Appendix B

Evaluation of the Effects of Future Subsidence on Capacity up to 2,500 cfs in Reach 4A and Middle Eastside Bypass

September 2019

San Joaquin River Restoration Program

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California Department of Water Resources
Division of Regional Assistance
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Acronyms and Abbreviations

cfs	cubic feet per second
DWR	California Department of Water Resources
EBCS	Eastside Bypass Control Structure
GCR	Geotechnical Condition Report
HEC-RAS	Hydrologic Engineering Center's River Analysis System
LiDAR	Light Detection and Ranging
MESB	Middle Eastside Bypass
SJRRP	San Joaquin River Restoration Program
SSCC	Sand Slough Connector Channel
UESB	Upper Eastside Bypass
WSE	water surface elevation

Introduction

Subsidence is affecting channel capacities within the San Joaquin River Restoration Program (SJRRP) Restoration Area; the reaches that subsidence has the highest potential to change flow capacity includes the Middle Eastside Bypass, 2.5 miles of the downstream end of Reach 4A, and 2 miles of the downstream end of the Upper Eastside Bypass. This study identifies the levees within these reaches that may need to be improved to convey 2,500 cfs considering future subsidence and the maximum allowable water surface elevation (WSE). The maximum allowable WSE was determined from a geotechnical evaluation of the levees in these reaches. The evaluation identified the water level on the levees that would create significant risk of levee failure due to levee underseepage based on U.S. Army Corps of Engineers (USACE) criteria for levee seepage and slope stability.

This study identifies the levee reaches that may need improvement to achieve this goal. The conclusions presented in this study are planning-level estimates of the levees that may not convey 2,500 cfs using hydraulic design criteria. This study does not consider the potential capacity limitations related to sediment transport. The study also does not evaluate the effects of flow capacity if subsidence rates are different than historical rates. Further work in these areas may be necessary prior to the development of site-specific actions to address the effects of subsidence shown in this report. Figure 1 shows the reaches that are included in the study area.

Background

In 2015, Department of Water Reources (DWR) completed a Geotechnical Condition Report (GCR) that identified the maximum WSE by evaluating the geotechnical conditions of the levees the study area. The GCR estimated the maximum allowable WSE "that can be placed on the waterside levee slopes without exceeding geotechnical criteria for stability and seepage (URS, 2015)." The maximum allowable WSE in the GCR were based on a 2008 Light Detection and Ranging (LiDAR) and 2010/2011 bathymetry datasets. The study area was split into reaches (GCR reaches) as shown in Figures 2 and 3, which were based on the levee's geotechnical characteristics. With these geotechnical results, Tetra Tech determined the levee capacity for each reach using a 1-D Hydrologic Engineering Center's River Analysis System (HEC-RAS) model. The reaches were evaluated up to a maximum Restoration flow of 4,500 cfs. In addition, Tetra Tech also evaluated the capacities considering the subsidence that has occurred between 2008 and 2014. Based on the maximum allowable WSE, the results showed that in 2008, four of the reaches had capacities less than 4,500 cfs, and considering subsidence, the number of reaches increased to six by 2014 (Tetra Tech, 2015).

In 2018, the SJRRP developed a *Funding Constrained Framework for Implementation* (Constrained Framework) that provides a more realistic schedule and associated future funding needs for the SJRRP Implementing Agencies. One of the objectives of the Constrained Framework includes having 2,500 cfs channel capacity in the San Joaquin River from Friant Dam to Reach 4A, Reach 5, and the Eastside Bypass by the end of 2024. DWR is currently improving 2 miles of levee in a portion of the Middle Eastside Bypass, which will increase the overall flow capacity of this reach to above 2,500 cfs. However, ongoing subsidence could continue to reduce the flow capacity of the reach to less than 2,500 cfs. Therefore, DWR has performed this study to understand the effects on channel capacity in the Middle Eastside Bypass, Upper Eastside Bypass, and Reach 4A from subsidence between 2016 and 2031.

Hydraulic Analysis and Results

Previous studies and modeling have shown that local subsidence has the potential to affect the hydraulics of an open-channel system by changing a channel's slope and water depths (California Department of Water Resources, 2018). Even though the overall WSE would decrease with subsidence, the change in water depth for any given flowrate would not necessarily decrease at the same rate as subsidence (California Department of Water Resources, 2018). In fact, in areas where channel slopes are decreasing, flow depths will increase creating more head on levees and decreasing capacity. The opposite can also happen where the depths are less, decreasing the amount of water on the levees but increasing velocities and capacity. This hydraulic study was completed to evaluate the depths and capacity changes at 2,500 cfs in 2016 and in 2031 as a result of subsidence when it is compared to the maximum allowable WSE

