Appendix D

Levee Capacity Evaluation of Geotechnical Middle Eastside Bypass (Reach 4A, Sand Slough Connector Channel, Upper and Middle Eastside Bypass) Study Area

August 2015

SAN JOAQUIN RIVER RESTORATION PROGRAM

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August 7, 2015

1. INTRODUCTION

To support the California Department of Water Resources (DWR) with estimates of levee capacity in the San Joaquin River Restoration Program (SJRRP) project reach, Tetra Tech Inc. performed an analysis to establish a maximum flow capacity along the lower 2.5 miles of Reach 4A, the Sand Slough Connector Channel (Connector Channel), the entire Middle Eastside Bypass (MESB) between the Connector Channel and the Eastside Bypass Control Structure, and approximately the lower 2 miles of the Upper Eastside Bypass (UESB) (**Figure 1**). The maximum flow capacity was based on results of a Geotechnical Condition Report (GCR) developed for the levees in these reaches (URS, 2015). The GCR indicates that, within the portions of the river and bypass mentioned above, a total of 18 reaches were assessed by the geotechnical team and designated by letters from A to R (**Figures 2 and 3**). Within each GCR reach, at least one analysis cross section was selected as being representative of the location where seepage or stability issues are most likely to occur. Two cross sections were selected in Reaches L and Q, which are the only reaches with more than one analysis cross section. The GCR identifies the selected maximum water-surface elevation on the levee at each cross section that would not exceed geotechnical criteria for seepage and slope stability (URS, 2015). This memorandum summarizes the methods and results of the hydraulic analysis to determine the maximum flow that corresponds to the maximum water-surface elevation on the levee at each cross section. This work was completed under the River Engineering Services for the San Joaquin River Restoration Program contract, Task Order 2.

2. METHODOLOGY

The locations of the GCR cross sections were mapped relative to the cross sections in the one-dimensional (1-D) hydraulic (HEC-RAS) model of each particular reach (Tetra Tech, 2014) using ArcGIS. In addition to the reach letter, the GCR cross sections are identified by a station number that refers to a distance along the levees. Both identifiers are referred to in this analysis, but the station is included for reaches containing more than one cross section. The model cross sections upstream and nearest to each of the GCR cross sections were identified to provide the reference locations in which to compare computed water-surface elevations for the purpose of estimating flow capacities (**Figure 4**). The model cross section upstream of the GCR cross section was selected since it has a higher water-surface elevation and provides a more conservative estimate of the maximum flow capacity than the one located downstream of the GCR cross section.

A range of flows up to a maximum Restoration Flow of 4,500 cfs was modeled in each of the aforementioned reaches. All flows used in the model were assumed to be local flows that continue from Reach 4A through the Connector channel into the MESB. No flow was assumed to come from the UESB; however, backwater conditions propagate immediately upstream from the confluence with the Connector Channel (i.e., in the lower end of the UESB) and the interpolated flow is reflective of the backwater in the UESB associated with flows in the MESB. Computed water-surface profiles in the MESB were developed based on the assumption that all flows pass through the Eastside Bypass Control Structure (EBCS) into the Lower Eastside Bypass (i.e., no flow is diverted into the Mariposa Bypass). The downstream boundary condition is based on computed water-surface elevations for the adjacent Lower Eastside Bypass model, but the water-surface elevations in the MESB are actually controlled by the EBCS (Tetra Tech, 2014).

The GCR elevation at the assigned model cross section was then used to interpolate a flow based on computed water-surface elevations that were run over a range of flows. If the associated flow was greater than 4,500 cfs, then a capacity of ">4,500" was reported and no further calculations were made.

2.1. Merced National Wildlife Refuge Weirs

Two weirs are located in the MESB that are used to divert water into the Merced National Wildlife Refuge (Refuge) between the months of September and March (**Figure 5**). To divert the irrigation water, boards are inserted into the weir bays. The number of boards needed depends on which portion of the refuge is being irrigated. To provide information regarding the sensitivity of the weir settings on the levee capacities, three weir configurations were evaluated based on a topographic survey completed by DWR in 2015, and from interviews between DWR and Refuge staff. One configuration assumes that both the up- and downstream weirs remain fully open. This configuration is representative of when the Refuge is not diverting flows and is referred to as "Boards Out". The second weir configuration is representative of the most common setting required by the refuge to divert flows during most years, and is referred to as "Typical Boards". The elevation of the boards in this configuration was surveyed by DWR in 2015. The third weir configuration assumes that both the upstream and downstream weirs are completely closed. According to refuge staff, if water is available, the Refuge will occasionally place all of the boards into the weir bays to fill ponds within the bypass that are approximately 3 miles upstream of the weirs. This condition is referred to as "Boards In".

2.2. Subsidence

In addition to performing a sensitivity analysis on the weir settings, the evaluation also included an assessment of the impact of subsidence on levee capacity. The geometry in the existing conditions hydraulic models are based on 2008 LiDAR overbank elevations and 2011/2012 in-channel bathymetry. The GCR reference elevations were also determined based on 2008 LiDAR mapping of the levees. Previous studies conducted by both DWR and Reclamation have indicated that considerable subsidence has occurred in these reaches since 2008 (Tetra Tech, 2015). Because of the age of the existing geometry, levee capacities for both pre- and post-subsidence conditions were evaluated to assess potential changes since the mapping was initially developed.

Rather than using the large-scale subsidence maps developed by Reclamation (Reclamation, 2013), the magnitudes of subsidence along these reaches were estimated based on detailed top-of-levee surveys performed under the direction of DWR in late 2013 and early 2014 (Tetra Tech, 2015). These top-of-levee surveys show that in the vicinity of the GCR reference locations, the amount of measured subsidence ranges from 2.7 feet in Reach 4A to about 1.5 feet in the MESB (Tetra Tech, 2015) (**Figure 6**). Subsidence elevation changes were applied to the geometry on each model cross section. Because the GCR reference elevations are associated with a relative height on the levee, subsidence of the levee geometry would result in the same subsidence of the reference elevation. Therefore, the same subsidence elevations changes were also applied to the GCR reference elevations.

3. RESULTS

Based on pre-subsidence geometry and the weirs set in the Boards Out configuration, 14 of the 18 reaches are predicted to have a capacity of at least 4,500 cfs (**Figures 7 and 8**; **Table 1**). The remaining four reaches, Reaches C, J, L, and O have capacities less than 4,500 cfs, at 3,420, 4,340, 2,690, and 1,380 cfs, respectively (Table 1). All but one of these reaches, Reach O, have the same capacity when comparing the three weir configurations. The Typical Boards configuration decreases the capacity of Reach O in the MESB from 1,380 cfs down to 1,080 cfs, and the Boards In condition further reduces the capacity to 1,070 cfs(**Figures 9 and 10**; Table 1). Reaches C, J, L, and O will not meet geotechnical criteria for levee seepage and slope stability at a maximum Restoration Flow of 4,500 cfs.

Application of the subsidence adjustments to the Boards Out configuration does not change the number of reaches that could pass 4,500 cfs (**Figures 11 and 12**; Table 1). The remaining four reaches, Reaches C, J, L, and O, have capacities of 3,290, 4,150, 2,600, and 1,070 cfs, respectively (Table 1). Similar to the pre-subsidence condition, adding boards to the wildlife refuge weirs under the post-subsidence condition only impacts the levee capacity in Reach O, with a decrease from 1,070 to 580 cfs for the Typical Boards and to essentially 0 cfs for the Boards In (**Figures 13 and 14**; Table 1). Subsidence has little effect on the results, as the same four reaches, Reach C, J, L, and O, will not meet geotechnical criteria for levee seepage and slope stability at a maximum restoration flow of 4,500 cfs.

4. REFERENCES

Bureau of Reclamation, 2013. December 2011 to December 2013 Subsidence Result Maps.

Tetra Tech, 2014. San Joaquin River and Bypass System 1-D Steady State HEC-RAS Model Documentation, Draft technical memorandum prepared for the California Dept. of Water Resources, Fresno, California, March.

Tetra Tech, 2015. Reaches 3, 4A and Middle Eastside Bypass (MESB) Subsidence and Capacity Study, Draft technical memorandum prepared for the California Dept. of Water Resources, Fresno, California, February.

URS, 2015. Geotechnical Conditions Report, San Joaquin River Restoration Program Eastside Bypass Study Area (Priority 1 Levees). Prepared for Department of Water Resources. April.

Table 1. Flow capacities at the GCR cross sections for pre- and post-subsidence adjustments under Boards In, Typical Boards, and Boards Out weir configurations.

