RECLAMATION

Managing Water in the West

Technical Report No. ENV-2019-003

Hydrology, Hydraulic, and Sediment Studies for Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project

San Joaquin River Restoration Project
Mid-Pacific Region

U.S. Department of the Interior
Bureau of Reclamation

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1 Executive Summary

The San Joaquin River Restoration Program Office of Reclamation has requested the Technical Service Center analyze the hydrology, hydraulic, and sediment transport of the alternatives to implement the Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project (Reach 4B Project), a component of the San Joaquin River Restoration Program (SJRRP). The SJRRP was established in late 2006 to implement the Stipulation of Settlement (Settlement) in *Natural Resources Defense Council, et al., v. Kirk Rodgers, et al*. Initial alternatives presented in this report are considered preliminary and will be refined and evaluated further as the alternatives formulation process moves forward.

This report is an update to Reclamation (2012) and supersedes the previous report. This report contains an additional alternative labeled as "Alternative 2 – Lower Eastside Bypass" (Alternative 2 – LESB) which routes restoration flow down the Lower Eastside Bypass. It also updates all sediment transport analyses for all alternatives by including the effects of subsidence on the sediment transport, erosion and deposition.

The alternatives analyzed in this report are given in Table 1-1. Alternatives 1, 2 and 3 are described in the Project Description document (SJRRP, 2010). However, Alternative 2 – LESB is not described in the Project Description. Furthermore, Alternative 3 as described in the Project Description is broken down into Alternative 3 and 4 for the purposes of this report.

The results of the hydrology, hydraulic and sediment analyses for each alternative are summarized below.

Table 1-1. Initial Alternatives Analyzed.

Channel/ Structure	Alternative 1 Main Channel Restoration	Alternative 2 Bypass Restoration	Alternative 2 - LESB Lower Eastside Bypass Restoration	Alternative 3 Bypass All Pulse Flows	Alternative 4 Split Pulse Flows and Restore Both
San Joaquin River Flows	Up to 4,500 cfs (all Restoration Flows)	At least 475 cfs of Flood Flows	At least 475 cfs of Flood Flows	Restoration Flows up to 475 cfs	Base and fall pulse flows; some spring pulse flows
Bypass System Flows	Flows greater than 4,500 cfs	All flows up to 16,500 cfs	All flows up to 16,500 cfs	Flow greater than 475 cfs	Flow greater than Reach 4B capacity
Fish Routing	Reach 4B1 and 4B2	Middle Eastside Bypass, Mariposa Bypass, Reach 4B2	Middle and Lower Eastside Bypass	Reach 4B1, Middle Eastside Bypass, Mariposa Bypass, Reach 4B2	Reach 4B1, Middle Eastside Bypass, Mariposa Bypass, Reach 4B2
Habitat	SJR	Bypass	Bypass	SJR and Bypass	SJR and Bypass
Reach 4B Headgates	Simple Gate	Simple Gate	Simple Gate	Construct gates and roughened channel fishway	Construct gates and roughened channel fishway
Merced NWR Options for Fish Passage	None	Remove Weir	Remove Weir	Remove Weir	Remove Weir
Eastside Bypass Control Structure	No Change	Fish Passage	Notch Center Bays	Fish Passage	Fish Passage
Mariposa Bypass Control Structure	No Change	Notch Center Bays	No Change	Notch Center Bays	Notch Center Bays
Mariposa Drop Structure	No Change	Remove Drop Structure	No Change	Remove Drop Structure	Fish Passage
San Joaquin River Reach 4B1 Levee Alignments	B, C, D	A	A	A	A
Middle Eastside and Mariposa Bypass Levee Alignments	Existing	Existing or Setback	Existing or Setback	Existing	Existing
Lower Eastside Bypass Levee Alignments	Existing	Existing	Existing	Existing	Existing

1.1 Hydrology

A daily operations model for the San Joaquin River Restoration Program was developed in RiverWare, a versatile hydrologic modeling software package (Reclamation, 2012). The model simulates hydrology along the San Joaquin restoration reaches from Millerton Lake to the Merced River, and along the Chowchilla and Eastside Bypasses. Daily Friant Dam operations are modeled as well as downstream routing, losses, and operations (bifurcations, diversions, etc.). Daily inflows sum to match monthly CalSim II volumes. Monthly diversions and some downstream inflows are taken from CalSim II results, with monthly to daily flow patterning applied where appropriate. Daily Friant releases are modeled independently from the CalSim II restoration runs used for the PEIS/R, including restoration release flow schedules and flood control releases.

The daily flow model incorporates both restoration flows and flood operations. It also includes the contributions of tributaries to and diversions from the San Joaquin. The daily flow model uses a historical period of record for Water Years (WY) 1922 to 2003. A water supply forecast is used to define the Restoration Water Year Type within the model and the resulting number of each year type for the 82-yr period of record is shown in Table 6-1.

It is important to recognize that delivery of irrigation water from Friant Dam to the Mendota Pool is not incorporated into the hydrologic simulations. This is because delivery of water to the Mendota Pool is not included into the CALSIM model upon which the model is dependent.

1.1.1 No Action

The No Action alternative has Restoration flow passing through the Bypass, but Restoration Flows into the Eastside and Mariposa bypasses are currently limited to avoid channel capacity and seepage concerns. The SJRRP has addressed seepage-related concerns in the Middle Eastside Bypass and Lower Eastside Bypass, but the Restoration Flows into this reach are limited by channel capacity concerns to about 300 cfs. The other projects implemented under the No Action Alternative would provide a capacity of about 2,500 cfs. Flood flows would be routed similar to existing conditions.

1.1.2 Alternative 1

This alternative will restore a capacity of 4500 cfs to Reach 4B1. Two flow conditions were analyzed:

1. All flows less than 4500 cfs routed into Reach 4B1.

2. Only restoration flows routed into Reach 4B1, meaning that flood flows would be routed down the Eastside Bypass.

Under the first flow condition, the median flow in Reach 4B1 would be 155 cfs, the 10% exceedance flow is 1,820 cfs and the 90 % exceedance flow is 45 cfs..

The 95% exceedance flow in Reach 4B1 is zero, so there would be times during Critical Dry and Critical High years when there is no flow in Reach 4B1. The capacity of Reach 4A is also 4500 cfs, and therefore most all the flow from the San Joaquin River in Reach 4A enters Reach 4B1 and the Sand Slough Bypass reach connecting Reach 4A to the Eastside Bypass has essentially no flow.

There would be less flow in the Bypass under Alternative 1 than under any of the other alternatives. Currently, the Middle Eastside Bypass is estimated to have flow approximately 35 % of the time, whereas under Alternative 1, and flow condition 1, the bypass would have flow approximately 15 % of the time. There would be many more years where the Bypass is dry under Alternative 1 than under the other alternatives. The Sand Slough Bypass Channel would not have any significant flow and would become essentially standing water separating the moving waters in the Bypass and San Joaquin River. It would be possible to remove the Sand Slough Bypass Channel and still maintain existing flood capacity.

Under the second flow condition, flood flows would be routed into the Middle Eastside Bypass, however, the operation of the flow control structure at the head of Reach 4B1 could be become complex if separation of restoration and flood flows is attempted.

1.1.3 Alternative 2

Under Alternative 2, Reach 4B1 would receive flow only when the capacity of the Eastside Bypass is exceeded, which was simulated to be 0.05 % of the time. This would equate to 17 days of the 82 years of simulation. Therefore, it is possible that Reach 4B1 would never have flowing water except from groundwater flow because it would be difficult to ensure flow capacity if it is rarely utilized. Reach 4B1 would likely become overgrown with vegetation such as it is currently.

The bypass has flow of 45 cfs or more 90% of the time under Alternative 2. The 75% exceedance flow is 65 cfs, the 50% exceedance flow is 175 cfs, the 25% exceedance flow is 355 cfs, and the 10% exceedance flow is 2000 cfs. The bypass would have zero flow less than 10% of the time.

Flow enters the Eastside Bypass from the Chowchilla Bypass in approximately 20% of the years, corresponding to wet years. If the James Bypass is contributing water to the San Joaquin, then flow is limited in Reach 2B because of capacity limitations in Reach 3. Therefore, the water in the Bypass during the spring runoff during a wet year would be a mixture of the San Joaquin and James Bypass/Fresno Slough system.

1.1.4 Alternative 3

The Bypass would have flow approximately 25% of the time, which is less than under existing conditions. However, the 10% exceedance flow increased from 1,100 cfs under existing conditions to 1,500 cfs under Alternative 3. The 1% exceedance decreases from 9,200 cfs to 7,800 cfs. Therefore, the midrange spring runoff pulse may increase in magnitude, but the largest flows in the Bypass should decrease in frequency.