Model Development

The study was conducted using validated 1-D steady state Hydrologic Engineering Center's River Analysis System (HEC-RAS) baseline models of the river and flood bypass with 2008 topography and where available 2010-2011 bathymetry. For this study, the topography in the HEC-RAS models and the maximum allowable WSE elevations were both adjusted to consider subsidence. The model geometry was updated to 2016 based on the DWR top of levee surveys. In updating the model geometry, the 2008 cross sections were adjusted based on the total subsidence measured between the 2008 LiDAR and the 2016 surveys. The model was also adjusted to reflect the removal of the weirs at Merced National Wildlife Refuge and the construction of the rock ramp at the Eastside Bypass Control Structure. Both projects are in the Middle Eastside Bypass and will start in 2020. For the 2031 condition, the model was adjusted using the total amount of subsidence that is projected to occur between 2016 and 2031 using the average rates from Reclamation's bi-annual surveys that were conducted between 2011 and 2018. Figure 2 shows a map of the observed rates and Table 1 shows the estimated total subsidence between 2016 and 2031. In 2031, total subsidence from 2016 to 2031 within the study area was estimated to range from almost 6 feet at the upstream end of the study area to about 3 feet at the downstream end of the study area. The maximum allowable WSE was also adjusted based on estimated future subsidence and is provided in Table 1.

Results

The HEC-RAS models were used to compute the WSE at 2,500 cfs through Reach 4A and the Middle Eastside Bypass in 2016 and 2031. The results for each of the GCR reaches are shown in Table 3. The results were also plotted in graphs provided in Figures 5 through 7. In 2016, the WSE at 2,500 cfs in Reach O was 1.7 feet greater than the maximum allowable WSE. Reach O is located along the right levee of the Middle Eastside Bypass and is scheduled to be improved by DWR in 2020.

By 2031, the HEC-RAS models show that three of the GCR reaches will encroach upon or exceed the maximum allowable WSE if subsidence continues at the average annual rates from 2011 to 2018. In addition to Reach O, a segment of Reach L and Reach F may encroach on the maximum allowable WSE by 2031. The WSE at 2,500 cfs would approximately be 0.1 feet above the maximum allowable WSE in Reach L and F. Reach P is in the Upper Eastside Bypass and is right at the maximum allowable WSE. Reach P does not convey Restoration flows, but is impacted by the backwater conditions from the Middle Eastside Bypass. The GCR reaches that exceed the maximum allowable WSE are shown in Figures 3 and 4.

Table 1 Comparison of the WSE at 2,500 cfs with the Allowable Maximum WSE for 2016 and 2031

				2016			2031		
GCR Reach[1]	GCR Station, ft	HEC-RAS Model Cross Section	2016-2031 Total Sub-sidence (ft)	Maximum Allowable WSE (ft)	2,500 cfs WSE (ft)	WSE Elevation Difference (ft)	Maximum Allowable WSE (ft)	2,500 cfs WSE (ft)	WSE Elevation Difference (ft)
A	102000	60106	-2.8	98.1	93.3	4.8	95.4	90.9	4.5
B	106500	64035	-3.1	104.1	93.7	10.4	101.0	91.3	9.7
C	111000	69622	-3.3	97.2	96.2	1.0	93.9	93.1	0.8
D	116400	73247	-3.5	99.3	98.5	0.8	95.8	95.1	0.7
E	136100	93015	-4.8	102.3	99.6	2.7	97.5	95.9	1.6
F	144600	101445	-5.4	101.2	99.9	1.3	95.9	96.0	-0.1
G	152300	107371	-5.7	109.7	100.9	8.8	104.1	96.3	7.8
H	155500	108228	-5.6	106.6	100.4	6.2	100.9	96.1	4.8
I	157000	109849	-5.6	106.1	100.4	5.7	100.4	96.1	4.3
J	106000	61699	-2.9	94.9	93.4	1.5	92.0	91.0	1.0
K	111830	67946	-3.2	99.5	95.3	4.2	96.3	92.4	3.9
L	116800	72501	-3.4	98.3	98.3	0.0	94.9	95.0	-0.1
L	124500	80459	-4.0	100.0	99.1	0.9	96.0	95.6	0.4
M	126500	82690	-4.1	104.1	99.2	4.9	100.0	95.7	4.3
N	134500	90952	-4.6	101.3	99.6	1.7	96.7	95.9	0.8
O	140500	96995	-5.0	98.1	99.8	-1.7	93.0	95.9	-2.9
P	152500	109849	-5.6	101.8	100.4	1.4	96.1	96.1	0.0
Q	937400	269381	-5.5	108.5	103.5	5.0	103.0	98.1	4.9
Q	939300	271595	-5.6	109.6	103.9	5.7	104.0	98.5	5.5
R	926300	270685	-5.6	106.2	103.8	2.4	100.6	98.4	2.2

[1] Reaches A through I, and J through P, are respectively located along the left and right levees of the Eastside Bypass. Reaches Q and R are respectively located along the left and right levees of Reach 4A of the San Joaquin River.