GCR Reach[1]	GCR Station (ft)	Representative Model Cross Section	Pre-Subsidence				Post-Subsidence			
				Boards In	Typical Boards	Boards Out	GCR Selected Maximum WSE (ft) [post-subsidence]	Boards In	Typical Boards	Boards Out
			GCR Selected Maximum WSE (ft)	Flow Capacity (cfs)	Flow Capacity (cfs)	Flow Capacity (cfs)		Flow Capacity (cfs)	Flow Capacity (cfs)	Flow Capacity (cfs)
A	102000	60106	99.5	>4,500	>4,500	>4,500	99.4	>4,500	>4,500	>4,500
B	106500	64035	105.8	>4,500	>4,500	>4,500	105.5	>4,500	>4,500	>4,500
C	111000	69622	98.7	3,420	3,420	3,420	98.2	3,290	3,290	3,290
D	116400[2]	73247	101.5	>4,500	>4,500	>4,500	100.9	>4,500	>4,500	>4,500
E	136100	93015	104.5	>4,500	>4,500	>4,500	103.2	>4,500	>4,500	>4,500
F	144600	101445	104.2	>4,500	>4,500	>4,500	102.6	>4,500	>4,500	>4,500
G	152300	107371	112.7	>4,500	>4,500	>4,500	111.4	>4,500	>4,500	>4,500
H	155500	108228	110.5	>4,500	>4,500	>4,500	109.2	>4,500	>4,500	>4,500
I	157000	109849	109.9	>4,500	>4,500	>4,500	108.6	>4,500	>4,500	>4,500
J	106000	61699	96.5	4,340	4,340	4,340	96.3	4,150	4,150	4,150
K	111830	67946	100.6	>4,500	>4,500	>4,500	100.2	>4,500	>4,500	>4,500
L	116800	72501	100.2	2,690	2,690	2,690	99.6	2,600	2,600	2,600
L	124500	80459	102.4	>4,500	>4,500	>4,500	101.5	4,450	4,450	4,450
M	126500	82690	106.5	>4,500	>4,500	>4,500	105.6	>4,500	>4,500	>4,500
N	134500	90952	103.5	>4,500	>4,500	>4,500	102.3	>4,500	>4,500	>4,500
O	140500	96995	100.6	1,070	1,080	1,380	99.2	0	580	1,070
P	152500	109849	105.6	>4,500	>4,500	>4,500	104.3	>4,500	>4,500	>4,500
Q	937400	269381	111.0	>4,500	>4,500	>4,500	109.7	>4,500	>4,500	>4,500
Q	939300	271595	112.4	>4,500	>4,500	>4,500	111.1	>4,500	>4,500	>4,500
R	926300	270685	108.6	>4,500	>4,500	>4,500	107.3	>4,500	>4,500	>4,500

[1] Reaches A through I are located along the left levee of the Eastside Bypass, Reach J through P are located along the right levee of the Eastside Bypass, Reaches Q and R are located along both the left and right levees of the downstream portion of Reach 4A of the San Joaquin River.
[2] A local drawdown uncharacteristic of the reach occurs at the model cross section immediately upstream of the GCR cross section. As a result, the next upstream cross section, which is only 26 feet upstream of the GCR cross section, was used instead.

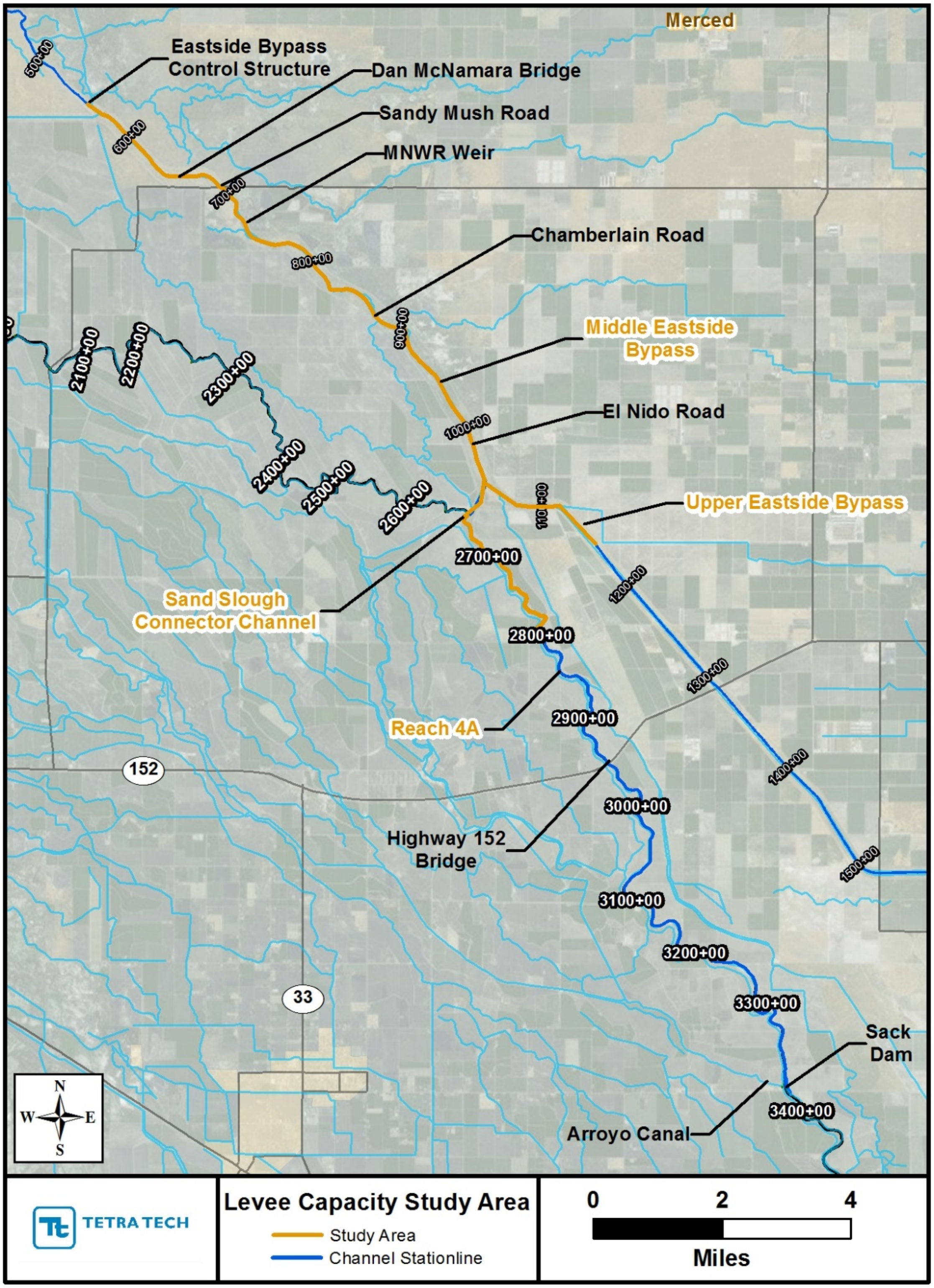

Figure 1. Site map of study area.