In the San Joaquin River, the 75% exceedance flow is 65 cfs, the 50% exceedance flow is 155 cfs, the 25% exceedance flow is 285 cfs, and the 10% exceedance flow is 475 cfs, which is the maximum flow allowed in Reach 4B1.

1.1.5 Alternative 4

Restoration flow larger than 1500 cfs would be routed into the Bypass. This would occur in Normal and Wet years, which comprised approximately 80% of the years in the historical record.

The Bypass would have flow approximately 20% of the time, which is less than under existing conditions. In addition, the 10% exceedance flow decreases in the Bypass from 1,100 cfs under existing conditions to 670 cfs under Alternative 4. The 1% exceedance decreases from 9,200 cfs to 6,774 cfs.

In the San Joaquin River the 75% exceedance flow is 65 cfs, the 50% exceedance flow is 155 cfs, the 25% exceedance flow is 285 cfs, and the 10% exceedance flow is 1500 cfs, which is the maximum flow in the reach.

1.2 Hydraulics

Both one-dimensional (1D) and two-dimensional (2D) hydraulic models were used to analyze the hydraulics in the river and bypasses under each alternative. HEC-RAS was used as the 1D model and SRH-2D was used as the 2D model.

1.2.1 No Action

Under the No Action alternative, the flood capacity in the Middle Eastside Bypass initially remains the same as existing conditions. However, active subsidence is occurring in this region and the flood capacity in the upper portion of the Middle Eastside Bypass will continue to decrease. The freeboard at the design flow in the upper Middle Eastside Bypass is expected to decrease up to 3 ft in 25 years.

1.2.2 Alternative 1

Under Alternative 1, the overall flood capacity of the San Joaquin system including the Bypass and San Joaquin River in the Project Reach is increased by 4500 cfs because of the addition of Reach 4B1 to the flood conveyance. The flood capacity of the Eastside Bypass itself would not be significantly altered because no significant additional vegetation growth is expected in the Bypass under this alternative.

Three different levee options are considered for Alternative 1: Option B, C, and D. Option B levees are typically 1300 to 2000 ft apart, Options C levees are 3500 to 5500 ft apart, and Option D levees are 5000 to 11000 ft apart. Levee Option A is not considered feasible for Alternative 1 because the water depth is over 15 feet for a flow of 4500 cfs and the levees would become unreasonably high and at high risk of erosion because of the high velocities against the levees.

The levees for Option B, C, and D would be designed to convey 4500 cfs including the effects of increased vegetation roughness, sediment deposition and subsidence.

1.2.3 Alternative 2

An approximately 50-ft wide channel would be excavated within the existing 150-ft wide low flow channel of the Middle Eastside Bypass. The MNWR weir would be removed and the road crossings would be elevated to pass at least 4500 cfs. The several bays of the Mariposa Control structure would also be lowered so that it did not impede fish passage and sediment could be sluiced through the structure.

A levee setback is considered in the Middle Eastside and Mariposa Bypasses. The setback alignment in the Middle Eastside Bypass is referred to as the Merced National Wildlife Refuge (MNWR) alignment. The levee setback is intended to encompass the Lone Tree Unit of that refuge.

With baseflow established in the bypass under Alternative 2, a significant amount of riparian vegetation would establish. Vegetation growth may be limited because of soil conditions, but the intention of the revegetation plan is to establish a band of woody riparian species adjacent the low flow channel and spaced throughout the floodplain. To estimate the future roughness conditions in the bypass, the values of roughness were taken from those calibrated in Reach 4B2 (Reclamation, 2012b).

In the Middle Eastside Bypass, if the vegetation approaches the high roughness values, the water surface increases more than 2.5 ft upstream of El Nido Road. If the Middle Eastside Bypass levee along the North side is setback according to the NMWR alignment, then the water surface at the design flow is increased less than 0.5 ft even for the high roughness case except for upstream of El Nido Road, where there is no levee setback.

In the Mariposa Bypass, the high roughness increases the water surface elevations for the design flow by less than 1 ft because the Alternative 2 design calls for the removal of the grade control structure on the downstream end of the reach. If there is a setback of the Mariposa Bypass levee by 500 ft, then the water surface elevation under the high roughness is less than the current condition.

1.2.4 Alternative 2 - LESB

The designed flood capacity of the Lower Eastside Bypass increases from 12,000 cfs downstream of the control structure to 13,500 cfs downstream of Owens Creek, to 18,500 cfs downstream of Bear Creek. The computed water surface elevation at the design flow is shown in Figure 7-19 for the current roughness condition and with a medium roughness assumption and with a high roughness assumption. The results from HEC-RAS under current conditions are also shown for comparison purposes.

Under the medium roughness assumption, the water surface increases approximately 1.25 ft at the design flow. Under the high roughness assumption, the water surface increases approximately 2.5 ft. As mentioned in the previous section, a medium roughness assumption is believed to be most appropriate for the Lower Eastside Bypass under Alternative 2-LESB condition.

1.2.5 Alternative 3

For Alternative 3, a base flow up to 475 cfs is restored to Reach 4B1 and there is no continuous base flow to the Eastside Bypass. Therefore, there would be little additional vegetation growth expected in the bypasses and no significant reduction in the capacity of the Eastside Bypass relative to the No Action Alternative.

There would have to be some improvement of road crossings and levees to contain the 475 cfs in 4B1. The hydraulic calculations are used in the design of these levees.

1.2.6 Alternative 4

For Alternative 4, a base flow up to 1500 cfs is restored to Reach 4B1 there is no continuous base flow to the Eastside Bypass. Therefore, there would be little additional vegetation growth expected in the bypasses and no significant reduction in the capacity of the Eastside Bypass relative to the No Action Alternative.

There would have to be some improvement of road crossings and levees to contain the 1500 cfs in Reach 4B1. The HEC-RAS hydraulic calculations are used in the design of these levees

1.3 Fish Habitat

SRH-2D was used to compute the depth and velocity for a range of steady flows within each reach of the Reach 4B project area. The total inundated area was computed as well as the weighted hydraulically suitable habitat area using habitat suitability indices (HSI).

For Alternative 1, the area are computed as the sum of the reaches 4B1 and 4B2. For Alternative 2, the areas are the sum of Middle Eastside Bypass, Mariposa Bypass and Reach 4B2. For Alternative 2-LESB, the areas are the sum of Middle Eastside Bypass and Lower Eastside Bypass. For Alternative 3 and 4, only the results from Reaches 4B1 and 4B2 are included. The maximum flow in Reach 4B1 in Alternative 3 is assumed to be 475 cfs and the maximum flow in Reach 4B1 under Alternative 4 is assumed to be 1500 cfs.

The total hydraulically suitable habitat is given in Figure 1-1. Alternative 1 has the largest area of available habitat of all alternatives for flows that occur under restoration releases. Alternative 2, where restoration flows are routed into the Middle Eastside and Mariposa Bypass then into Reach 4B2, has significantly more available habitat than Alternative 2 – LESB, where restoration flows are routed into the Middle Eastside and Lower Eastside Bypass. This is because there is significantly more inundated habitat in Reach 4B2 than the Lower Eastside Bypass. For example, the total weighted habitat area available in the LESB at a flow of 2200 cfs is only 54 acres, whereas it is 286 acres in Reach 4B2.

The hydraulically suitable fish habitat for the No Action alternative will be qualitative similar to Alternative 2-LESB with No Levee Setback because Restoration flows are routed down the same path. Similar to Alternative 2-LESB, the No Action alternative includes removal of the fish weir in the Merced National Wildlife Refuge. However, the No Action alternative will have slightly higher suitable habitat values because it does not include channel grading to increase the slope of the MESB and, therefore, the water surface elevations are higher resulting in more inundation in the MESB.The setback of the Middle Eastside Bypass and Mariposa increases the available habitat at high flows. For Alternative 2 – LESB, the setback is only in the Middle Eastside and no setbacks are considered for the Lower Eastside.

