West Field (RM 8.9)	23.74	25.12	1.38	26.44	27.83	1.38
Sites Outfall (RM 10.5)	23.74	25.28	1.54	27.02	28.33	1.31
RM 16	23.74	25.28	1.54	28.37	29.24	0.87
Balsdon Weir (RM 25.329)	30.24	30.27	0.03	33.45	33.46	0.01

[a] Flow Profile 1 includes Existing Conditions flow of 50 cfs and Proposed Conditions flow of 1,050 cfs

[b] Flow Profile 2 includes Existing Conditions flow of 1,700 cfs and Proposed Conditions flow of 2,700 cfs

5.3 CBD WSE Changes

Figures 17 to 20 show flow and stage results at CBD cross section, at RM 8.9 near the agricultural field with the lowest elevation on the western side, for the 4 water years that were modeled. The figures identify the periods when the proposed conditions stage exceeds the critical elevation of 25.3 feet, NAVD 88; they also indicate the quantity and timing of when Sites Reservoir volumes can be conveyed to Sacramento River with a constant flow rate of 1,000 cfs. The dashed yellow line shows the cumulative water released from Sites Reservoir, when there would not have been a water level effect on the agricultural field at RM 8.9. The figures illustrate that the 1,000 cfs reservoir release can be conveyed without causing WSE effects primarily during the months of April through July, and October. In August and September, the CBD carries high flows, resulting from rice field agricultural drainage, and does not have capacity to convey reservoir releases of 1,000 cfs.

Table 4 summarizes the information from the figures. The table shows that critical years (followed by dry years) have the highest percentage of days when reservoir releases can be made without causing WSE effects. The table and figures also indicate that Sites Reservoir can release less than 1,000 cfs many times during this period, to prevent WSE effects and increase the overall volume of release.

TABLE 4. SUMMARY OF WSE EFFECTS ON SITES VOLUME DELIVERY

Month	CBD Existing Conditions Monthly Average Flow (cfs)				# of Days without WSE Effects[a]				Sites Volume Conveyed to Sacramento River[b] (TAF)			
	2013 (D)	2014 (C)	2015 (C)	2017 (W)	2013 (D)	2014 (C)	2015 (C)	2017 (W)	2013 (D)	2014 (C)	2015 (C)	2017 (W)
Apr	332	161	307	307	1	19	28	0	2.0	37.7	55.5	0.0
May	451	85	229	229	4	26	29	0	7.9	51.6	57.5	0.0
Jun	435	158	376	376	5	16	30	10	9.9	31.7	59.5	19.8
Jul	555	148	387	387	0	22	31	0	0.0	43.6	61.5	0.0
Aug	1,319	509	1,022	1,022	0	4	5	0	0.0	7.9	9.9	0.0
Sep	636	633	940	940	8	4	10	4	15.9	7.9	19.8	7.9
Oct	137	43	60	60	26	31	31	31	51.6	61.5	61.5	61.5
Total					**44**	**122**	**164**	**45**	**87.3**	**241.9**	**325.2**	**89.2**

[a] Critical WSE of 25.3 feet, NAVD 88, was used to calculate # of days without WSE effects

[b] Sites volume was calculated using 1,000 cfs constant flow, for the total number of days in the water year without WSE effects

6.0 Next Steps

The following tasks were identified for continuing the hydraulic analysis to inform Project planning and design:

- Verify with RD108 the lowest field elevation (RM 8.9) and the CBD operations for 2013 because they are not consistent with Jacobs' understanding for dry-year operations.
- Conduct field visit to collect geometric data for Balsdon and Davis Weirs, to improve model representation and evaluation.
- Improve the representation of CBD and Ridge Cut junction in the HEC-RAS model. Currently, the junction is modeled with reaches connecting to a storage area.
- Calibrate and validate CBD HEC-RAS model for additional events with historical gate operations.
- Model other Sites Reservoir release scenarios with variable release rates of less of 1,000 cfs.