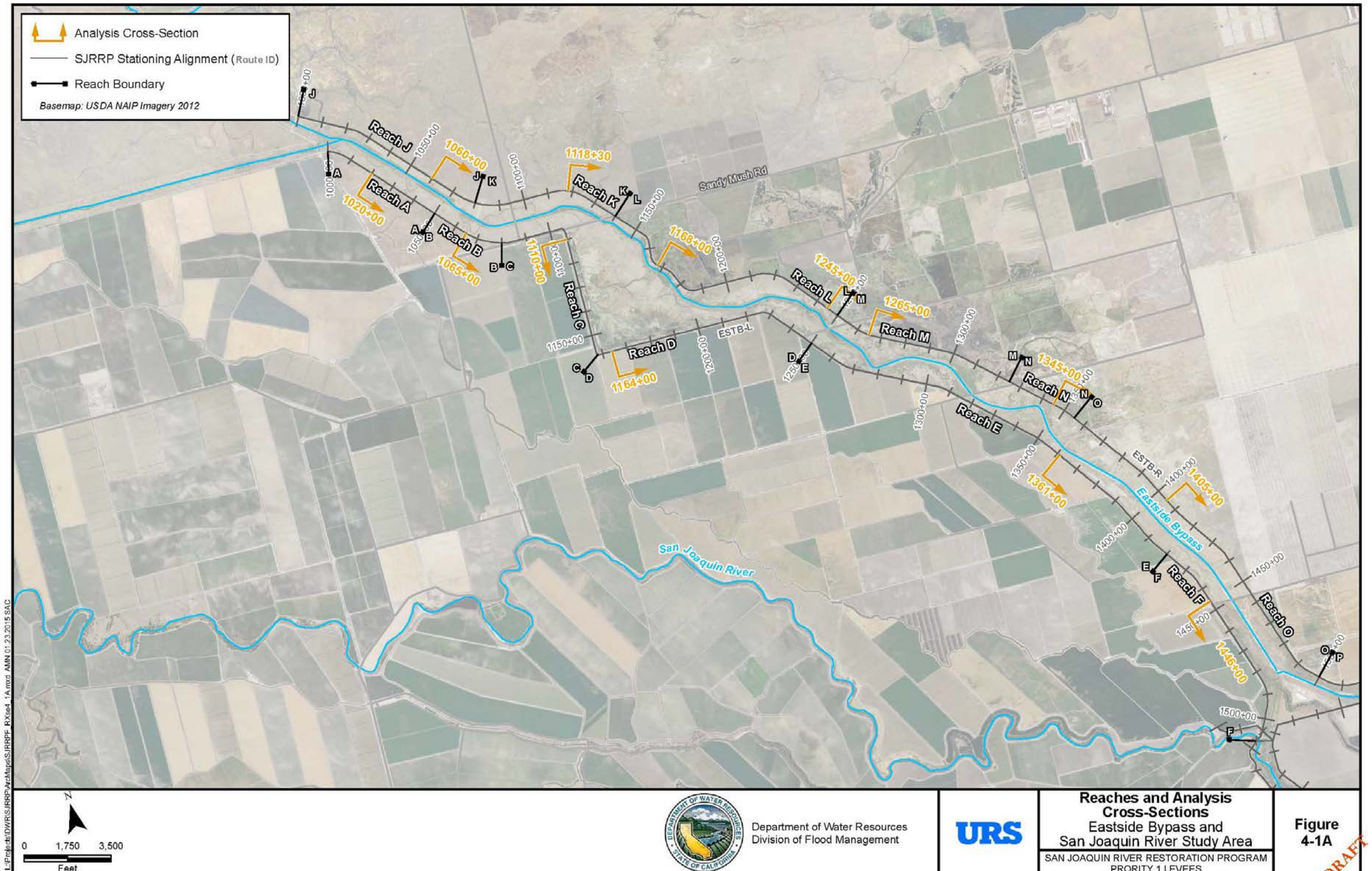

Figure 2. GCR analysis reaches and cross sections in the MESB (Figure 4-1a from URS, 2015).

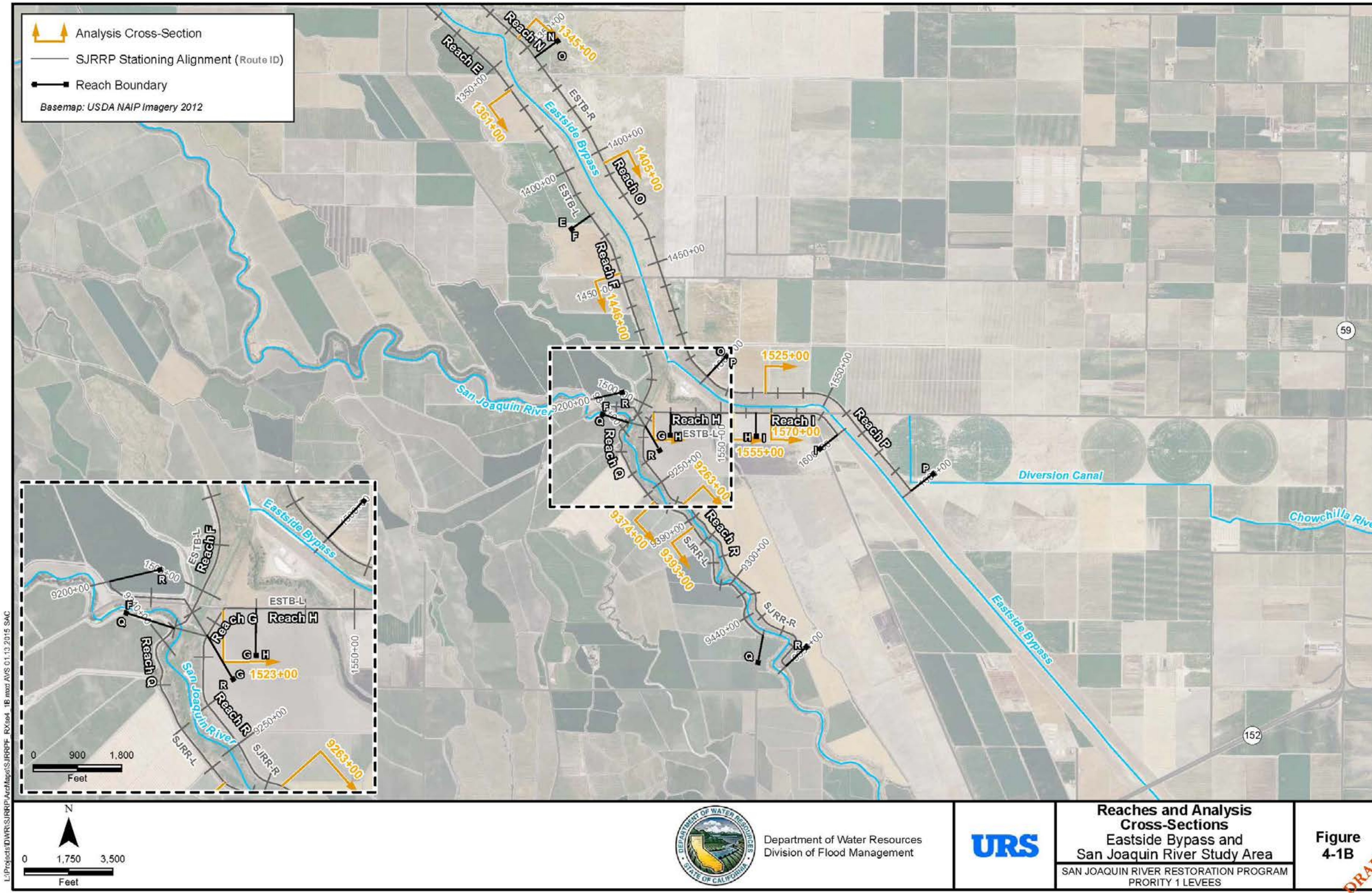

Figure 3. GCR analysis reaches and cross sections in the UESB, Connector Channel and Reach 4A (Figure 4-1b from URS, 2015).