Conclusion

The results of this hydraulic analysis show that the WSE at 2,500 cfs is still below the maximum allowable WSE in 2016 even when subsidence is considered. Although Reach O is currently exceeding the maximum allowable WSE, DWR plans on improving Reach O in 2020 which will increase the capacity of the reach to least 2,500 cfs. However, because subsidence is reducing the capacity in this reach, the SJRRP needs to determine if additional reaches need improvement over the next several years. The results show that subsidence could reduce the capacity to less than 2,500 cfs by 2031 in Reaches F and L. Although the SJRRP will meet its goal of providing channel capacity up to 2,500 cfs by 2024, the reaches that are close to the maximum allowable WSE at 2,500 cfs will be evaluated periodically to determine if improvements will be needed over the next five to ten years.

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Figure 1 Study Area

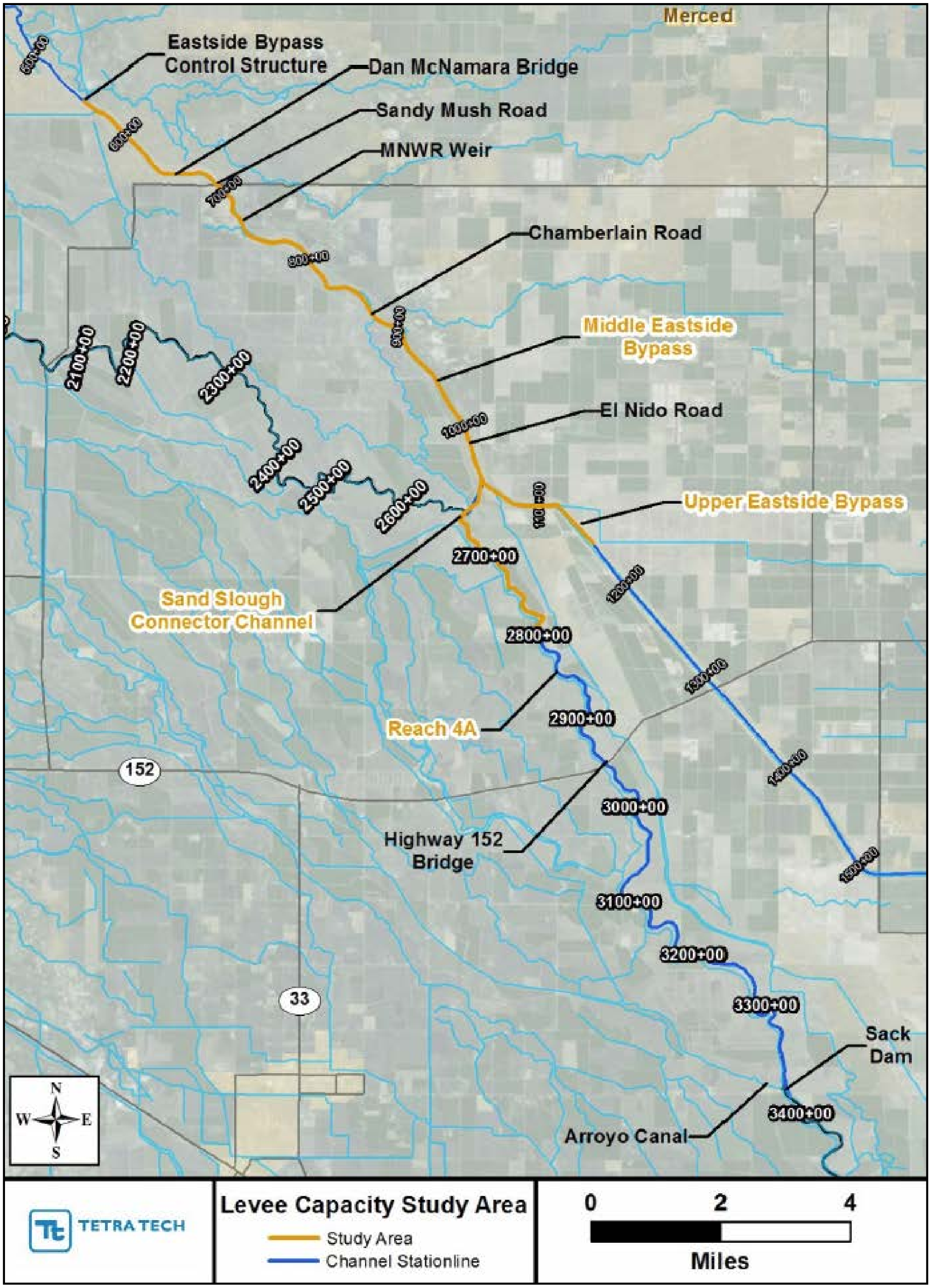


Figure 2 GCR Reaches and Cross Sections in the Middle Eastside Bypass

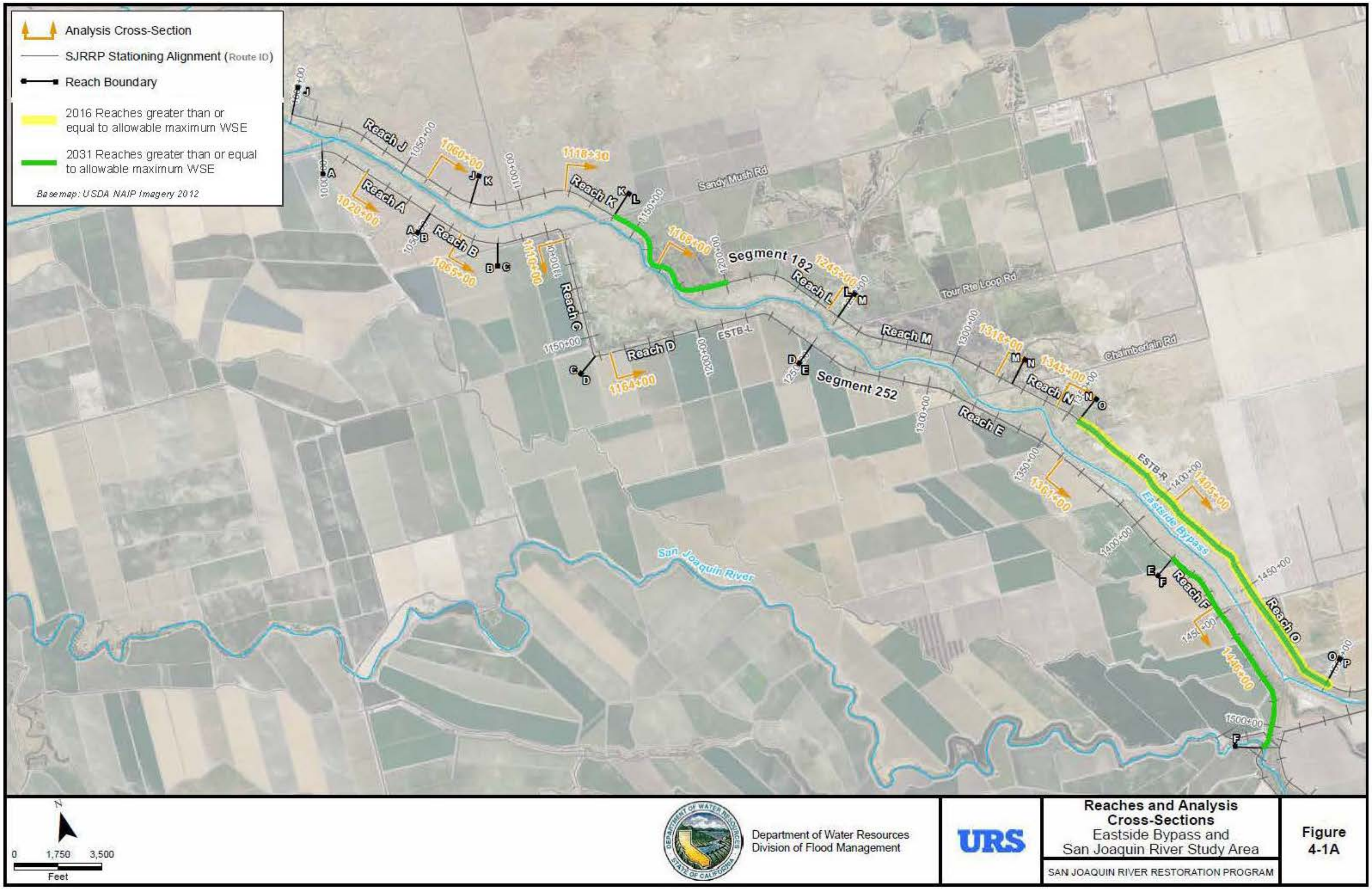


Figure 3 GCR Reaches and Cross Sections in the Upper Eastside Bypass and Reach 4A