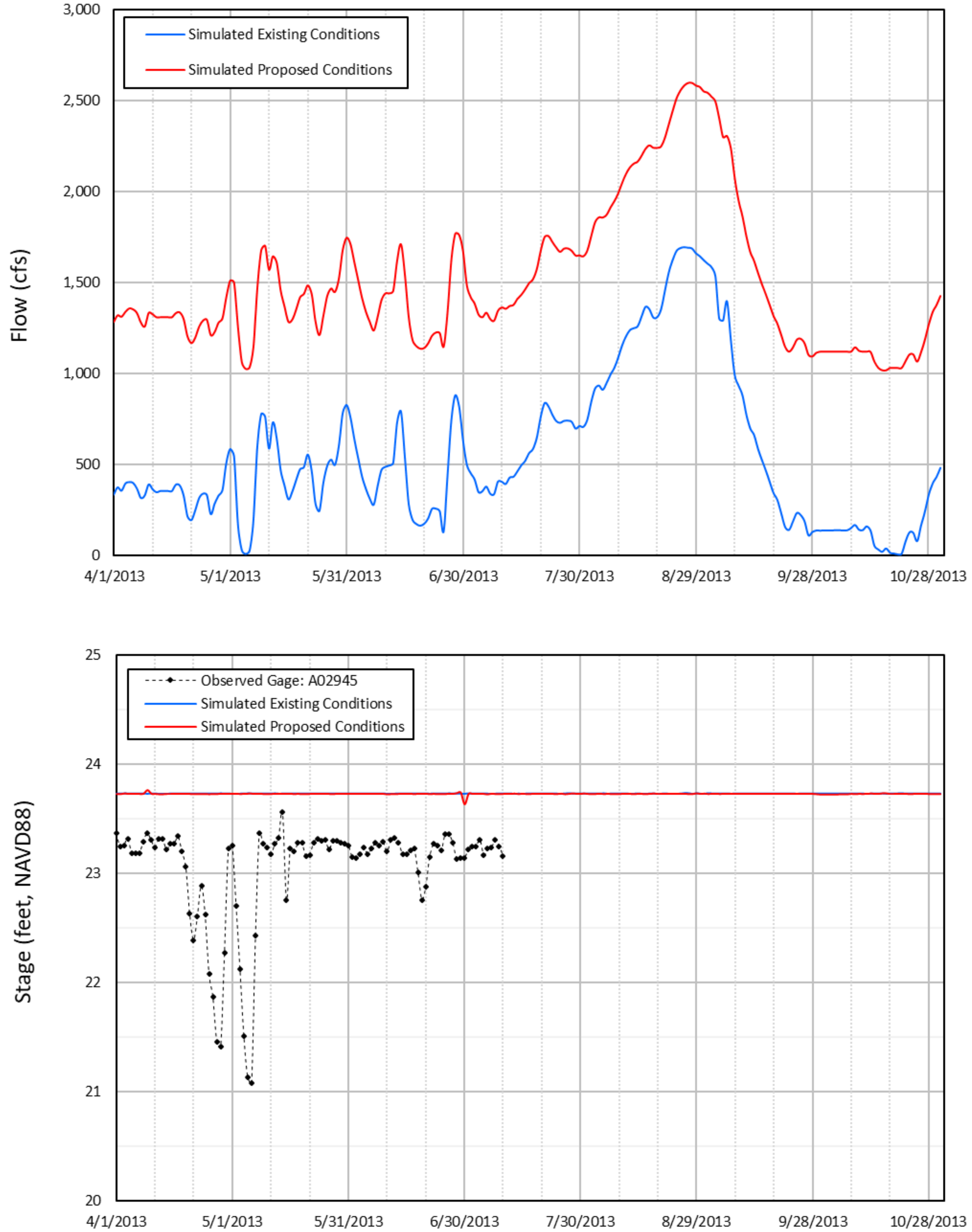


FIGURE 10. Water Year 2013 KLOG Flow and Stage Data

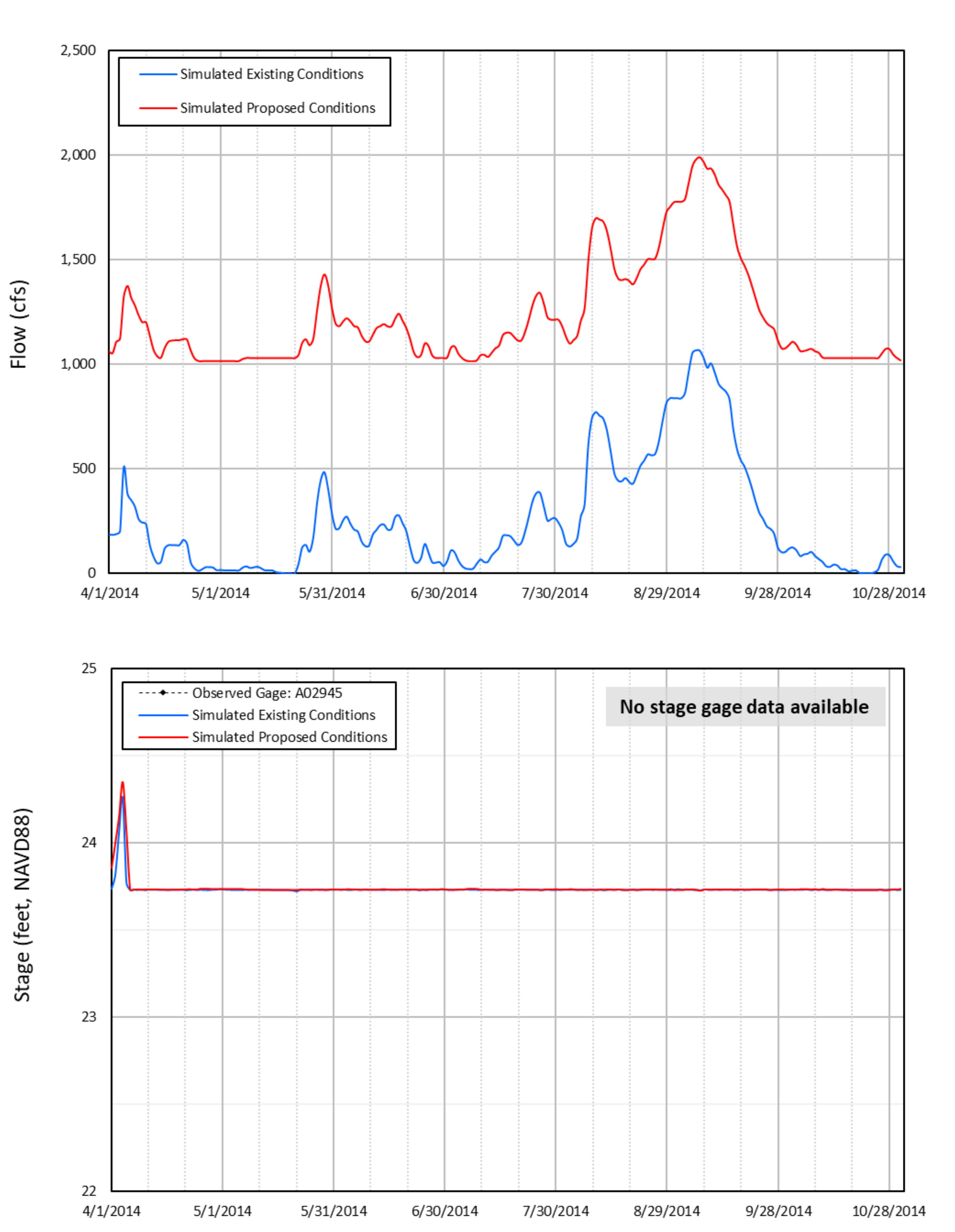