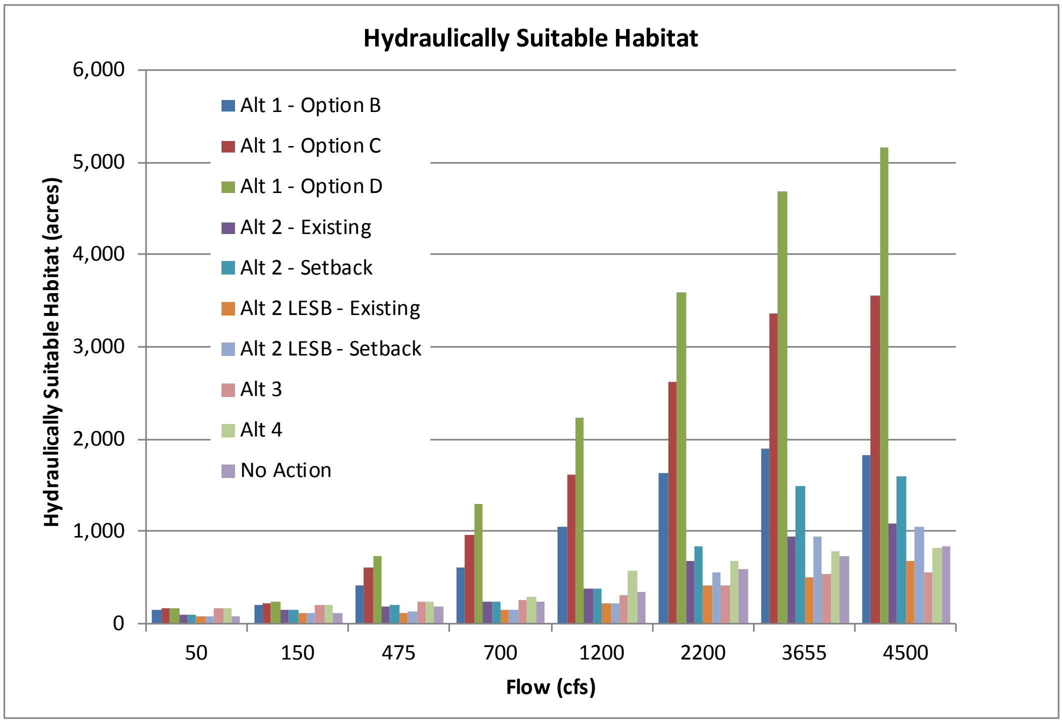

Figure 1-1. Hydraulically Suitable Area for Juvenile Salmon.

1.4 Sediment Transport

SRH-1D V4.0 was used to simulate the erosion and deposition under the alternative conditions. It is a one-dimensional cross section based model that simulates the hydraulics, sediment transport, and bed geometry of natural rivers. The input daily average flows were taken from the daily flow model described in Section Future Hydrology. A 50-yr simulation was performed in which the period from WY 1954 through 2003 was used.

A reach was simulated only if it is intended to convey restoration flows. The Mariposa Reach was not simulated under existing conditions because of uncertainties about how the flows are split during current operations and because the reach is controlled by concrete structures on the upstream and downstream ends. Levee Options B and C were simulated for Alternative 1. Levee Option D was not simulated because the 1D model could not accurately model the extensive side channel network that exists under that option. No levee setback alternatives were simulated for Alternative 2 and 2-LESB and it is assumed that the major sediment conclusions for the Alternative 2 are also valid for the levee setback options.

Reach 4B1 and the Eastside Bypass were divided into sub-reaches based upon hydraulic controls within the reach and changes in the bed slope.

1.4.1 No Action

Deposition is expected to continue in the upper portion of the MESB under the No Action alternative. The majority of the sand-sized sediment that enters the MESB from upstream deposits in the first subreach of the MESB. Because of the deposition in the subreach MESB-1, there is lack of sediment supply resulting in erosion in the reaches downstream of this.

Assuming 25 years of future subsidence, the freeboard will reduce approximately 1 ft in the MESB downstream of Chamberlain Road. The decrease in freeboard will be up to 3 ft upstream of El Nido Rd. Because of the subsidence and deposition in MESB-1, seepage impacts will occur when there is any water present in the river because the water surface is above the root zone at all flows.

1.4.2 Alternative 1

Alternative 1 increases the capacity of Reach 4B1 to 4500 cfs and passes most all restoration flow into Reach 4B1. The Bypass system is not used to convey restoration flow. Only levee options B and C were simulated.

Deposition will occur in the first two sub-reaches 4B1-1 and 2. Erosion is likely downstream of these reaches because of the reduction of sediment supply to the lower reaches. The same qualitative sediment behavior is expected for levee options B and C, with slightly more deposition occurring within the first two sub-reaches under Option C than B.

The erosion in the lower reaches of Reach 4B1 and the relatively small depths in 4B1, create a condition where the future subsidence causes relatively small decreases in the levee freeboard after 25 years.

1.4.3 Alternative 2

Deposition of sediment in the Middle Eastside Bypass under Alternative 2 may be less than under No Action for two reasons:

1. The flood releases are less frequent under Project conditions

2. The regrading of the Bypass, elimination of the MNWR weir, and lowering of the Mariposa Bypass increases the channel velocities for restorations flows and increase the overall transport capacity of the reach.

However, deposition in the MESB-1 will still occur, especially if subsidence continues and levees will need to include extra freeboard to accommodate this accumulation of sediment. It is estimated that the freeboard will reduce approximately 1 ft in the MESB downstream of Chamberlain Road. The freeboard will decrease up to 2.5 ft upstream of El Nido Rd.

1.4.4 Alternative 2-LESB

In the MESB, the results for Alternative 2-LESB are similar to those for Alternative 2. However, slightly less deposition occurs in MESB-1 under Alternative 2-LESB than for Alternative 2.

The LESB shows evidence of historical and active incision and this is expected to continue under Alternative 2-LESB. The incision will occur throughout the entire LESB and further decrease the connection between the low flow channel and the floodplain. The incision may also cause increase in bank erosion and there is the potential that significant bank armoring is necessary to protect existing levees.

1.4.5 Alternative 3

The maximum flow entering Reach 4B1 under Alternative 3 is 475 cfs. Because of the limited flow range supplied to the reach, the reach is expected to function like an earthen canal and a simple channel would likely form in this reach with minimal in-channel complexity.

The first two sub-reaches of Reach 4B1 will be depositional and it will be difficult to maintain a low flow channel because of the lack of high flows that would scour the channel and prevent the channel from becoming overgrown with vegetation.

1.4.6 Alternative 4

The first two subreaches of 4B1 are still depositional under Alternative 4, however, significantly more sediment makes it through these upper reaches. In addition, significantly more erosion occurs in the lower subreaches of 4B1 because of the narrow levee alignment that constrains the flow and increases the channel velocities.

Because the maximum flow is 1500 cfs, the peak flow in most years will be 1500 cfs. The lack of flow diversity and narrow levee alignment will likely cause a simplified floodplain to form to contain this flow. The more variable flows under

Alternative 1, with a maximum flow of 4500 cfs and wider levee alignments would create and maintain a more diverse set of side and overflow channels.

2 Introduction

The San Joaquin River Restoration Program Office of Reclamation has requested the Technical Service Center analyze the hydrology, hydraulic, and sediment transport of the alternatives to implement the Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project (Reach 4B Project), a component of the San Joaquin River Restoration Program (SJRRP). The SJRRP was established in late 2006 to implement the Stipulation of Settlement (Settlement) in *Natural Resources Defense Council, et al., v. Kirk Rodgers, et al*. Initial alternatives presented in this report are considered preliminary and will be refined and evaluated further as the alternatives formulation process moves forward.

The location of the Reach 4B project is given in Figure 2-1. Reach 4B1 is located between Reach 4A and Reach 4B2. At the upstream end of Reach 4B1, the Sand Slough Bypass channel conveys water to the Eastside Bypass. The Mariposa Bypass allows some flows to reenter the San Joaquin downstream of Reach 4B1 and all bypass flows reenter the San Joaquin at the downstream end of Reach 4B2. The Eastside Bypass is separated into three reaches (Upper, Middle and Lower). These reaches will be referenced as UESB, MESB, and LESB, respectively.

This report is an update to Reclamation (2012) and all results in this report supersede the previous report. This report contains an additional alternative labeled as “Alternative 2 – Lower Eastside Bypass” (Alternative 2 – LESB). It also updates all sediment transport analyses for all alternatives by including the effects of subsidence on the sediment transport, erosion and deposition.