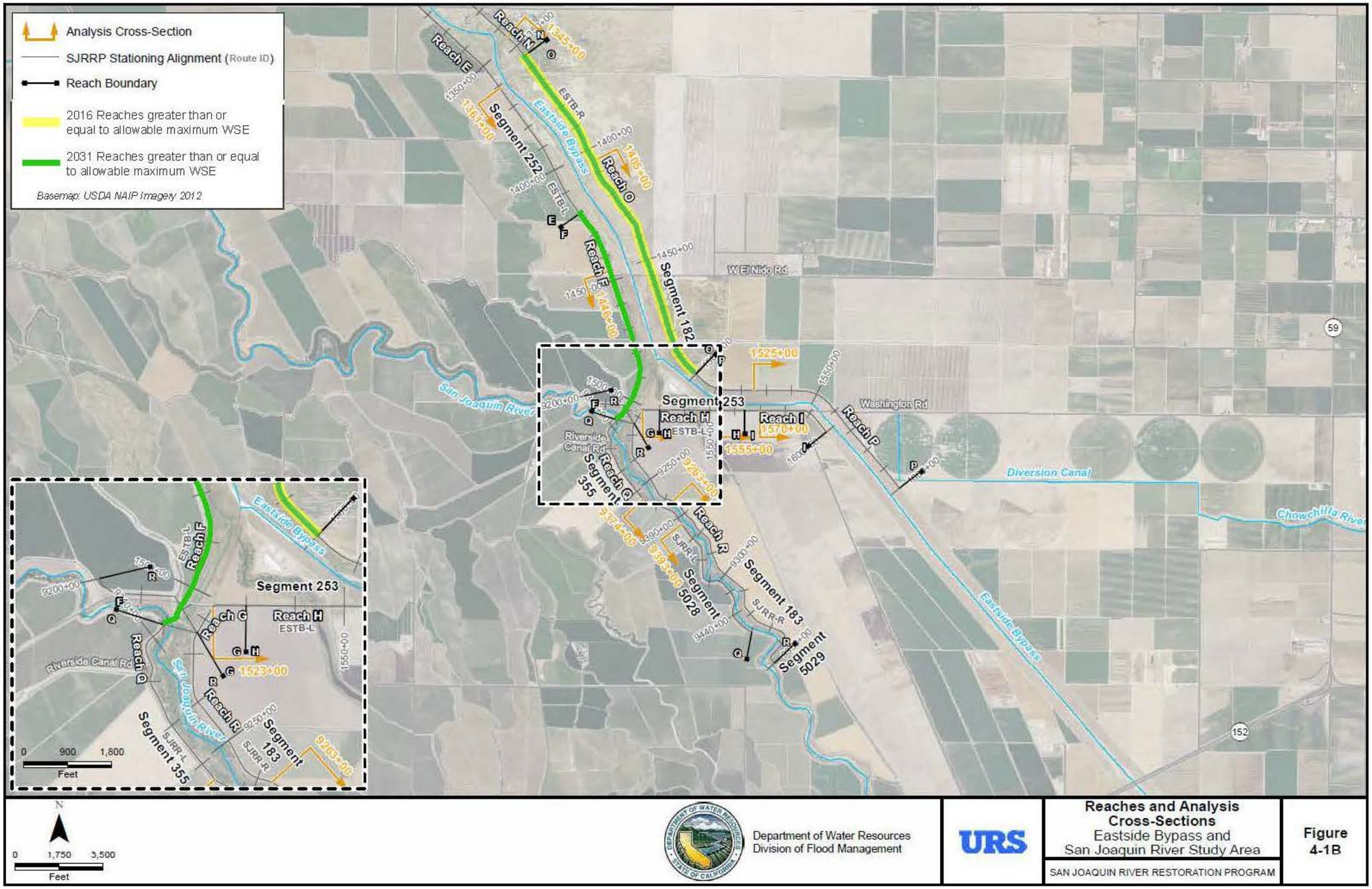


Figure 4 U.S. Bureau of Reclamation Subsidence Rates from 2011 to 2018