FIGURE 11. Water Year 2014 KLOG Flow and Stage Data

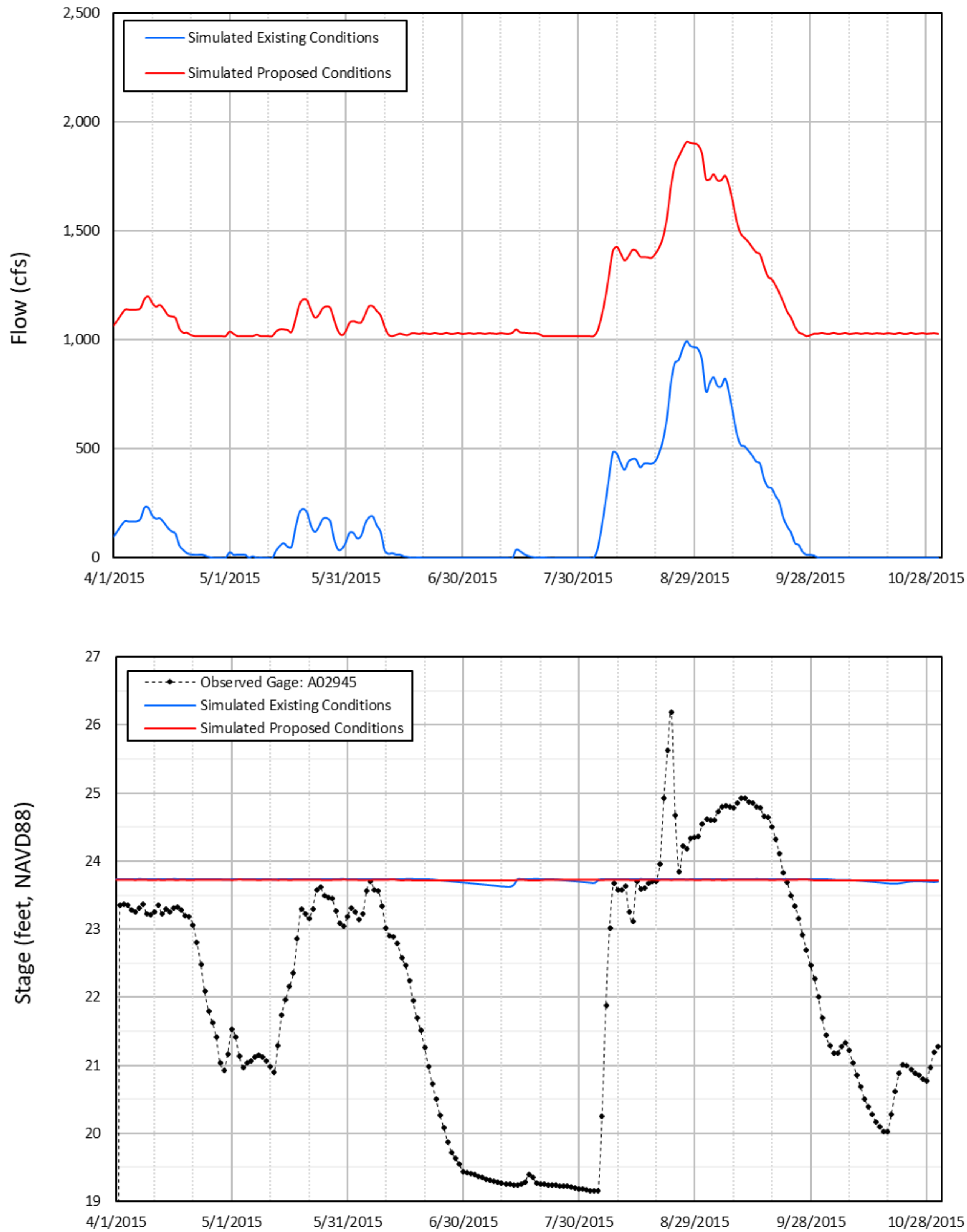
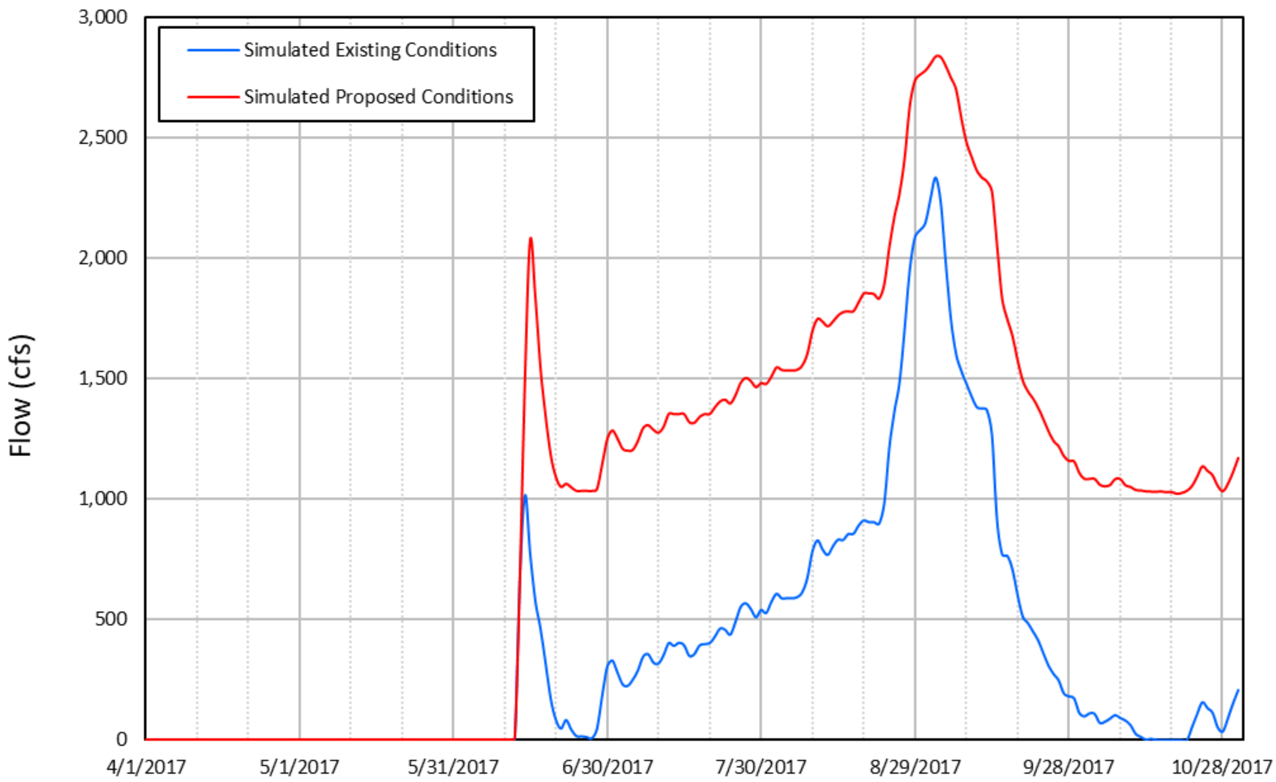