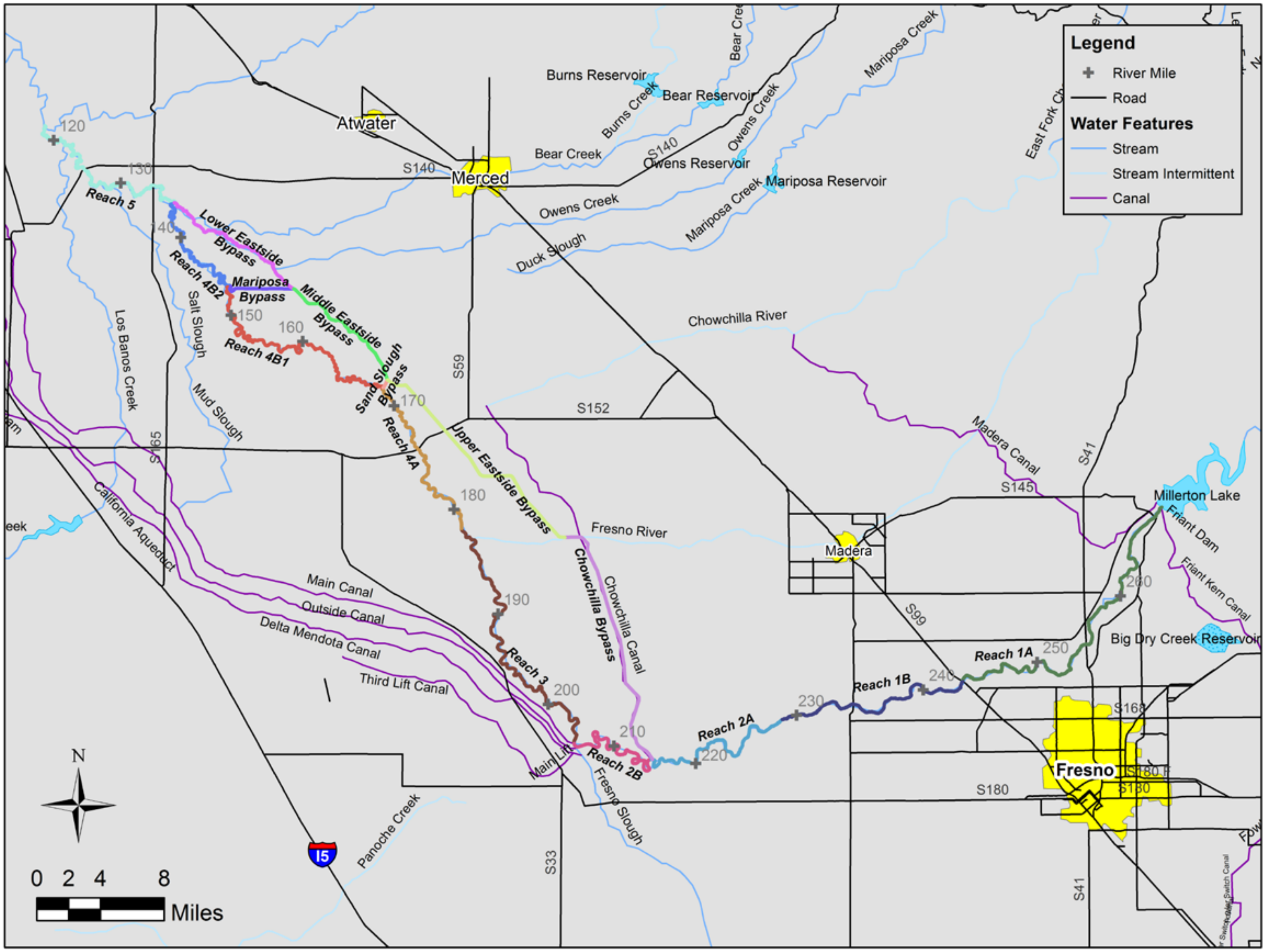

Figure 2-1. Project Overview Map for Reach 4B Project.

3 Existing Hydrology

3.1 Flood Control

The flood management system greatly influences the hydrology in the Project Reach. The levees within the Restoration Reach are shown in Figure 3-1. The design and "future operating" capacities of the flood bypass system as stated in the Project Operations and Maintenance Manual (Reclamation Board, 1985) are given in Figure 3-2. The "future operating capacity" and are not necessarily what the actual capacity of the levee is currently or what was actually designed, as will be discussed in the hydraulic analysis sections of this report. The assumed design capacities of the levees for the purposes of this report are given in Table 3-1.

The information in this section was largely taken from the Programmatic Environmental Impact Statement (PEIS) Section 11.1.3 (SJRRP, 2011).

There are two classes of levees and dikes along the San Joaquin River study area: (1) those associated with the San Joaquin River Flood Control Project (project levees), and (2) those constructed by individual landowners to protect site-specific properties, and thus not associated with the San Joaquin River Flood Control Project (non-project levees).

The San Joaquin River Flood Control Project consists of a parallel conveyance system: (1) a leveed bypass system on the east side of the San Joaquin Valley, and (2) a leveed flow conveyance system in the San Joaquin River. The mainstem San Joaquin River levee system within the study area is composed of approximately 192 miles of project levees and various non-project levees located upstream from the Merced River confluence. Project levees are levees constructed as part of the San Joaquin River Flood Control Project by U.S. Army Corps of Engineers (USACE), and occur in Reach 2A downstream from Gravelly Ford and extend downstream to the Chowchilla Bypass Bifurcation Structure. A small section of project levees extends into reach 4A upstream of Sand Slough. They begin again in Reaches 4B and 5 at the Mariposa Bypass confluence downstream to the Merced River confluence.

The State constructed a bypass system consisting of levees and channel improvements. These improvements were coordinated with the Federal Government to ensure the effectiveness of the Federal portion of the projects. The bypass system consists primarily of man-made channels (Eastside, Chowchilla, and Mariposa bypasses), which divert and carry flood flows from the San Joaquin River at Gravelly Ford, along with inflows from other eastside tributaries, downstream to the mainstem just upstream of the Merced River. The system consists of about 193 miles of new levees, several control structures, and other appurtenant facilities, and about 80 miles of surfacing on existing levees. Construction of the original State system was initiated in 1959 and completed in 1966. Operations and maintenance (O&M) of the completed State upstream bypass features of the project are accomplished by the Lower San Joaquin Levee District.

Design capacity was authorized as the amount of water that can pass through a given reach with a levee freeboard of 3 feet within the historical San Joaquin River and 4 feet of freeboard along the bypasses, except along the left side (looking downstream) of the Eastside Bypass, which has 3 feet of design freeboard. Project design channel capacity was probably estimated to be similar to flows that produced little or no significant damage during the planning, design, construction, and initial operation phases of water resource facilities in the San Joaquin River system. However, over time, river stages in various reaches of the river have increased, and flood, seepage, and erosion damages have increased.

Non-project levees are typically associated with levees and dikes constructed by early flood control districts and adjacent landowners between the Chowchilla Bypass Bifurcation Structure and the Mariposa Bypass confluence. Canal embankments bordering both sides of the San Joaquin River between the Mendota Dam and approximately two miles upstream of the Sand Slough Control Structure effectively form a set of non-project levees that have significantly reduced the width of the floodplain, primarily on the east side of the river. The existing channel capacity in this reach is approximately 4,500 cfs, but flows of this magnitude can cause seepage and levee stability problems. In addition, local landowners have constructed other low-elevation berms within the reach creating a narrower floodplain. Information on dimensions of estimated channel capacities for locally constructed levees are difficult to obtain and, in some cases, currently unavailable.

The Eastside Bypass extends from the confluence of the Fresno River and the Chowchilla Bypass to its confluence with the San Joaquin River at the head of San Joaquin River Reach 5. The Eastside Bypass is subdivided into three reaches (Upper, Middle and Lower). The Upper Eastside Bypass gradually increases in design channel capacity from 10,000 cfs to 17,000 cfs as it receives flows from the Fresno River, Berenda Slough, and Ash Slough, and ends at the downstream end of the Sand Slough Bypass, where it intercepts flows from the Chowchilla River. The Middle Eastside Bypass, with a design channel capacity of 16,500 cfs, extends from the Sand Slough Bypass confluence to the Mariposa Bypass Bifurcation Structure at the head of the Mariposa Bypass and the Eastside Bypass Control Structure. The Lower Eastside Bypass, with a design channel capacity of 12,000 cfs at the Eastside Bypass Control Structure, and a design channel capacity of 18,500 cfs at its confluence with Bear Creek, extends from the Eastside Bypass Control Structure to the head of the San Joaquin River Reach 5, and receives flows from Deadman, Owens, and Bear Creeks. The gated Eastside Bypass Control Structure works in coordination with the Mariposa Bypass Bifurcation Structure to direct flows to either the Lower Eastside Bypass or to the Mariposa Bypass. The Lower Eastside Bypass ultimately joins with Bear Creek to return flows to the San Joaquin River.

The Mariposa Bypass Bifurcation Structure controls the proportion of flood flows that continue down the Eastside Bypass or leave through the Mariposa Bypass back into the San Joaquin River Reach 4B. The Mariposa Bypass delivers flow back into the San Joaquin River from the Eastside Bypass at the head of Reach 4B2. Of 14 bays on the Mariposa Bypass Bifurcation Structure, eight are gated. The stated operating rule for the Mariposa Bypass is to divert all flows to the San Joaquin River when flows in the Eastside Bypass above the Mariposa Bypass are less than 8,500 cfs, with flows greater than 8,500 cfs remaining in the Eastside Bypass, eventually discharging back into the San Joaquin River at the Bear Creek Confluence at the end of San Joaquin River Reach 4B (SJRRP, 2011). However, actual operations have deviated from this rule, flows of up to 2,000 cfs to 3,000 cfs have historically remained in the Eastside Bypass, and approximately one-quarter to one-third of the additional flows are released to the Mariposa Bypass (McBain and Trush, 2002). Flood flows not diverted to the San Joaquin River via the Mariposa Bypass continue down the Eastside Bypass and are returned to the San Joaquin River via Bravel Slough and Bear Creek. Bravel Slough reenters the San Joaquin River at mile post 136 and is the ending point of the bypass system.