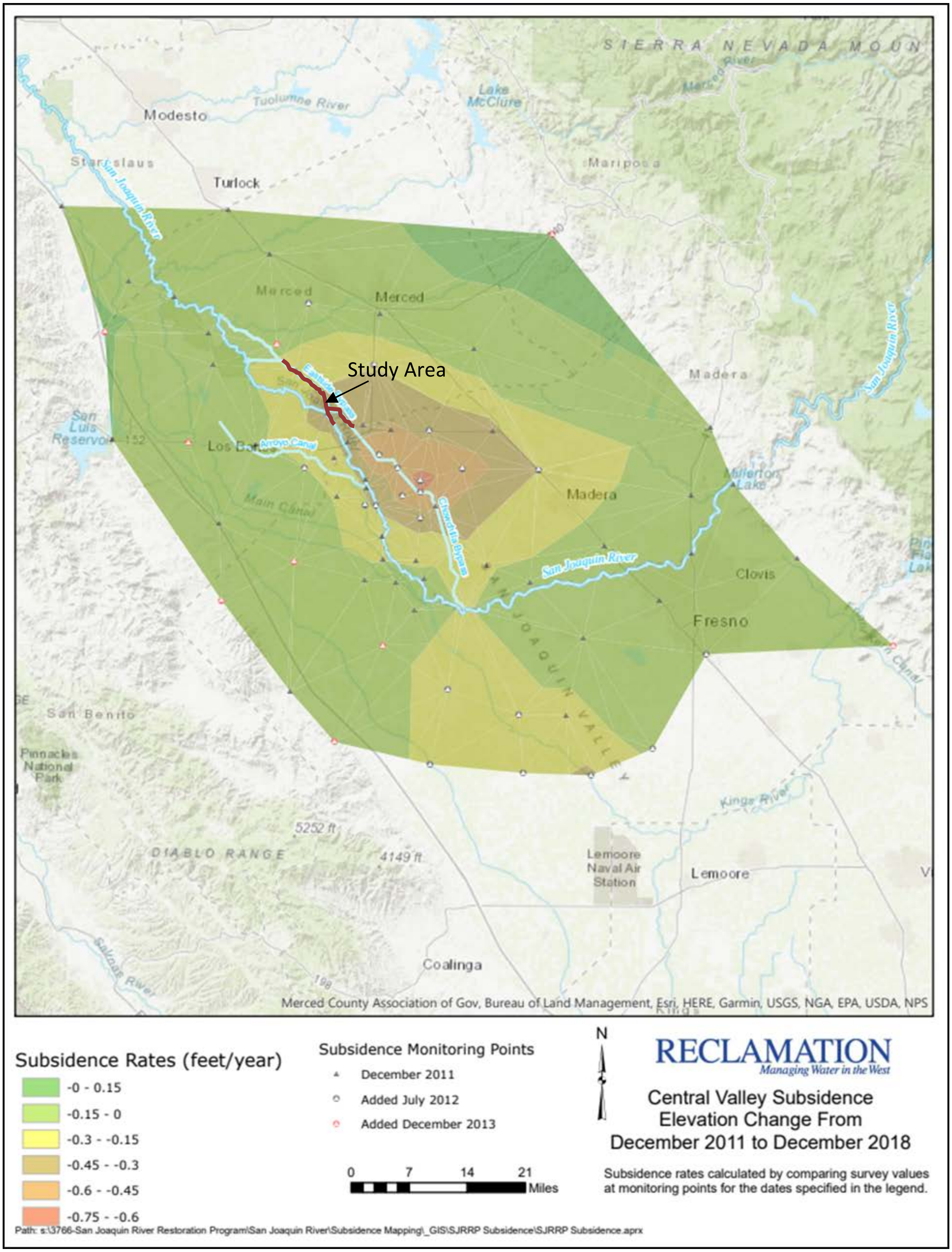


Figure 5 **2016 and 2031 Maximum Allowable WSE and WSE at 2,500 cfs in the Middle Eastside Bypass**