FIGURE 12. Water Year 2015 KLOG Flow and Stage Data



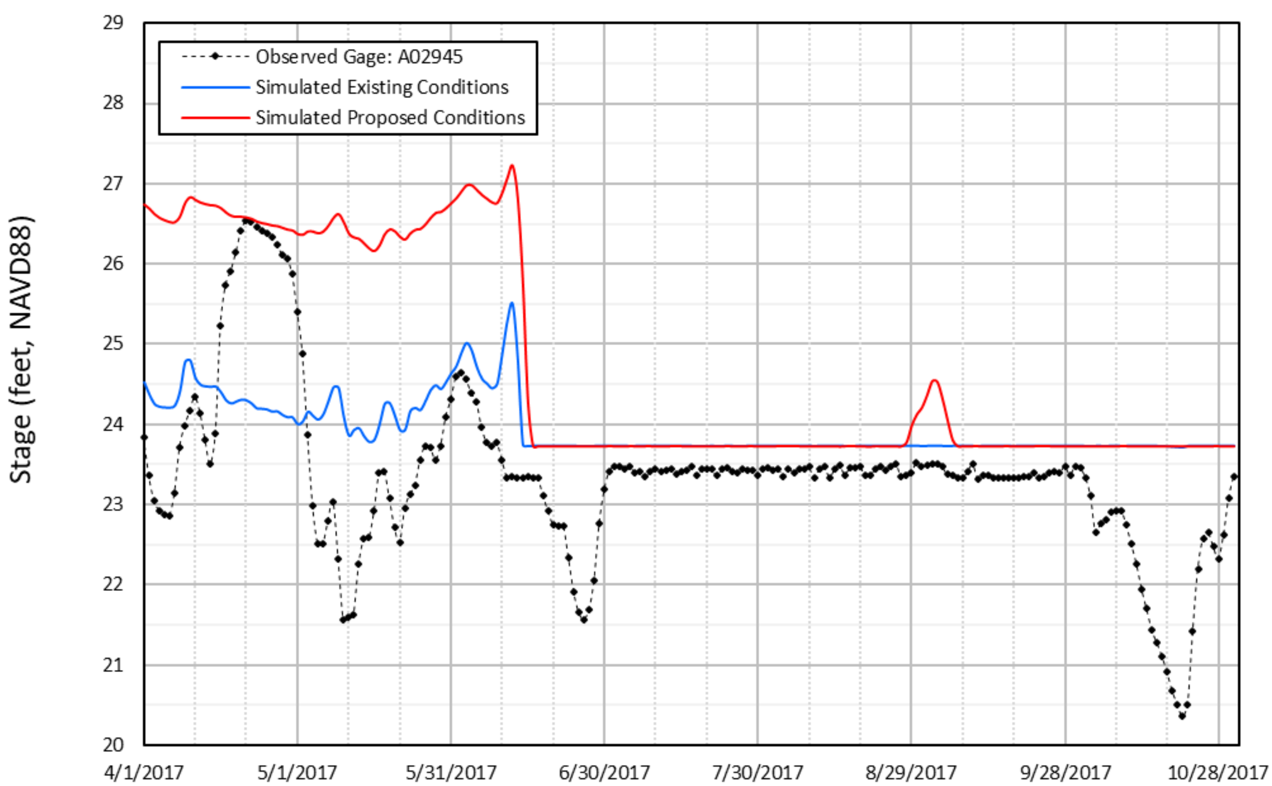


FIGURE 13. Water Year 2017 KLOG Flow and Stage Data

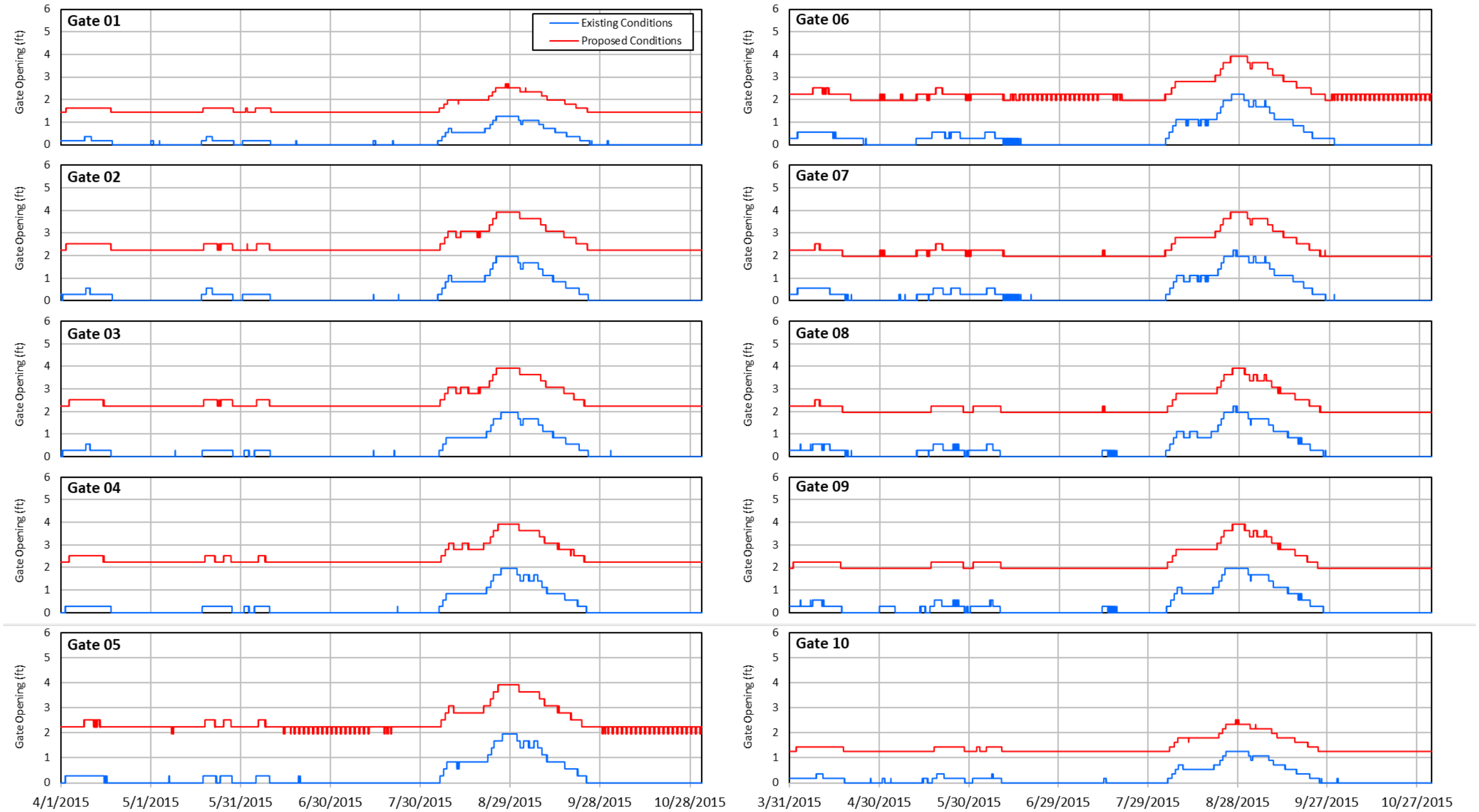


FIGURE 14. KLOG Gate Opening for Water Year 2015