The Sand Slough Control Structure, located in the short connection between the San Joaquin River at mile post 168.5 and the Eastside Bypass between Eastside Bypass reaches 1 and 2, is an uncontrolled weir working in coordination with the San Joaquin River Headgates to control the flow split between the mainstem San Joaquin River and the Eastside Bypass. The Sand Slough Control Structure diverts flows from the San Joaquin River to the Eastside Bypass, and the San Joaquin River Headgates allow flows from San Joaquin River Reach 4A into Reach 4B. While there are no documented operating rules for the San Joaquin River Headgate structure during low flows, the headgates have not been opened for several decades.

3.2 Stream Gage Analysis

Several stream gages are operating in the San Joaquin Basin and a map of those near the Project Reach are given in Figure 3-3. The period of record of data collection at each stream gage is given in Table 3-2.

The flow duration curve for the stream gage at the upper end of Reach 4A (San Joaquin near Dos Palos) and at the upstream end of the Eastside Bypass (El Nido) are given in Figure 3-4. The upper end of Reach 4A has a flow less than 10 cfs the majority of the time. A flow of 10 cfs generally will infiltrate into the groundwater and not make it to the lower end of Reach 4A. The El Nido Gage has a flow of 10 cfs or less 70 % of the time.

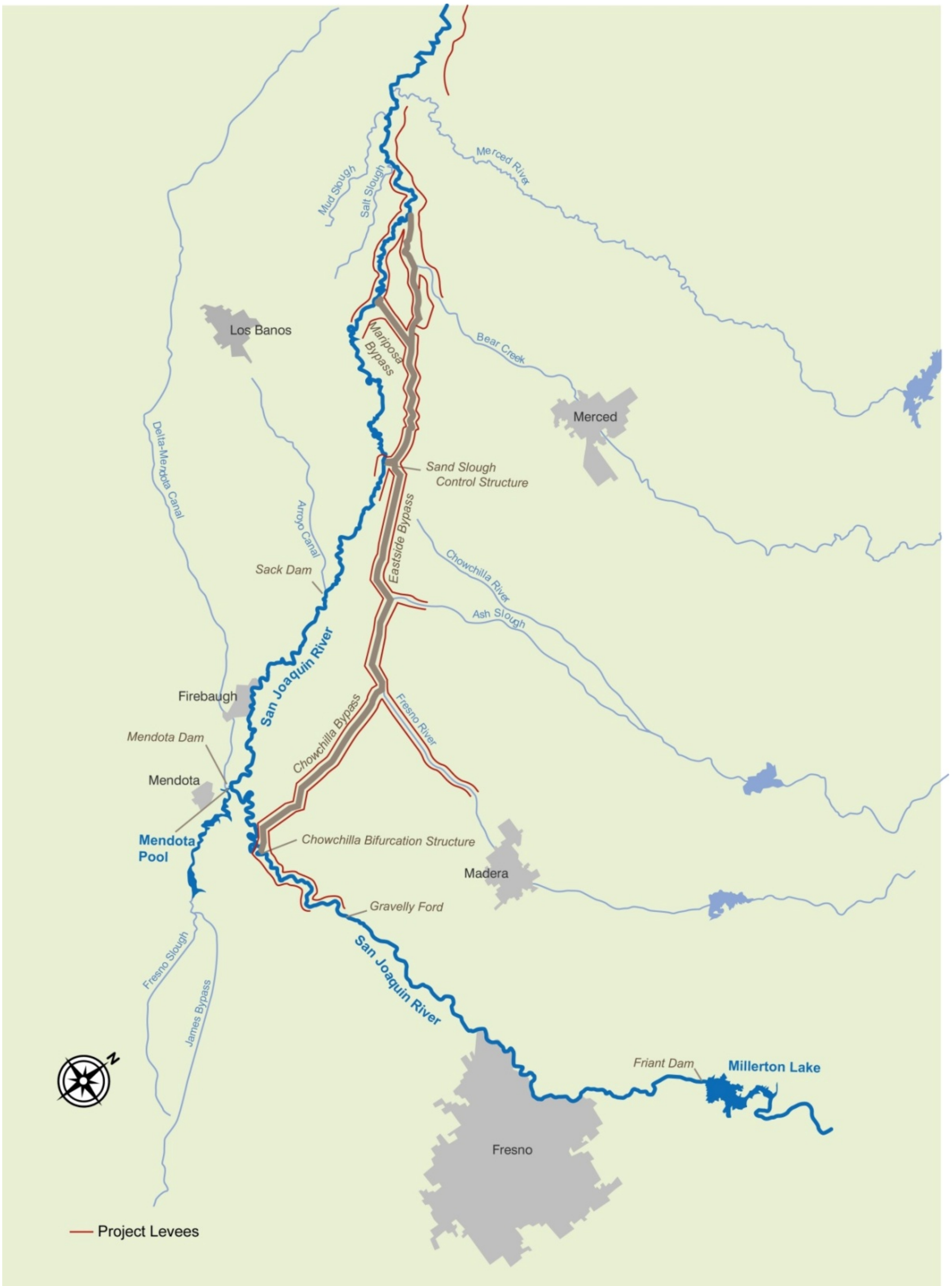

Figure 3-1. Project Levees along the San Joaquin River and flood bypass system from Friant Dam to the Merced River Confluence (Figure 11-2 from PEIS, 2009).

Table 3-1. Assumed Design Capacities of San Joaquin River and Bypasses with Restoration Area for purposes of the Reach 4B project (Table 11-1 from PEIS, 2009).

River	Reach	Upstream Extent	Downstream Extent	Levee Type	Design Capacity (cfs)
San Joaquin	Reach 1A	Friant Dam	State Route 99	None	8,000
	Reach 1B	State Route 99	Gravelly Ford	None	8,000
	Reach 2A	Gravelly Ford	Chowchilla Bypass Bifurcation Structure	Project	8,000
	Reach 2B	Chowchilla Bypass Bifurcation Structure	Mendota Dam	Non-project	2,500
	Reach 3	Mendota Dam	Sack Dam	Non-project	4,500
	Reach 4A	Sack Dam	Sand Slough Control Structure	Non-project	4,500
	Reach 4B1	Sand Slough Control Structure	Confluence with Mariposa Bypass	Non-project	1,500
	Reach 4B2	Confluence with Mariposa Bypass	Confluence with Bear Creek and Eastside Bypass	Project	10,000
	Reach 5	Confluence with Bear Creek and Eastside Bypass	Confluence with Merced River	Project	26,000
Chowchilla Bypass		Chowchilla Bypass Bifurcation Structure	Confluence with Fresno River and Eastside Bypass	Project	5,500
Eastside Bypass	All Reaches	Confluence with Fresno River and Chowchilla Bypass	Confluence with Bear Creek and San Joaquin River	Project	10,000-18,500
	Reach 1	Fresno River	Sand Slough Bypass	Project	10,000 - 17,000
	Reach 2	Sand Slough Bypass	Mariposa Bypass Bifurcation Structure/Eastside Bypass Bifurcation Structure	Project	16,500
	Reach 3	Mariposa Bypass Bifurcation Structure/Eastside Bypass Bifurcation Structure	Head of Reach 5	Project	12,000-18,500
Sand Slough Bypass		Sand Slough Control Structure	Eastside Bypass	Project	3,000
Mariposa Bypass		Mariposa Bypass Bifurcation Structure	Confluence with San Joaquin River	Project	8,500
Kings River North		Fresno Slough Bypass	Mendota Pool	Non-project	4,750
Sand Slough Bypass		Sand Slough Control Structure	Eastside Bypass	Project	3,000