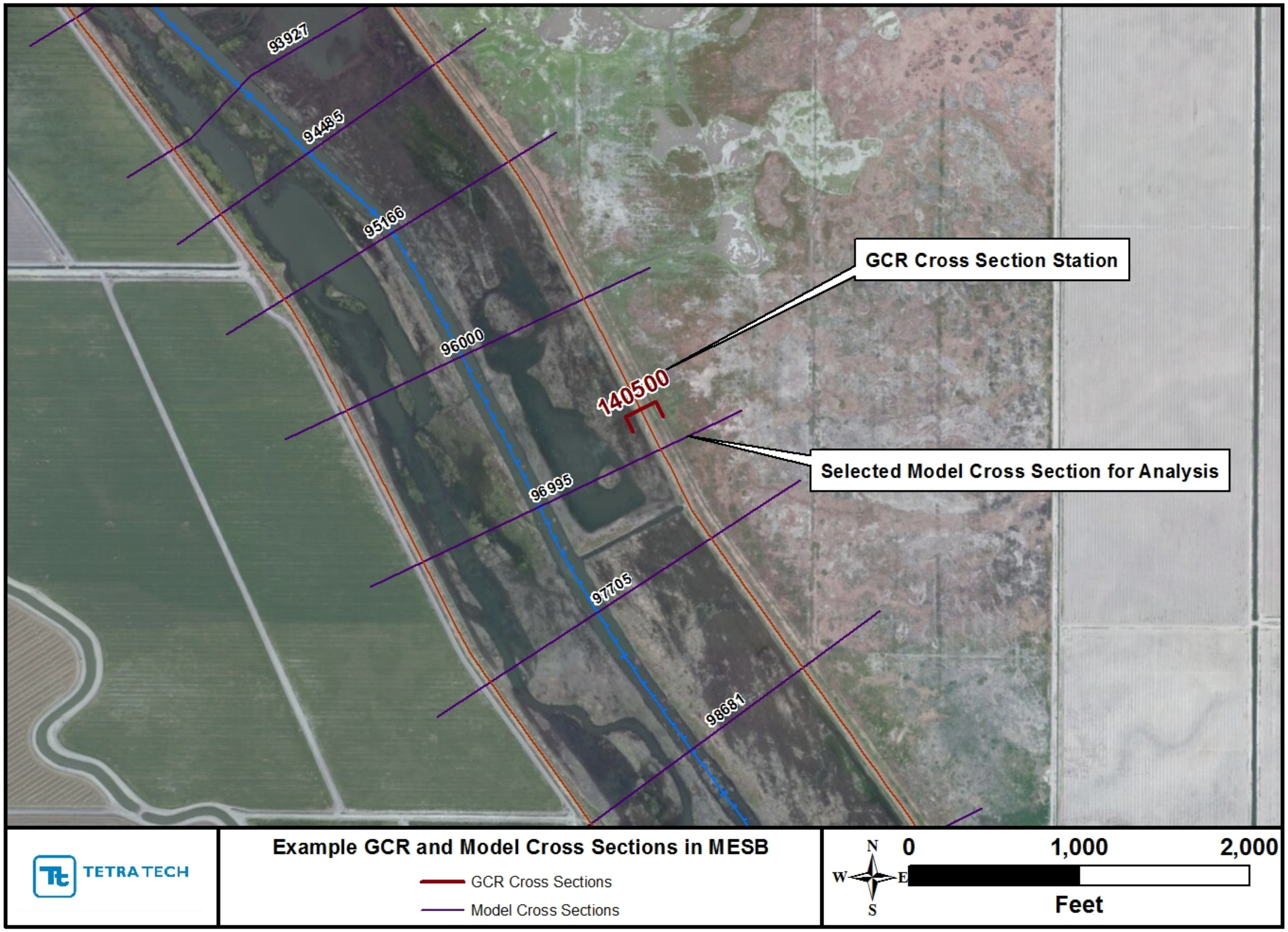

Figure 4. Planview of example GCR cross section and HEC-RAS model cross section selected for capacity calculations.

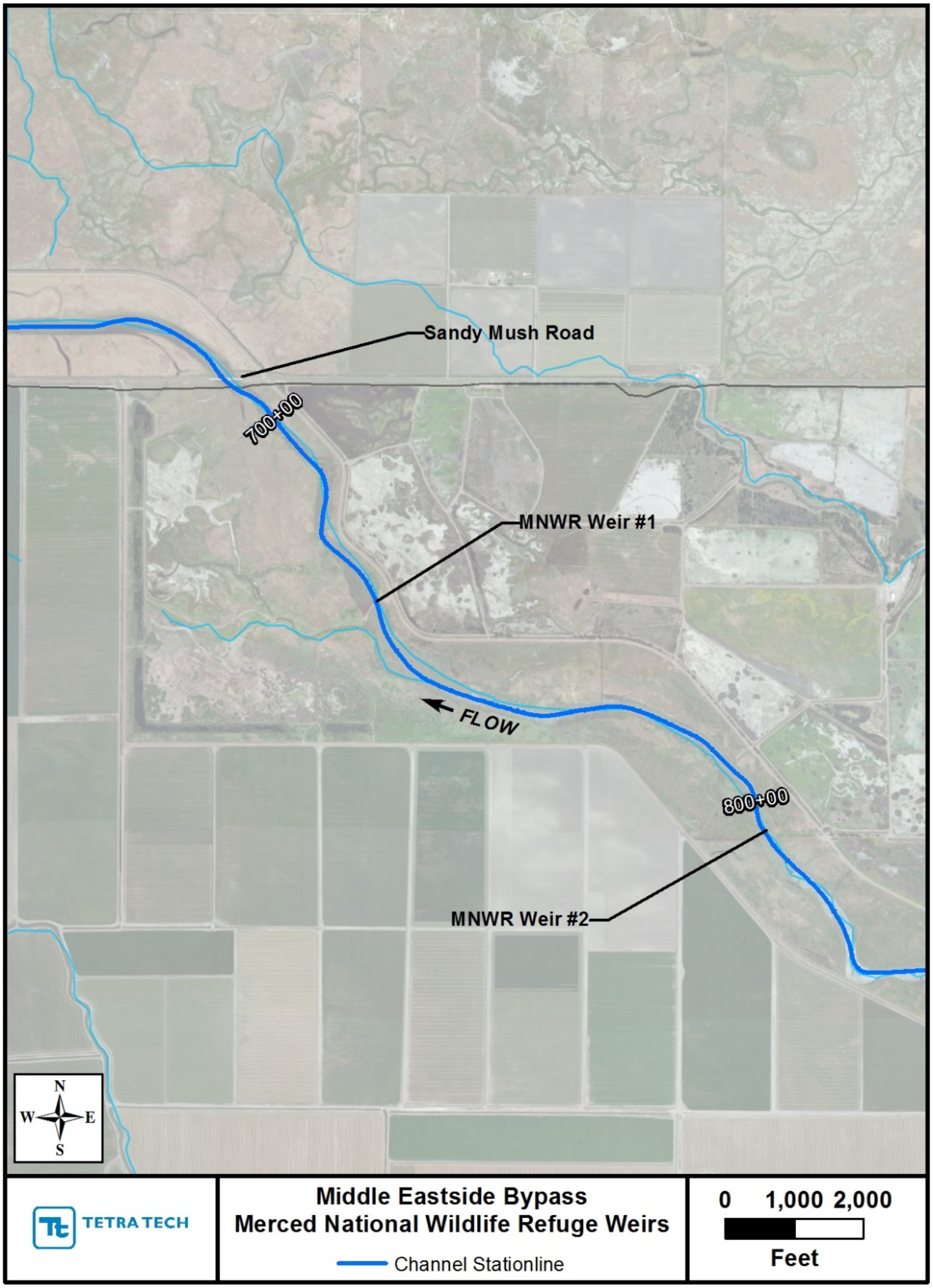

Figure 5. Location of the Merced National Wildlife weirs in the Middle Eastside Bypass.