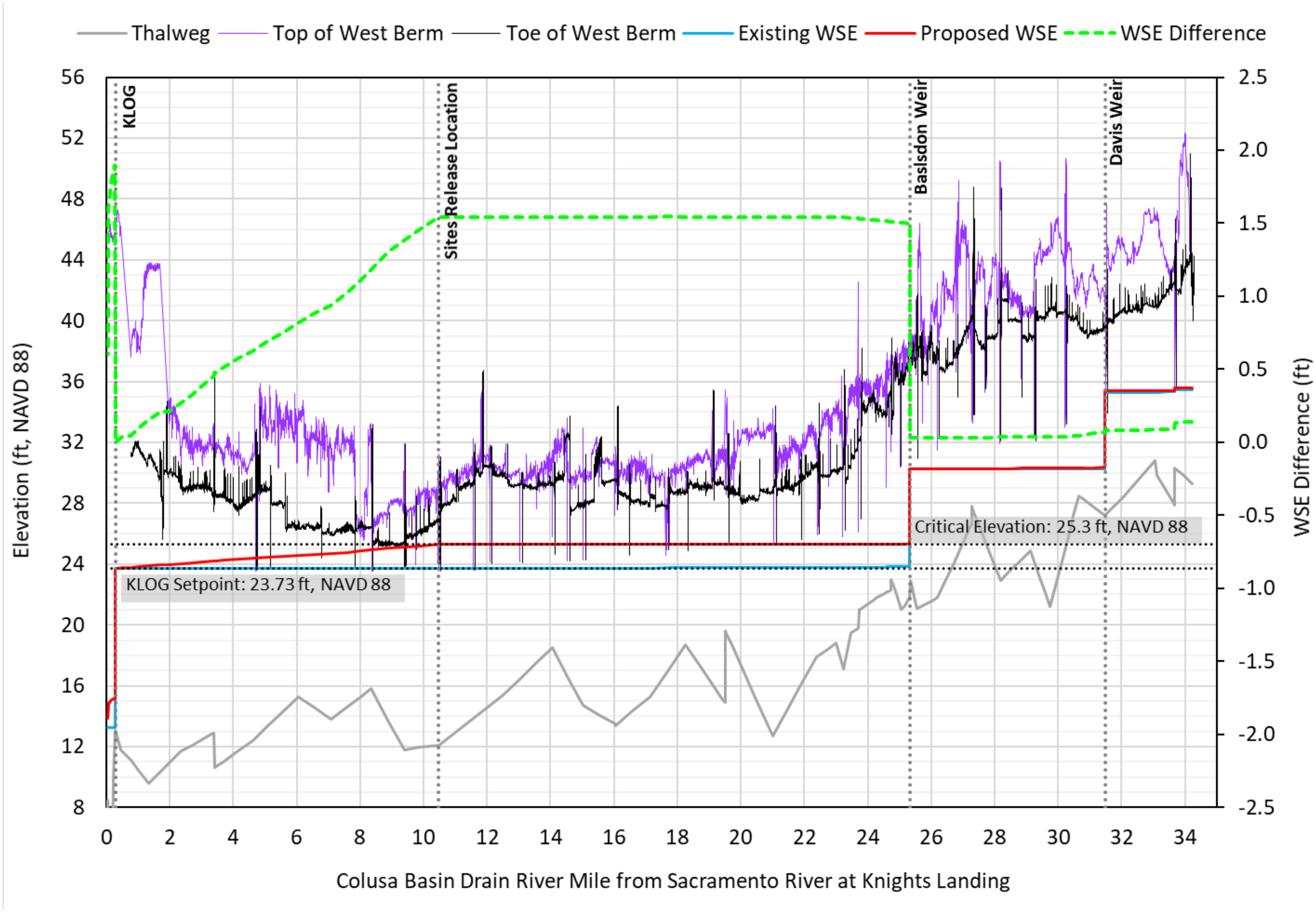


FIGURE 15. CBD WSE Profiles for Flow Profile 1 (Existing Flow: 50 cfs, Proposed Flow: 1,050 cfs)

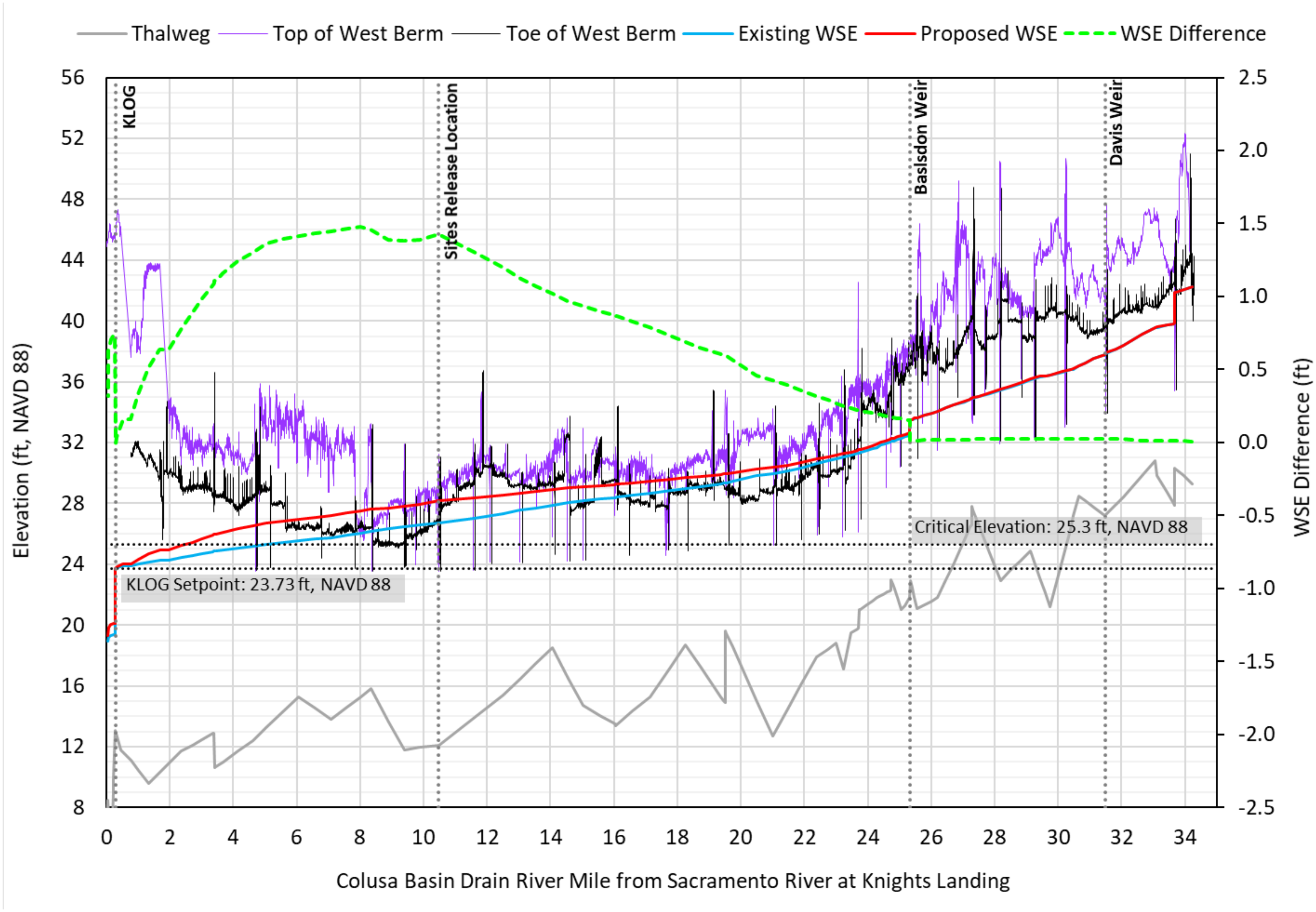


FIGURE 16. CBD WSE Profiles for Flow Profile 2 (Existing Flow: 1,700 cfs, Proposed Flow: 2,700 cfs)