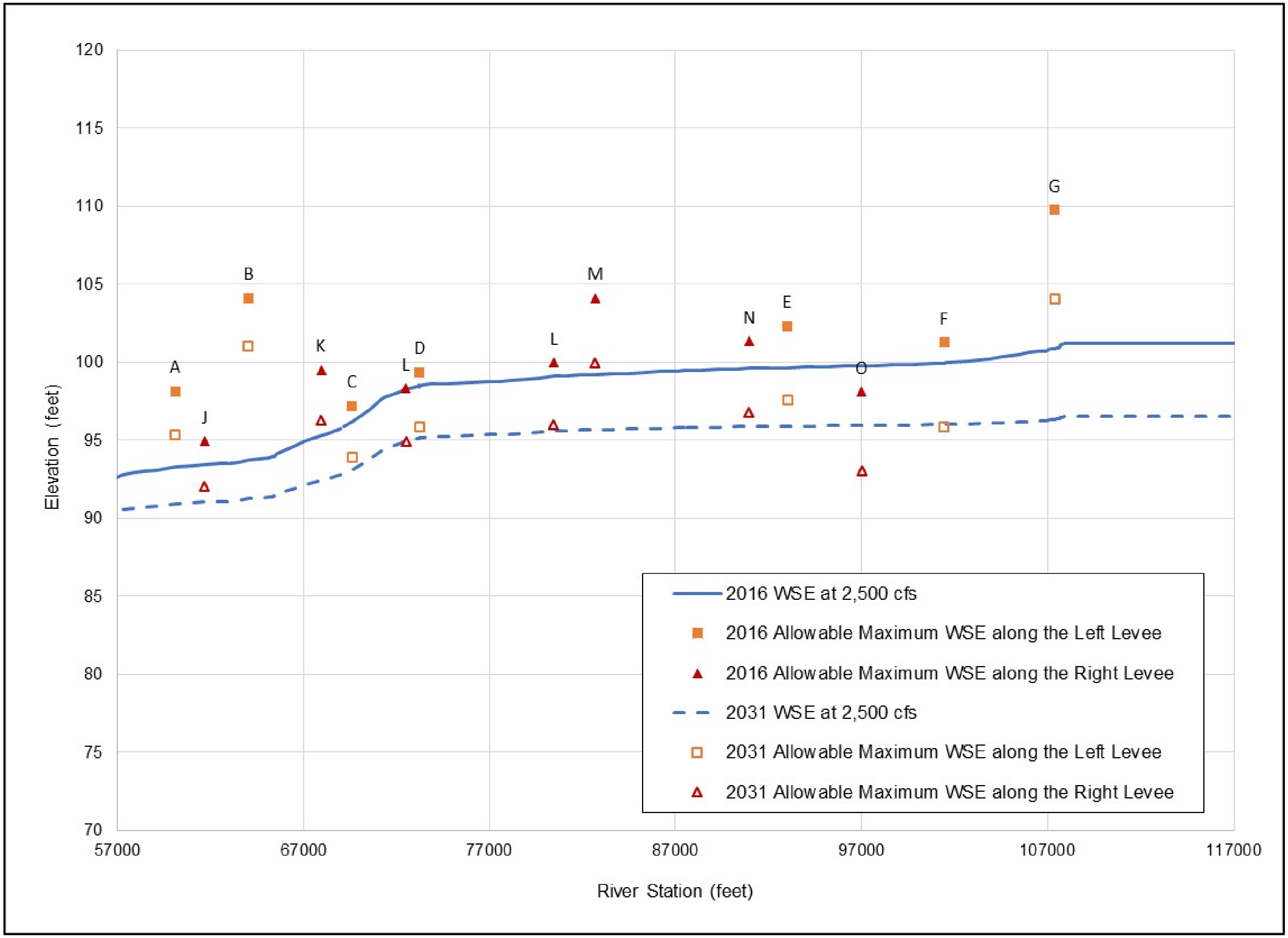


Figure 6 2016 and 2031 Maximum WSE and WSE at 2,500 cfs in the Upper Eastside Bypass