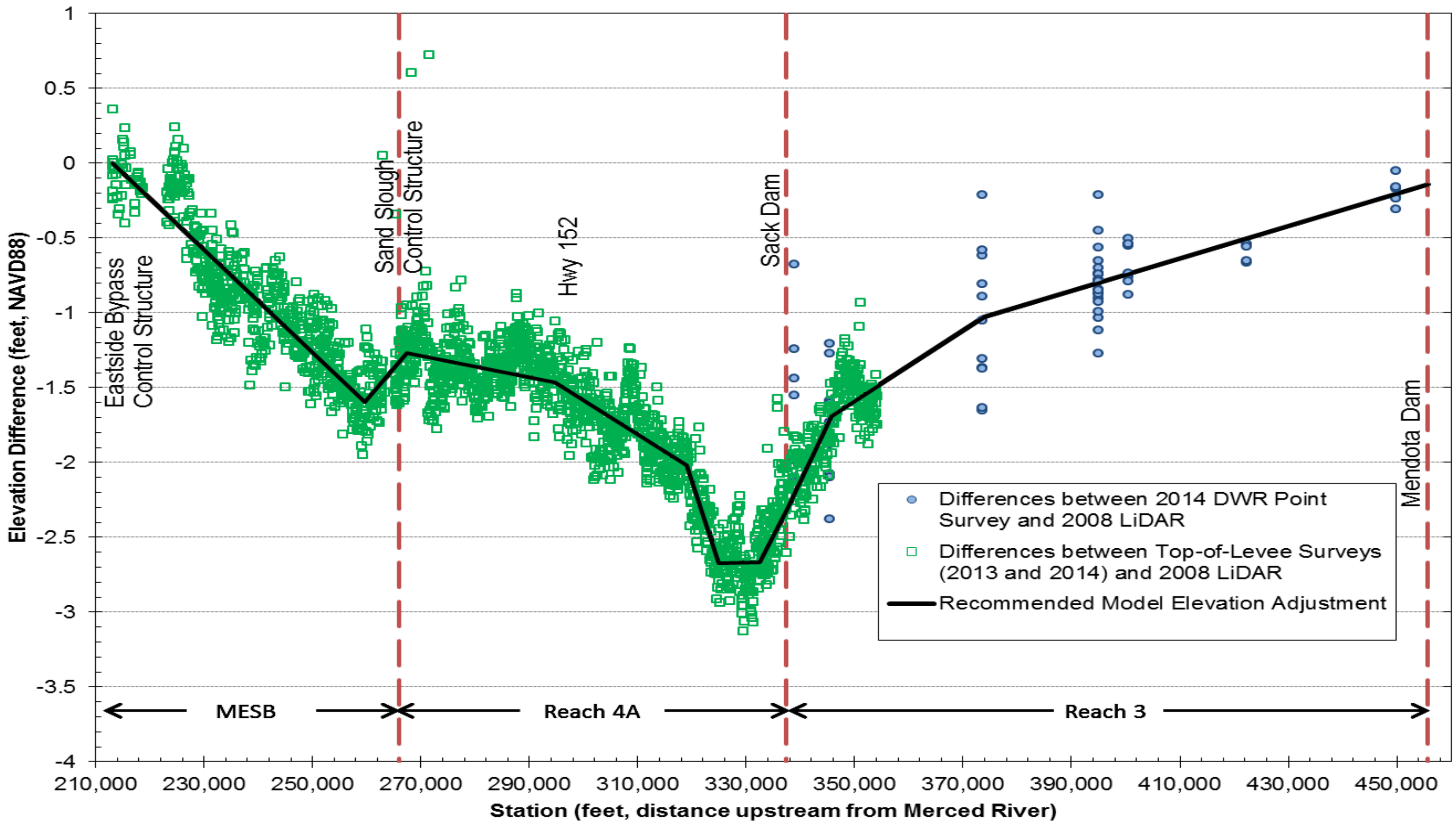

Figure 6. Differences between the 2013/2014 ground surveys and the 2008 LiDAR elevations. Negative values indicate that elevations have decreased from 2008 to 2013/2014. Note: Stationing indicated in figure is based on river stationline; thus, values along the MESB are relative to the downstream end of Reach 4A (from Tetra Tech, 2015).

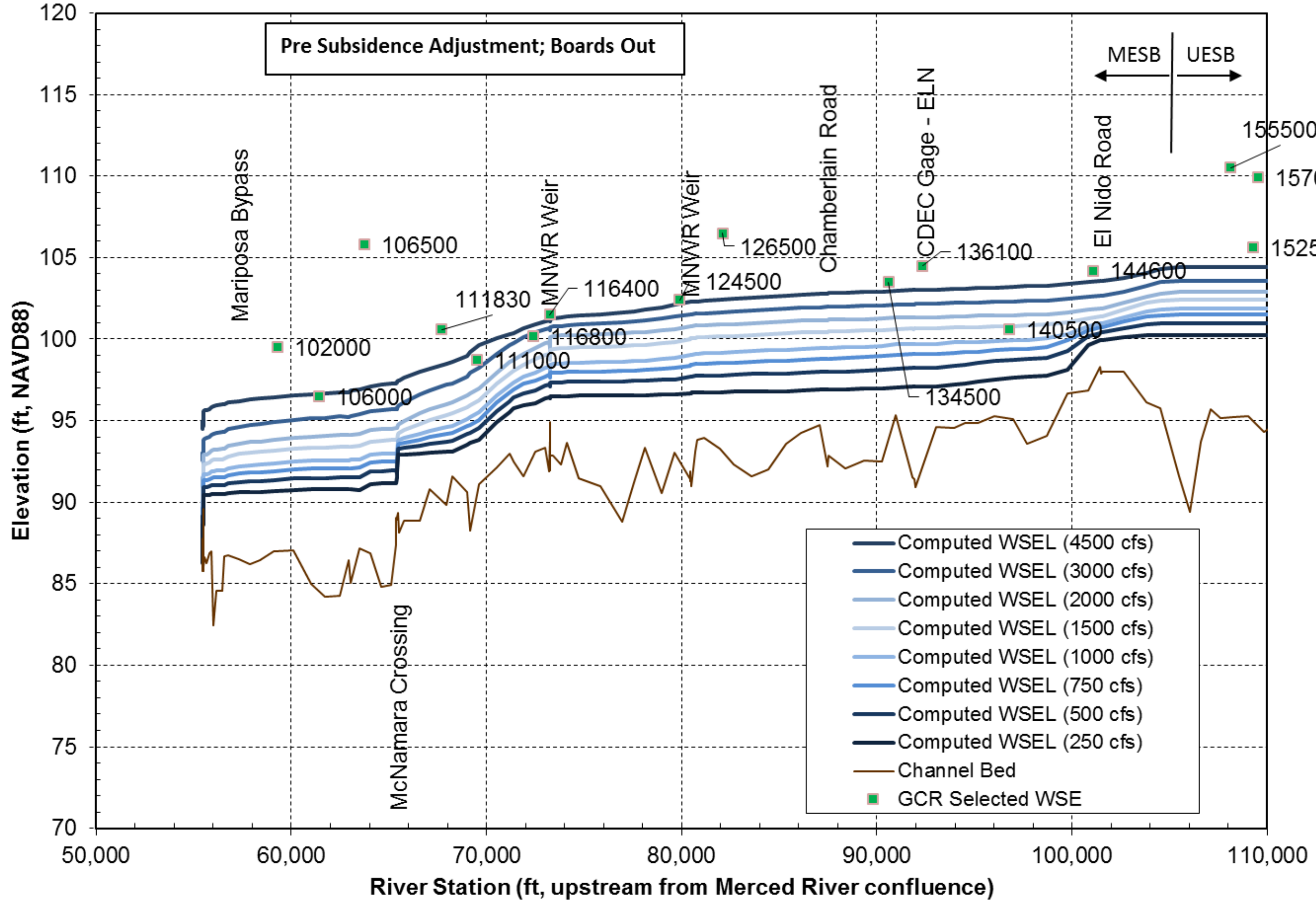

Figure 7. Computed water-surface profiles along the MESB and UESB for pre-subsidence conditions with Boards Out. Also shown are the reference points and station identifier for each of the GCR cross sections in these reaches.