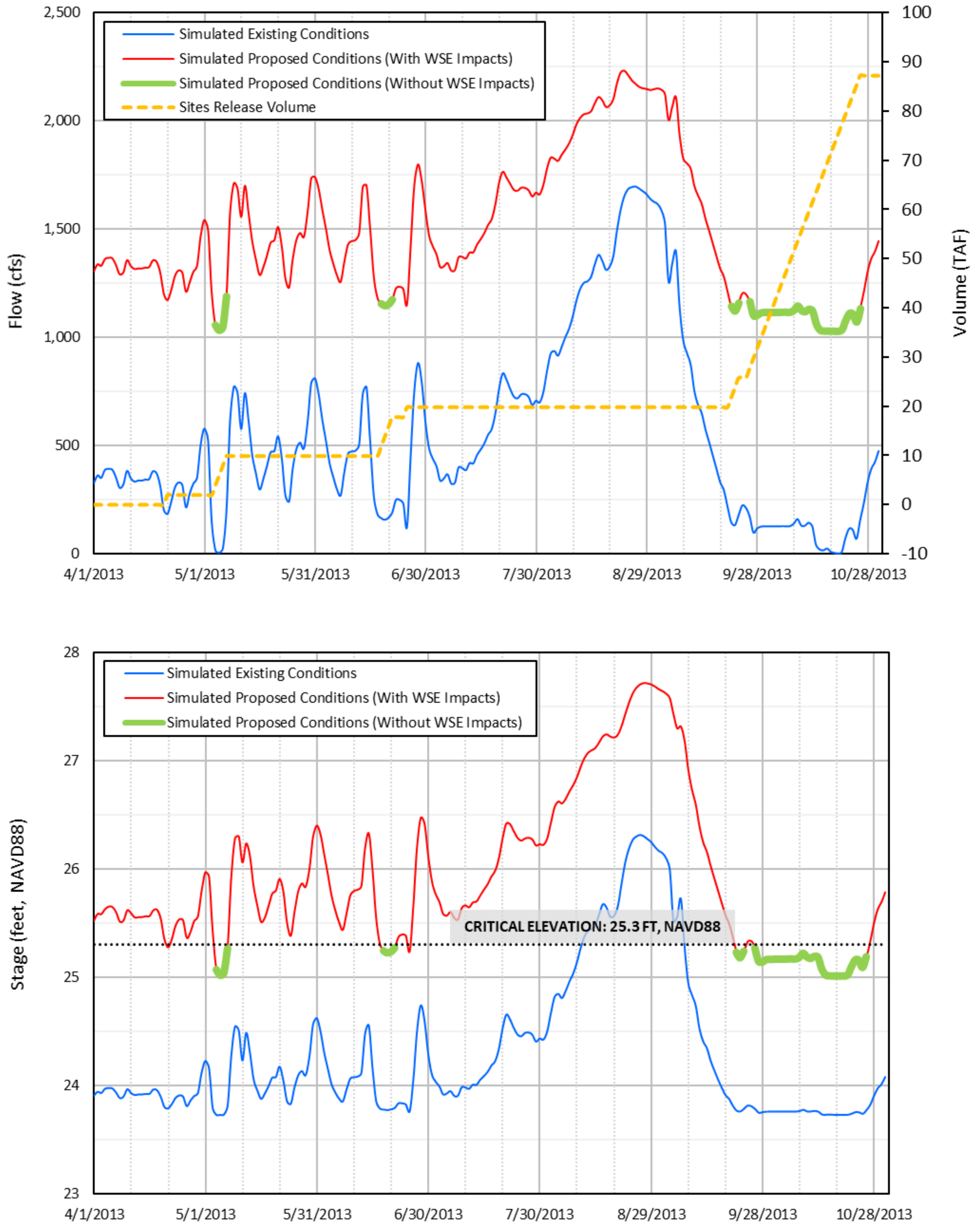
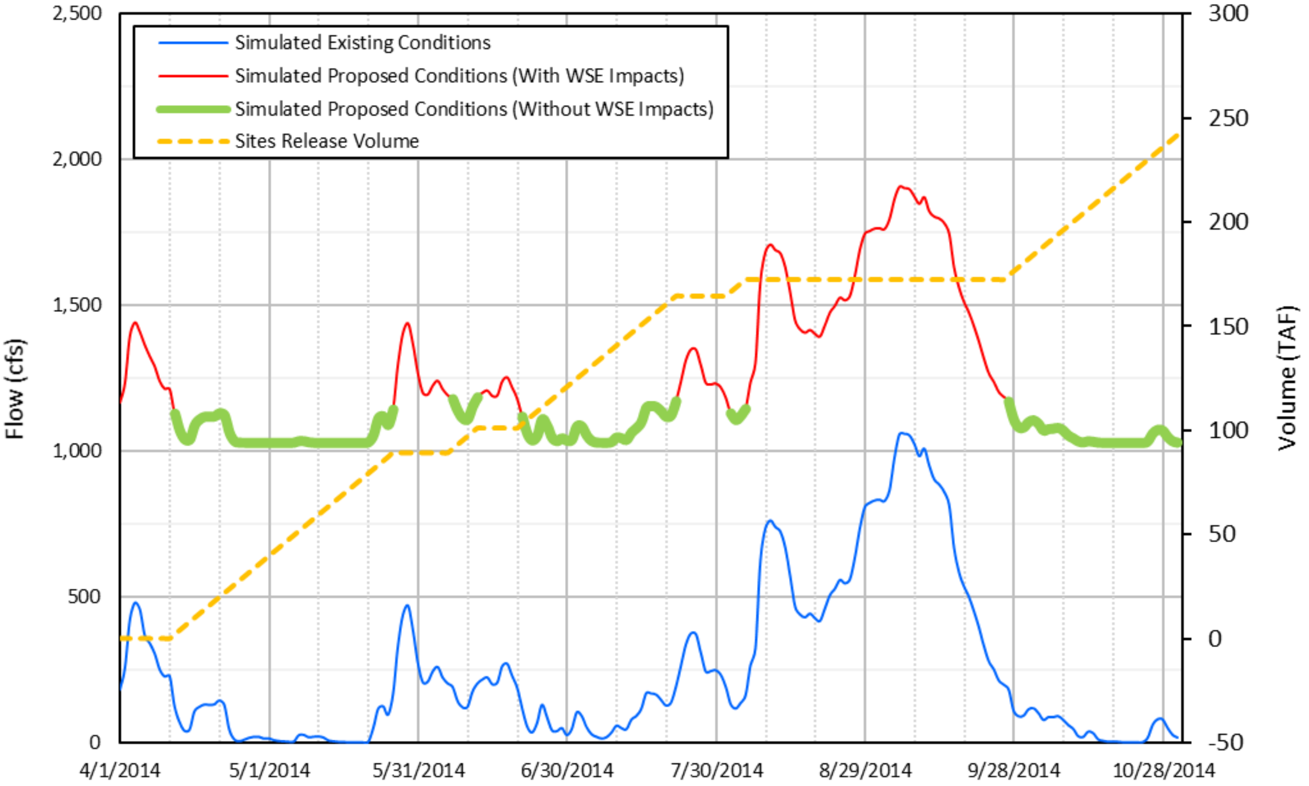