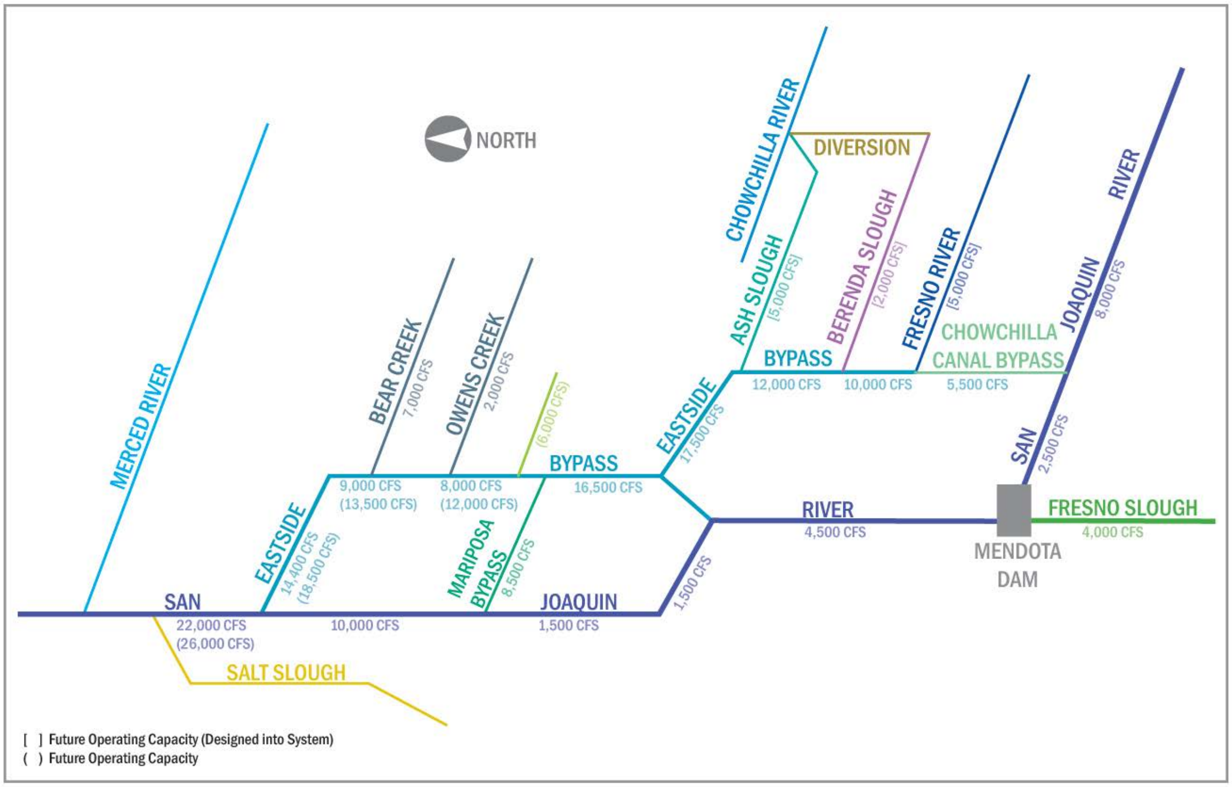

Figure 3-2. Design Capacity of Flood Control System. Figure adapted from Reclamation Board (1985).

Table 3-2. Stream gages used in historical flow analysis.

Description	Stream Gage ID	River Post (RP)	Agency	Period of Record
San Joaquin River Below Friant Dam	MIL	267.5	USBR	1944 – Present
Donny Bridge	H41	255	USBR	1989 - Present
Highway 145 Bridge (Skaggs Bridge)	SKB	234	USBR	1988 – Present
San Joaquin River near Gravelly Ford	GRF	227.5	USBR	1974 - Present
Chowchilla Bypass downstream of Chowchilla Bifurcation Structure	CBP	N/A	DWR	1974 – Present
San Joaquin River downstream of Chowchilla Bifurcation Structure	SJB	216	USBR	1986 - Present
San Joaquin River near Mendota	MEN	202	USGS	1940-1954
			USBR	1974 – 1997 2000-present
San Joaquin River near Dos Palos	11256000	181	USGS	1941-1954
			USBR	1974-1987, 1995
	SDP		DWR	2010 - Present
San Joaquin River near Washington Rd	SWA	N/A	DWR	2010-Present
San Joaquin River near El Nido	11260000	N/A	USGS	1940-1949
Eastside Bypass near El Nido	ELN	N/A	DWR	1980 - present
Mariposa Bypass near Crane Ranch	N/A	N/A	DWR	1981-1994
Eastside Bypass below Mariposa Bypass	EBM	N/A	DWR	1980 - present
Bear Creek below Eastside Canal	BBE	N/A	DWR	1980 - present
San Joaquin River near Stevinson	SJS	133	DWR	1981 - present
Salt Slough at HW 165 near Stevinson	11261100	N/A	USGS	1986 - 1994, 1996- present
			DWR	1980 - present
San Joaquin River at Fremont Ford Bridge	11261500	125	USGS	1937 - 1989
Mud Slough near Gustine	11262900	N/A	USGS	1986 - present
Merced River near Stevinson	11272500	N/A	USGS	1941 - Present
San Joaquin River near Newman	11274000	118	USGS	1912 - present

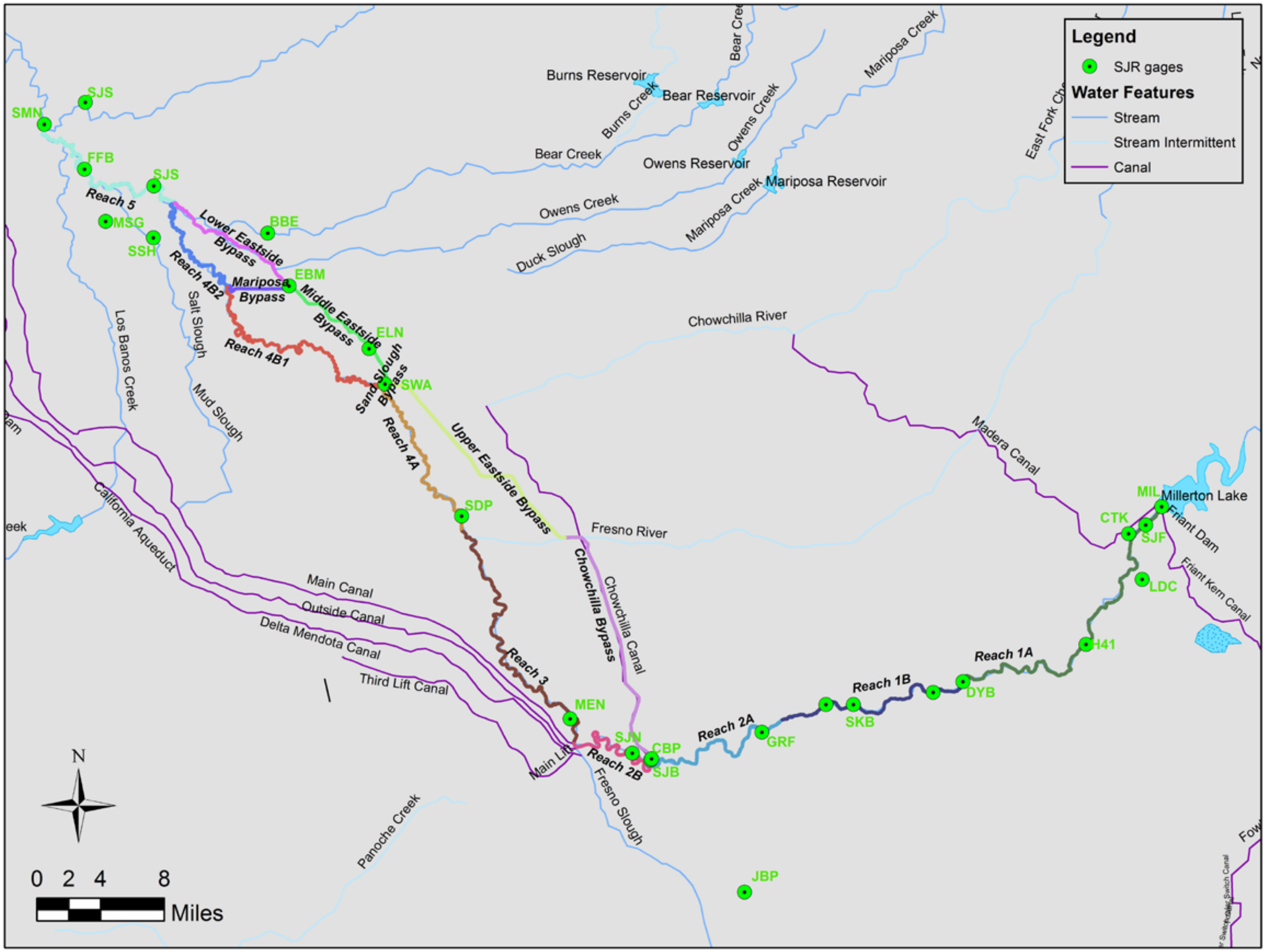

Figure 3-3. Stream Gage Locations Used in Analysis.