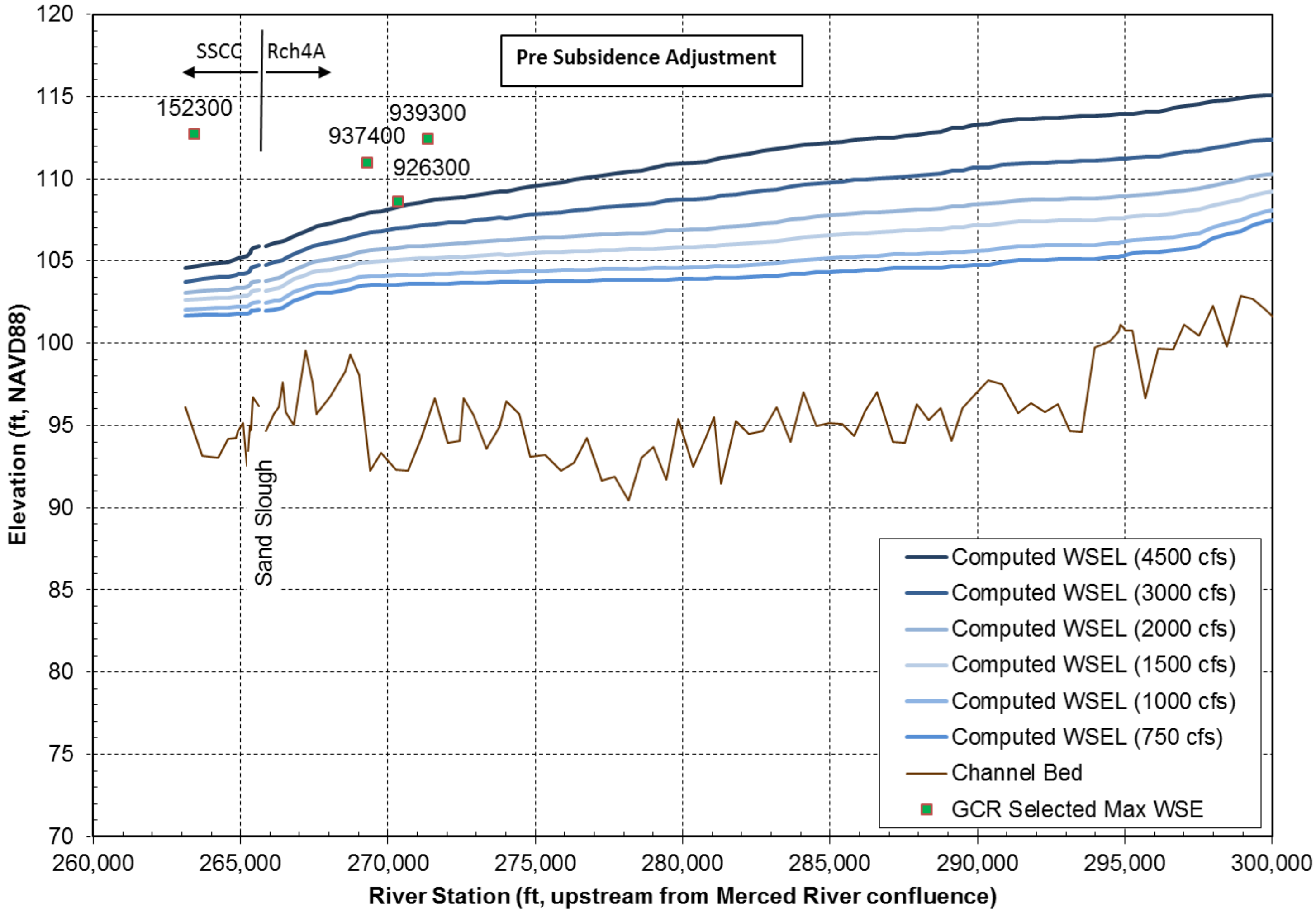

Figure 8. Computed water-surface profiles along the Sand Slough Connector Channel and Reach 4A for pre-subsidence conditions with Boards Out (flows greater than 2,500 cfs are not affected by the boards at the Merced National Wildlife weirs; and thus, do not impact capacities). Also shown are the reference points and station identifier for each of the GCR cross sections in these reaches.

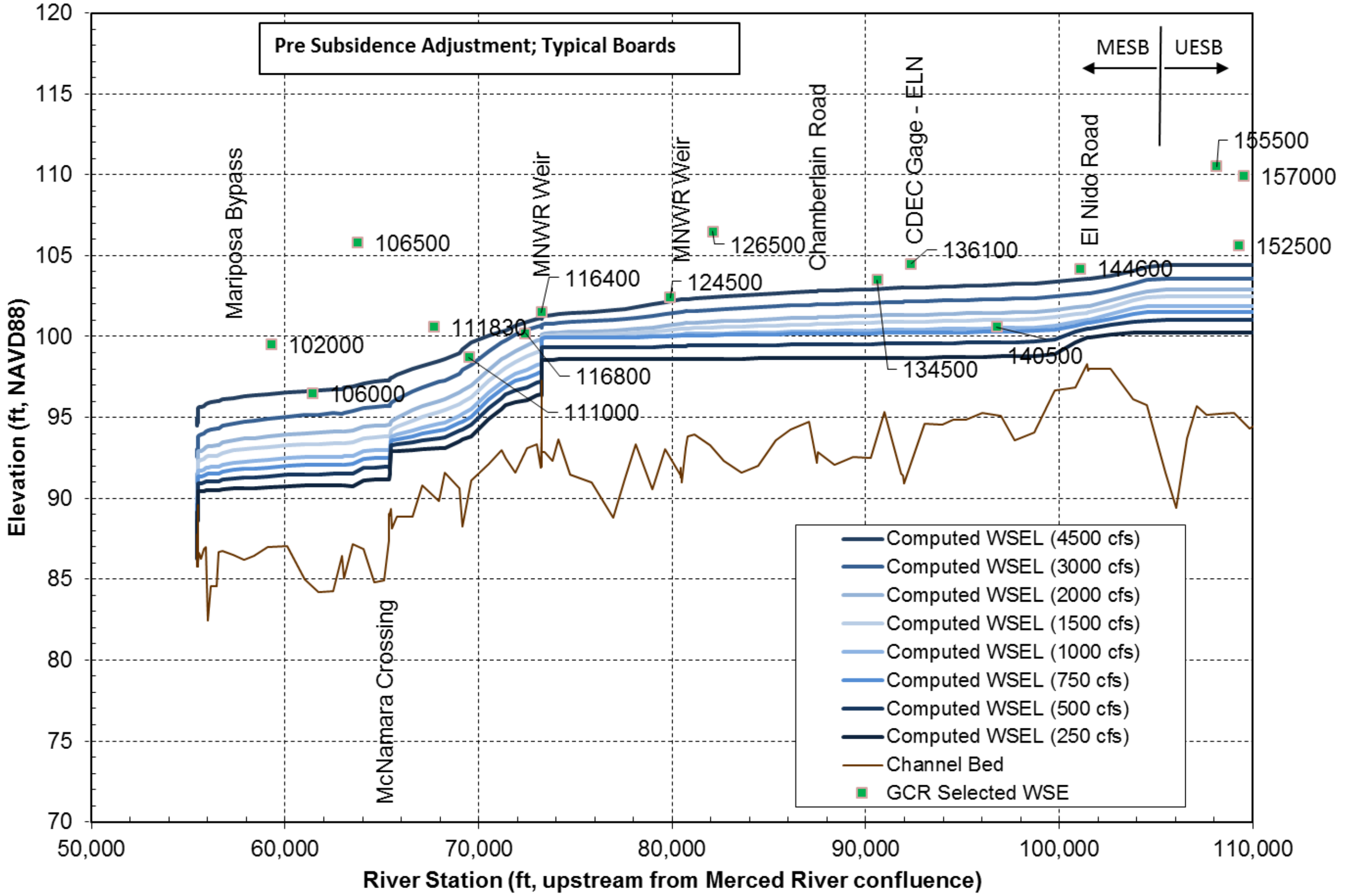

Figure 9. Computed water-surface profiles along the MESB and UESB for pre-subsidence conditions with Typical Boards. Also shown are the reference points and station identifier for each of the GCR cross sections in these reaches.

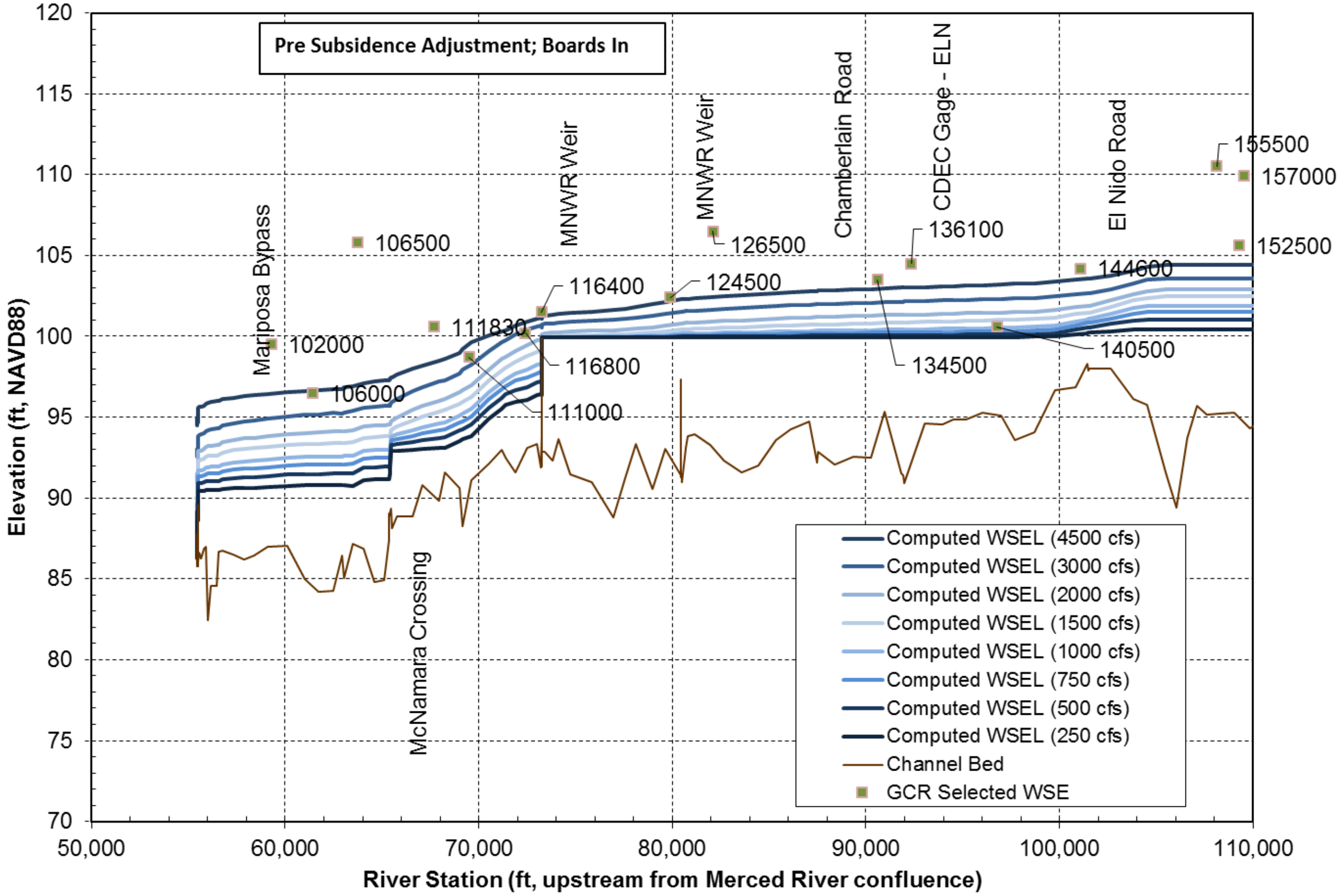

Figure 10. Computed water-surface profiles along the MESB and UESB for pre-subsidence conditions with Boards In. Also shown are the reference points and station identifier for each of the GCR cross sections in these reaches.