FIGURE 17. Water Year 2013 CBD at RM 8.9 Flow and Stage Data



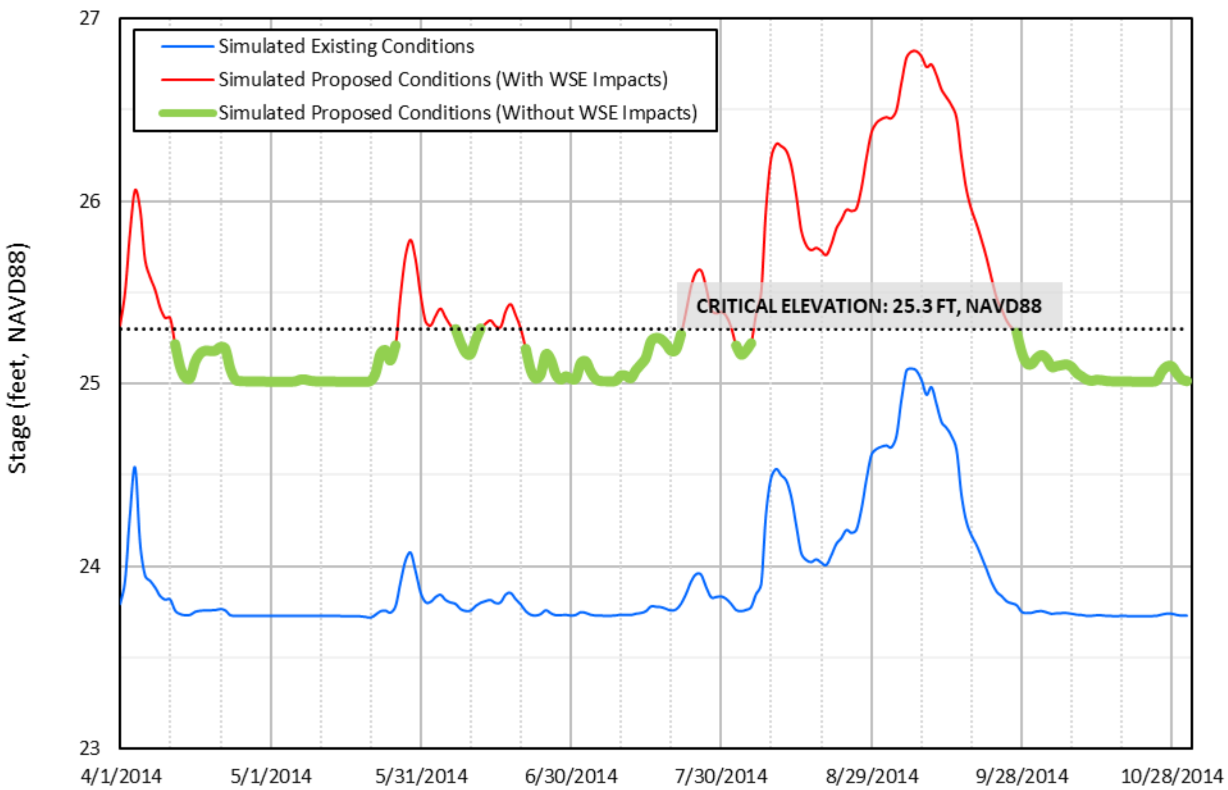
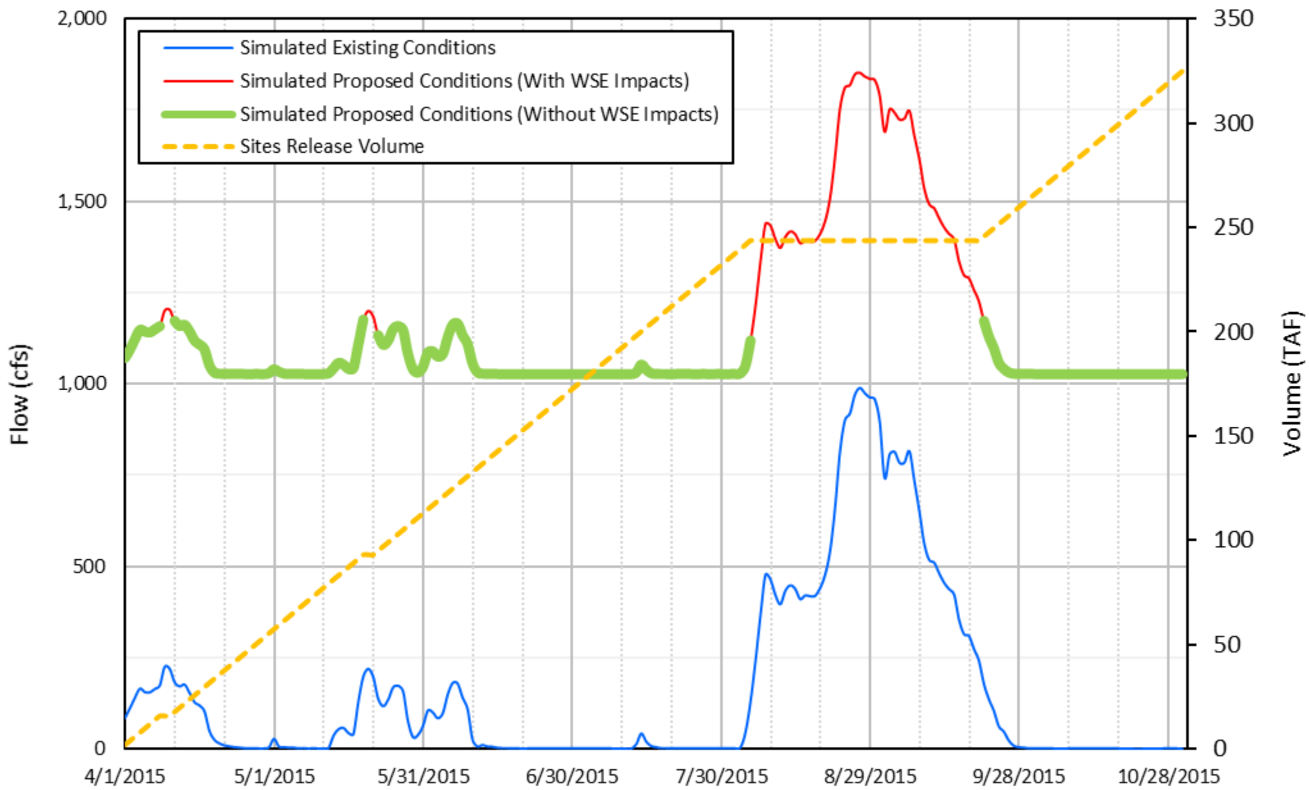