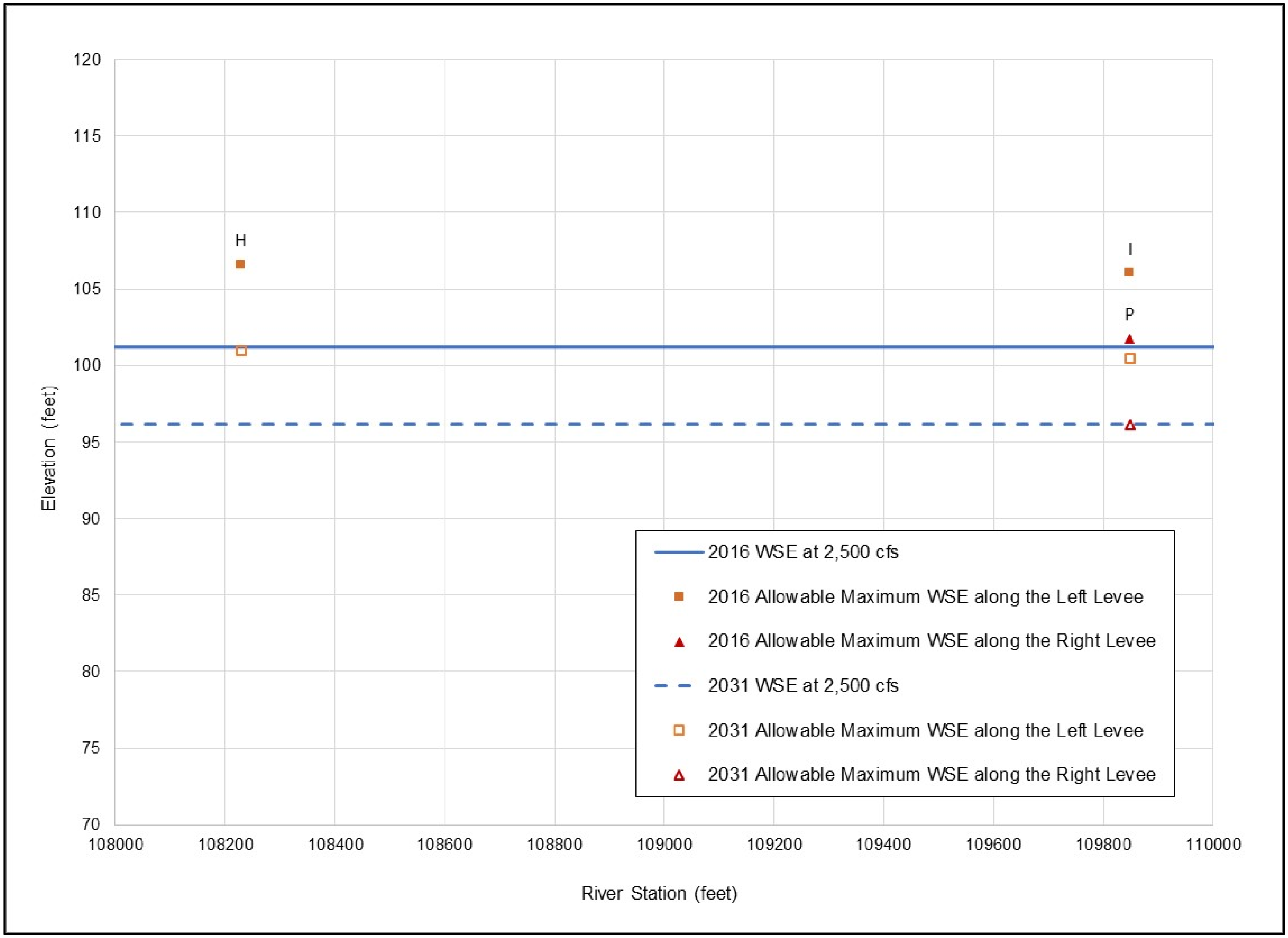
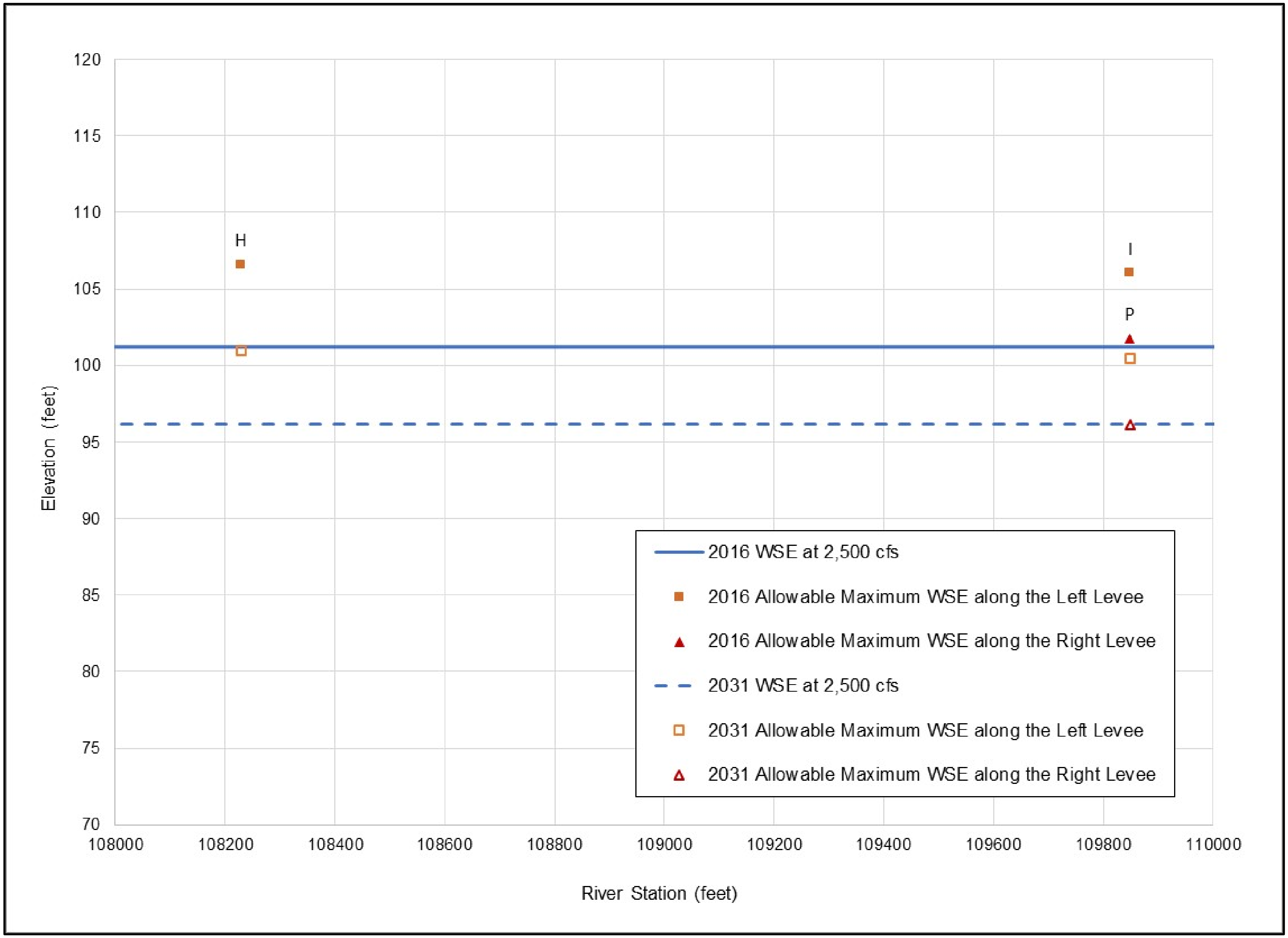


Figure 7 2016 and 2031 Maximum WSE and WSE at 2,500 cfs in Reach 4A



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