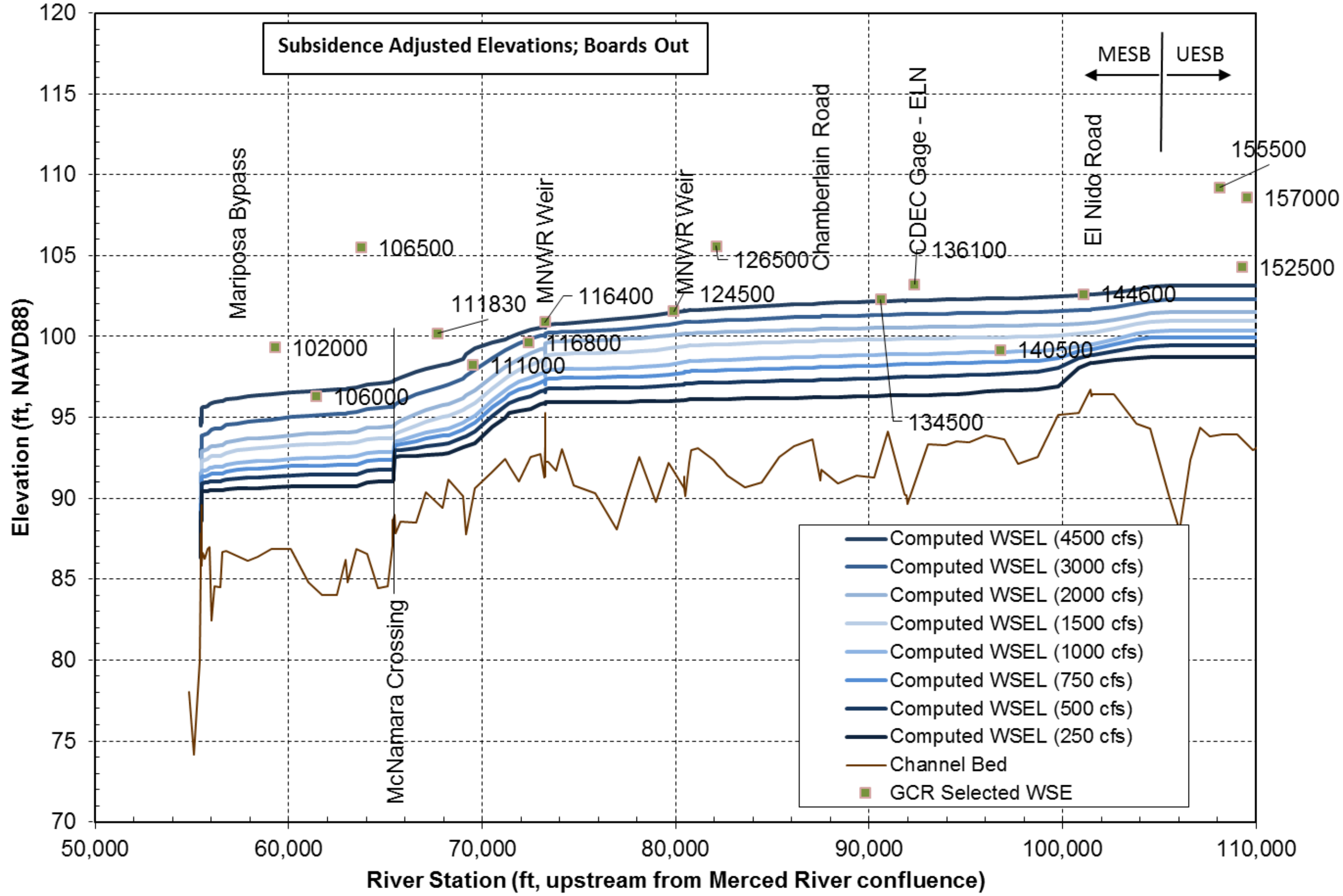

Figure 11. Computed water-surface profiles along the MESB and UESB for post-subsidence conditions with Boards Out. Also shown are the reference points and station identifier for each of the GCR cross sections in these reaches.

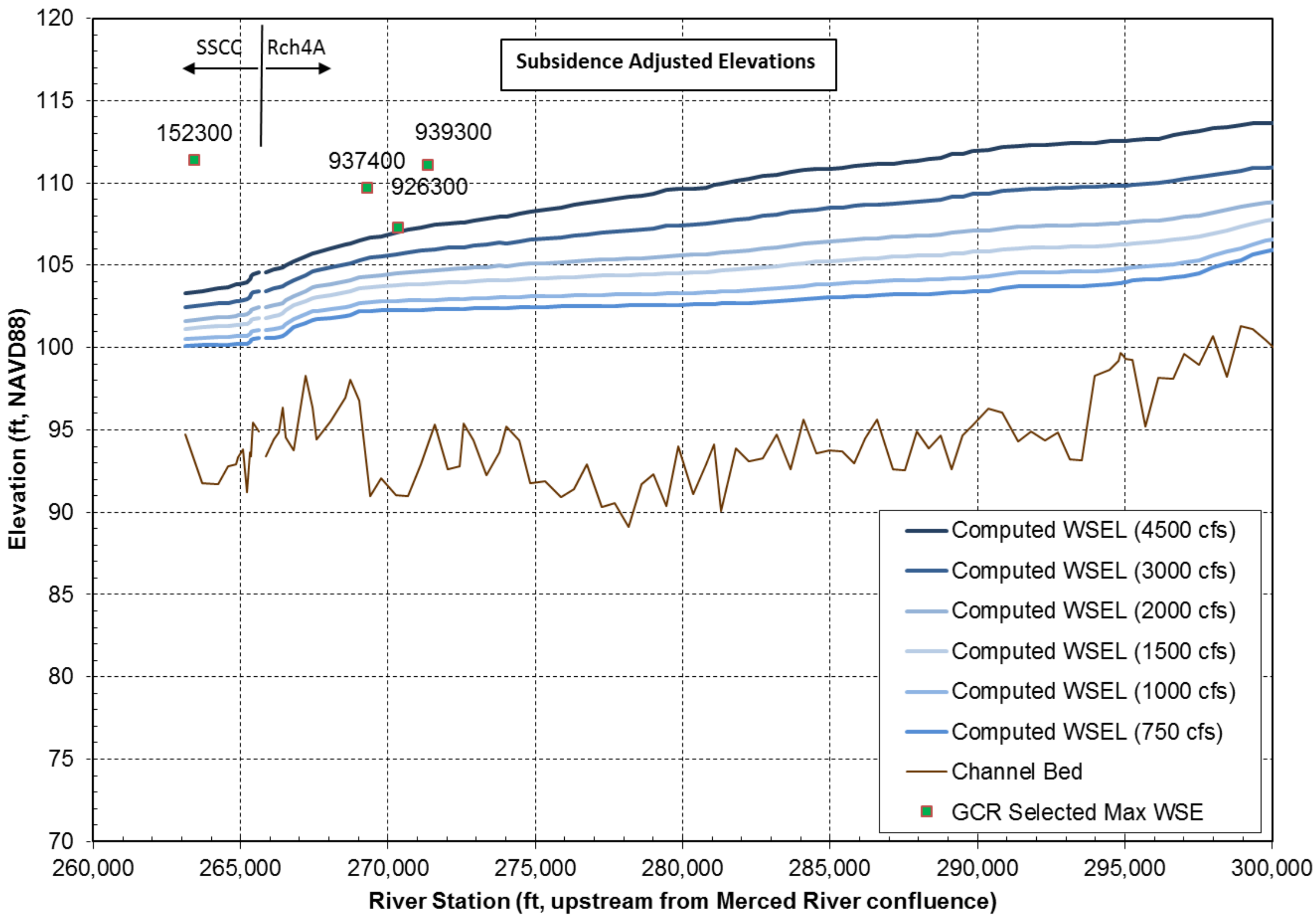

Figure 12. Computed water-surface profiles along the Sand Slough Connector Channel and Reach 4A for post-subsidence conditions with Boards Out (flows greater than 2,500 cfs are not affected by the boards at the Merced National Wildlife weirs; and thus, do not impact capacities). Also shown are the reference points and station identifier for each of the GCR cross sections in these reaches.