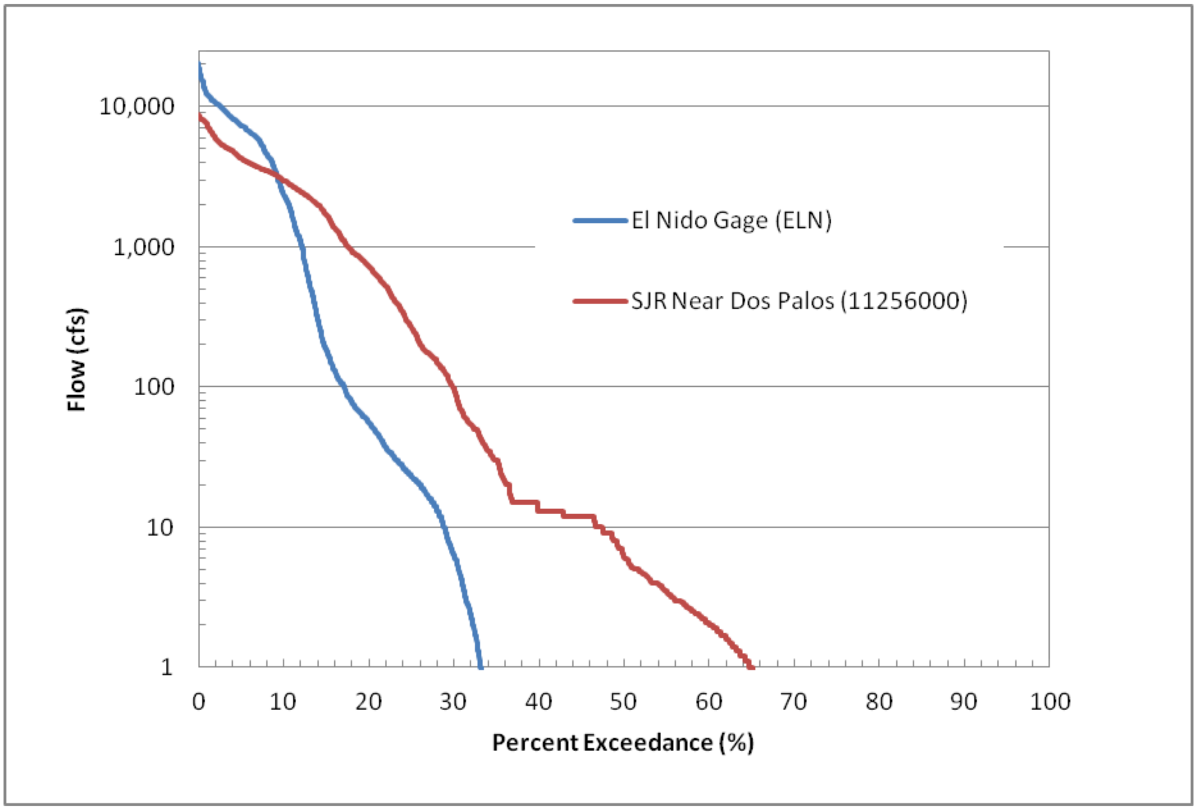

Figure 3-4. Percent Exceedance for the El Nido Stream Gage (10/1/1980 to 2/13/2008, DWR ID: ELN) and San Joaquin Near Dos Palos (10/1/1940 to 12/31/1995, USGS ID: 11256000).

4 Existing Hydraulics

Two basic models of the project reach were constructed: 1. A one-dimensional (1D) cross section based model using HEC-RAS 4.1, and a two-dimensional (2D) model of the reaches using SRH-2D. This section describes the development and calibration of these models using existing data.

4.1 One-Dimensional Model

The basis of the 1D model was the HEC-RAS model developed by Tetra-Tech (2013). The model is briefly described below, and some modifications were made to the calibrated n-values so that a similar description of the channel and floodplain roughness were obtained. This was necessary to facilitate easier comparisons between alternatives and under future conditions when the roughness is modified by vegetation. The hydraulic model used in this study consisted of Reach 4A, Reach 4B1, the Middle and Lower Eastside Bypass, and Mariposa Bypass. There are four basic pieces of information needed to construct such a model: river geometry, structure characteristics, hydraulic roughness, and boundary conditions.

1. River Geometry is the above water and below water geometry of the stream, floodplain and levees. For this study, we obtained the 2008 LiDAR for the entire reach from California Department of Water Resources (CDWR). Two separate boat surveys were performed in April 2010 and in January 2011 to obtain the below water geometry of the stream channel. The cross section locations are shown in Appendix A and B.
2. Structure characteristics are defined as the geometric information and operational criteria for bridges, weirs, and control structures located on the river. Original as-built design drawings of the Eastside Bypass Control Structure, the Sand Slough Control Structure, and the MNWR weir were used to provide the necessary information for the HEC-RAS model. Information on the bridges was obtained from the Tetra-Tech (2013) hydraulic modeling study.
3. Hydraulic roughness is the resistance of the channel and overbank topography to the flow. The hydraulic roughness is related to the bed material, bed forms, vegetation, and channel planform. In one-dimensional models such as HEC-RAS, the hydraulic roughness is often used as a calibration parameter because it incorporates several difficult–to-measure physical properties into one parameter. In this study, boat surveys of the water surface elevations performed in April 2010 and January 2011 from Highway 152 to just upstream of the Eastside Bypass Control Structure were used as the data to which the model was calibrated. The channel roughness values were adjusted such that the model results were consistent with the measured water surface elevation data. The floodplain hydraulic roughness values were taken from the MEI (2008) study in which they

based hydraulic roughness on the vegetation density of the floodplain. The categories are listed in Table 4-1.

Table 4-1. Hydraulic Roughness Values used in the Floodplain.

Vegetation Density	Floodplain Roughness
Bare Soil	0.045
Scattered Trees and Light Brush	0.06
Medium Density Trees and Brush	0.08
Dense Trees and Brush	0.1

4. Boundary conditions in the model consist of water surface elevations at the downstream end of the simulated reaches for each modeled flow. The boundary condition at the downstream end of the Lower Eastside Bypass and Reach 4B1 were taken from the Tetra-Tech (2013) hydraulic modeling study (Figure 4-1 and Figure 4-2).

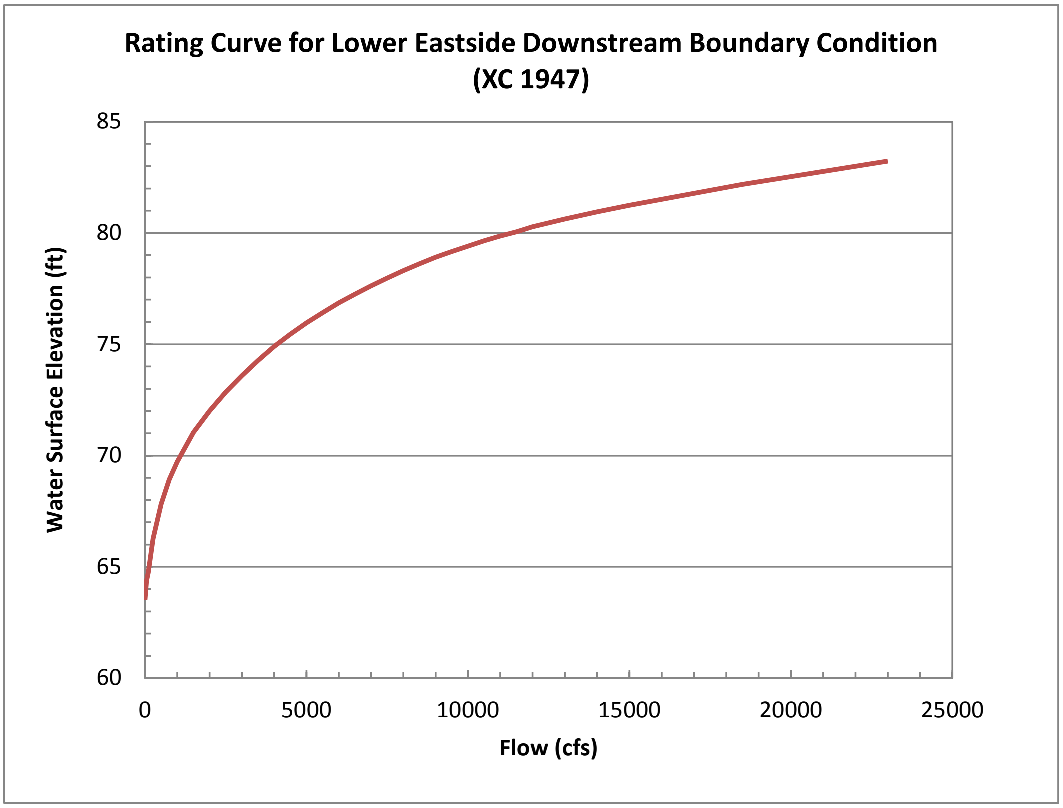

Figure 4-1. Rating Curve used for downstream boundary condition at XC 1947, which is the downstream most cross section of the Lower Eastside Bypass.