FIGURE 18. Water Year 2014 CBD at RM 8.9 Flow and Stage Data



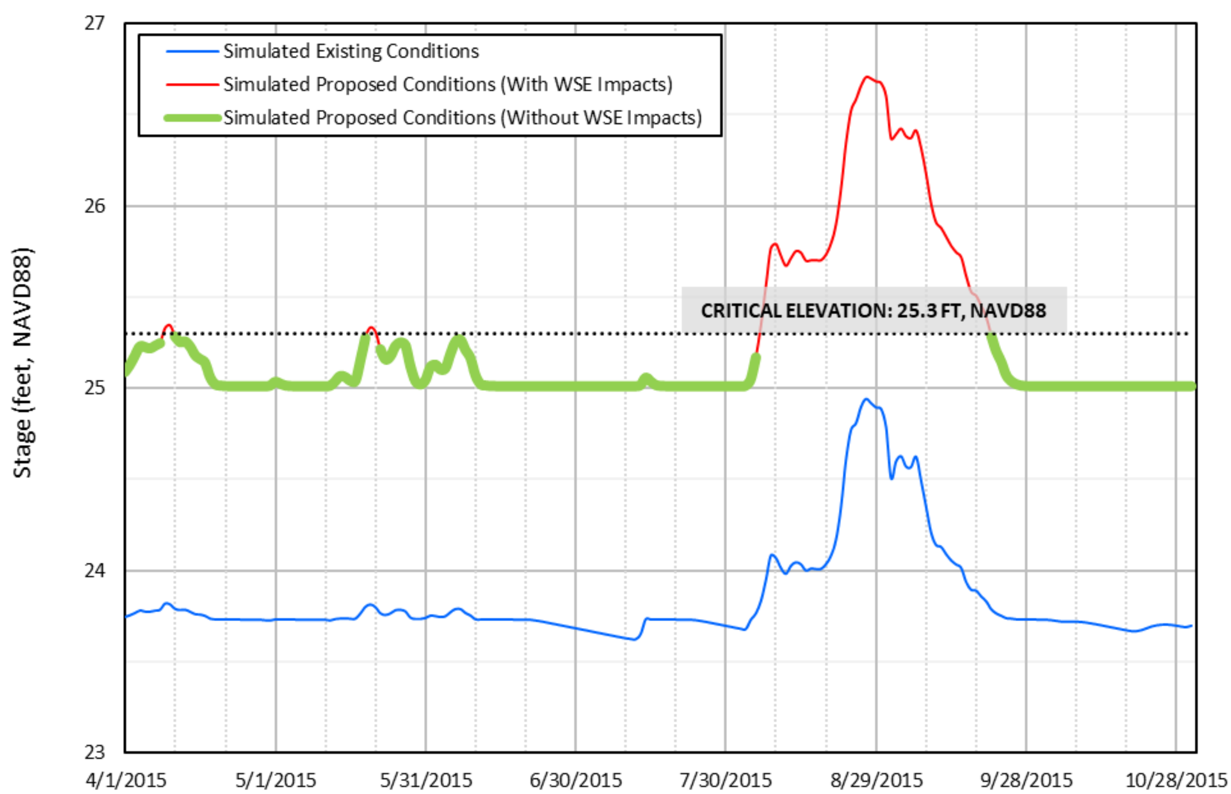


FIGURE 19. Water Year 2015 CBD at RM 8.9 Flow and Stage Data

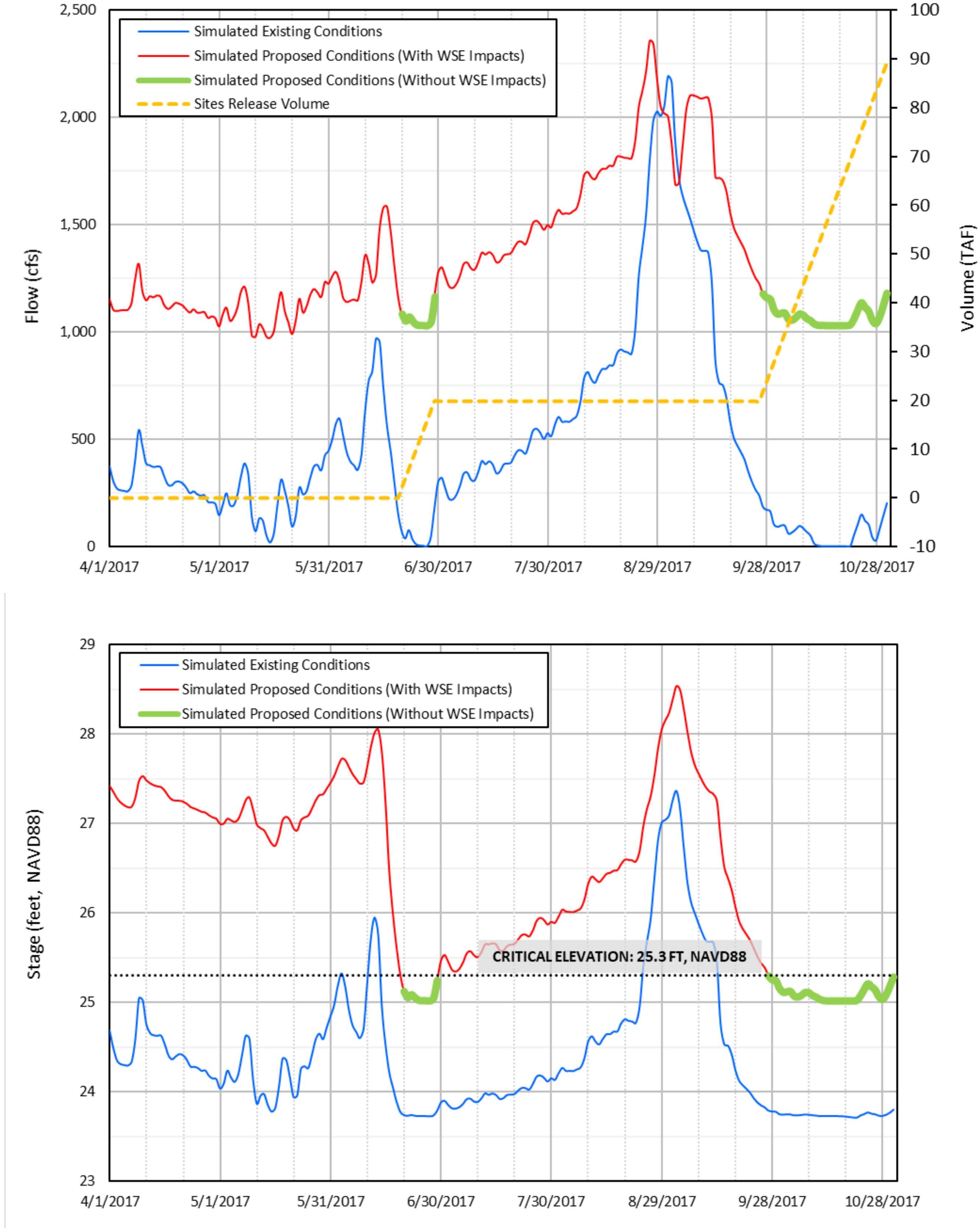


FIGURE 20. Water Year 2017 CBD at RM 8.9 Flow and Stage Data