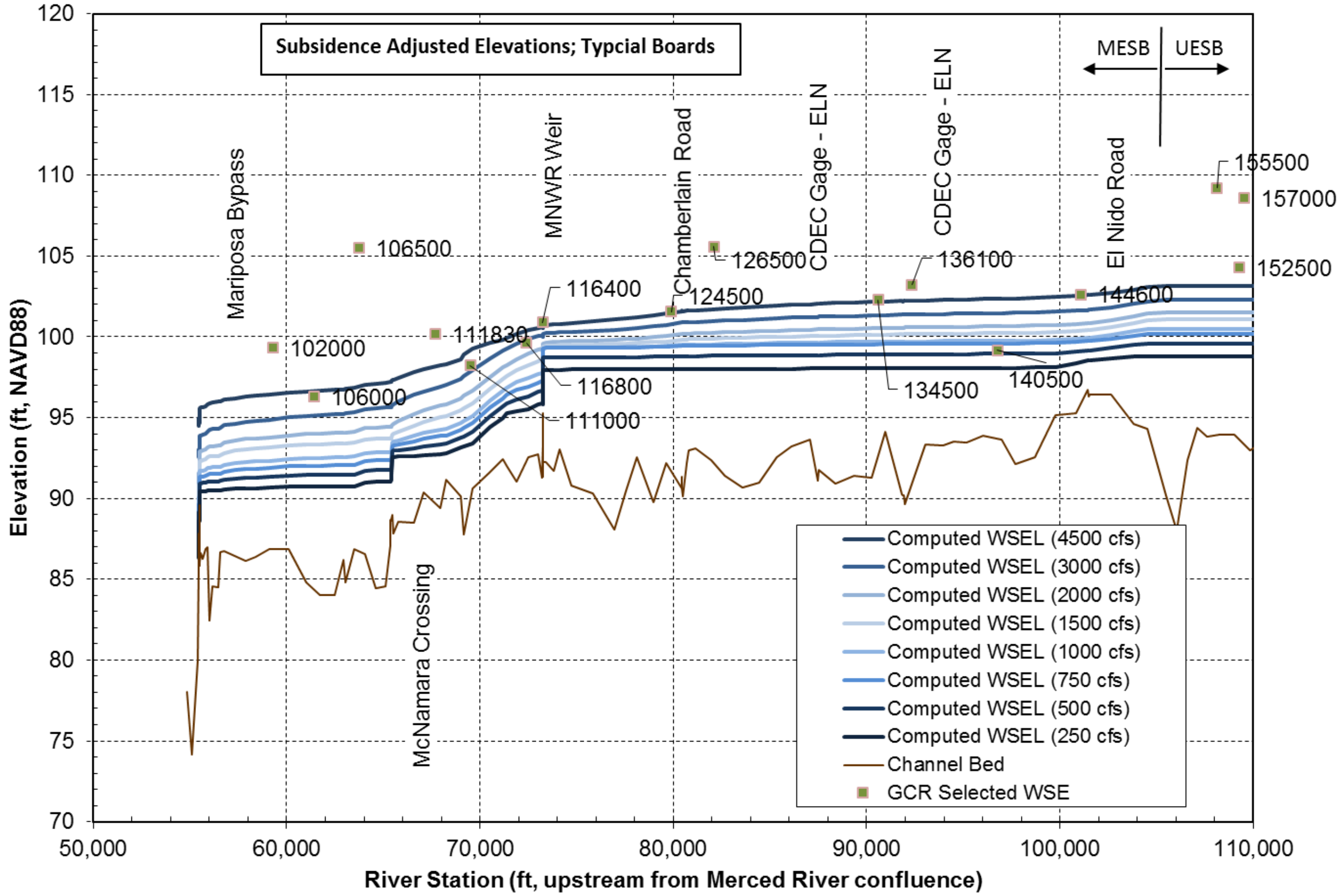

Figure 13. Computed water-surface profiles along the MESB and UESB for post-subsidence conditions with Typical Boards. Also shown are the reference points and station identifier for each of the GCR cross sections in these reaches.

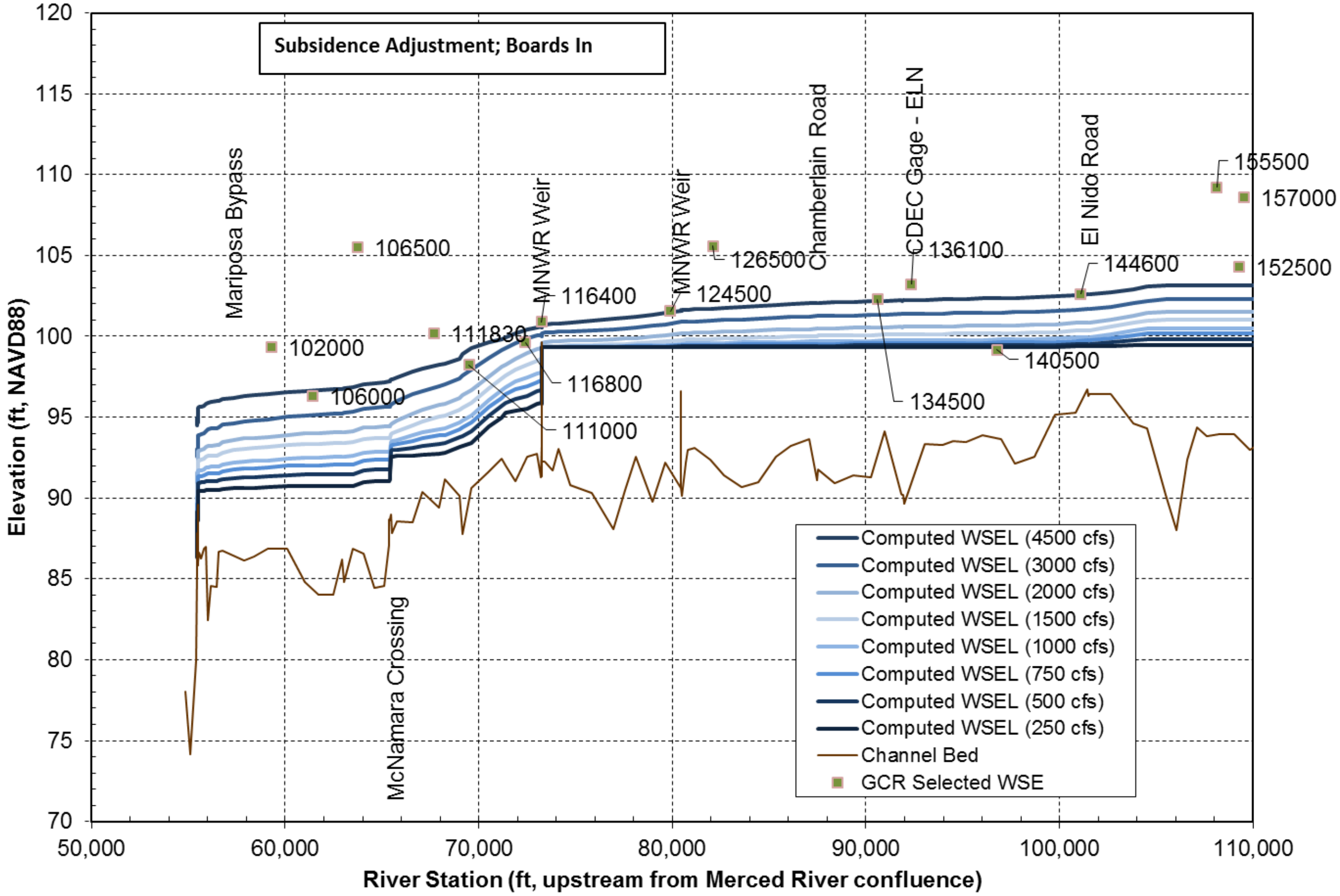

Figure 14. Computed water-surface profiles along the MESB and UESB for post-subsidence conditions with Boards In. Also shown are the reference points and station identifier for each of the GCR cross sections in these reaches.