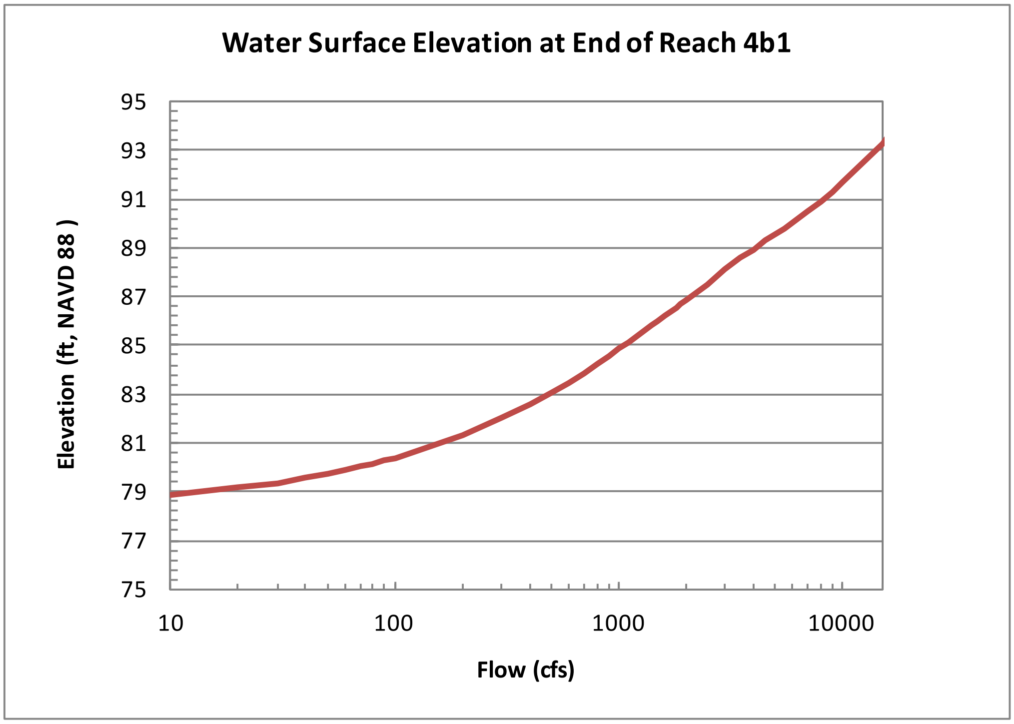

Figure 4-2. Rating Curve used for downstream end of Reach 4B1.

4.1.1 Calibration

Hydraulic roughness values in the main channel for the 1D model were calibrated based upon water surface elevation data collected on January 17, 2011 in the Middle Eastside Bypass and January 21, 2011 in the Lower Eastside Bypass.

The measured flow rate at the San Joaquin River Near Dos Palos (SDP) stream gage at the upstream end of Reach 4A is shown in Figure 4-3 for January 17, 2011. The measured flow rate at the Eastside Bypass Near El Nido (ELN) Stream Gage near El Nido Rd on the Eastside Bypass is shown in Figure 4-4 for January 17, 2011. The El Nido gage is not reliable at low flows is due to its proximity of 4 miles upstream of the MNWR weir. As will be shown, when the stop logs of the MNWR weir are in place, the low flow water surface elevations increase by up to 5 feet at the weir and the backwater from the weir can extend upstream almost 8 miles. There can also be debris blockage at the weir (Figure 4-5). It is estimated that the MNWR weir can significantly affect the rating curve at the El Nido gage for flows of 2,000 cfs and below, thereby decreasing the reliability of the stream gage record for flows below 2,000 cfs. However, the gage will be more reliable for larger flows such as occurred on January 17, 2011.

On January 17, 2011, the flow rate was assumed to be 1,200 cfs in Reach 4A and 3,000 cfs in the Eastside Bypass. On January 21, 2011 the observed flow in the LESB was taken from the estimated of flow from Tetra Tech (2013). The stream gage downstream of the Eastside Bypass Control Structure in the Lower Eastside Bypass may not include other inflows from Owen's and Bear Creek, so the flow recommended in Tetra Tech (2013) was used as the observed flow on January 21, 2011.

A channel roughness of 0.035 and floodplain roughness of 0.045 were used throughout the Bypass reach to match the measured water surface profiles. The only exception is in a heavily vegetated reach from the Sand Slough Control structure to about 1 mile upstream. A channel roughness of 0.1 was used for the cross sections where vegetation is blocking flow in the main channel. Figure 4-6 is a photo of the April 10, 2010 channel approximately 2,000 ft upstream of the Sand Slough and shows the dense vegetation along the main channel.

The comparison between the simulated water surface elevations and the measured data of January 17, 2011 in the Middle Eastside Bypass is shown in Figure 4-7 and the comparison between the simulated water surface elevations and the measured data of January 21, 2011 in the Lower Eastside Bypass is shown in Figure 4-8. The average difference between the simulated and measured water surface elevations was near 0.1 ft and the standard deviation near 0.2 ft for both the Middle and Lower Eastside Bypasses (Table 4-2).

Table 4-2. Comparison between Measured and HEC-RAS Simulated Water Surface Elevations for the data collected in January 2011.

Date	**Reach**	**Flow (cfs)**	**Average Difference (ft)**	**Standard Deviation (ft)**	**Root Mean Square (ft)**
January 17, 2011	MESB	3000	0.08	0.18	0.20
January 19, 2011	LESB	1893	0.11	0.21	0.24

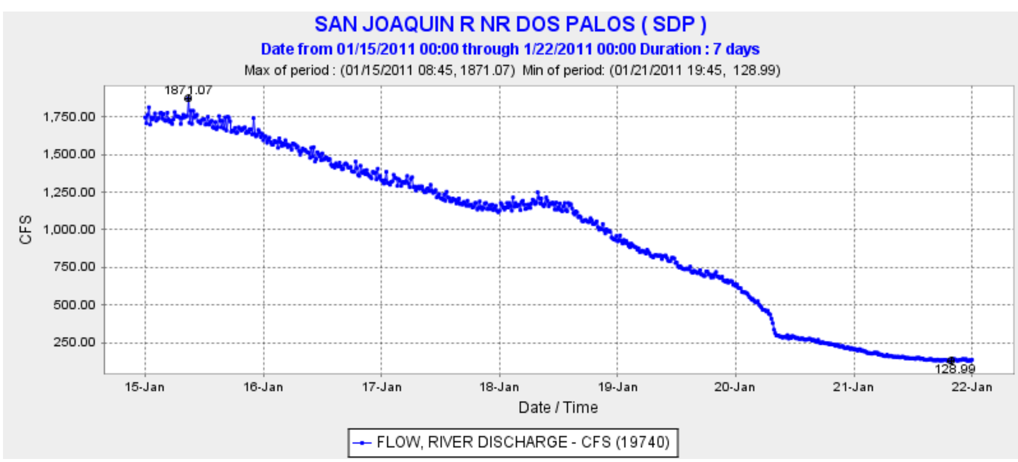

Figure 4-3. Flows on San Joaquin River near Dos Palos (downstream of Sack Dam) for January 2011.

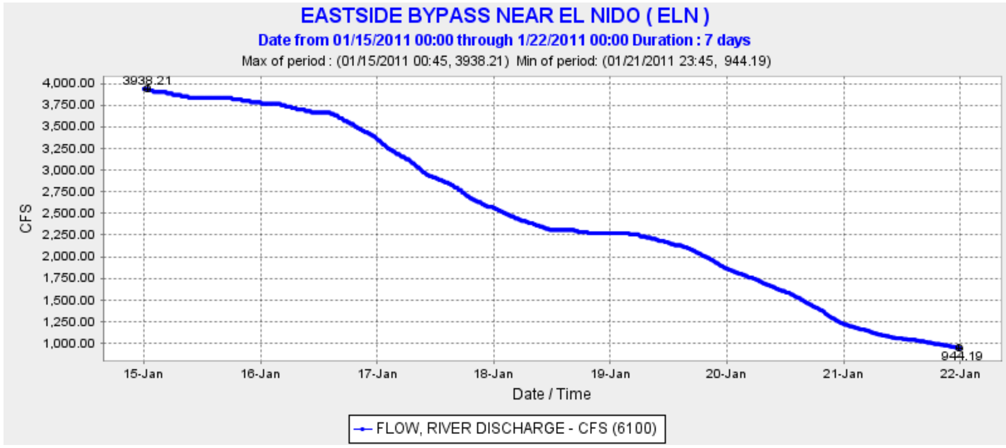

Figure 4-4. Flows on San Joaquin River near El Nido (on Eastside Bypass) for January 2011.

Figure 4-5. Merced National Wildlife Refuge Weir April 10, 2010.

Figure 4-6. Looking downstream at heavy brush blocking the main channel in lower portion of Reach 4A, April 10, 2010 approximately 2000 ft upstream of the Sand Slough Control Structure.

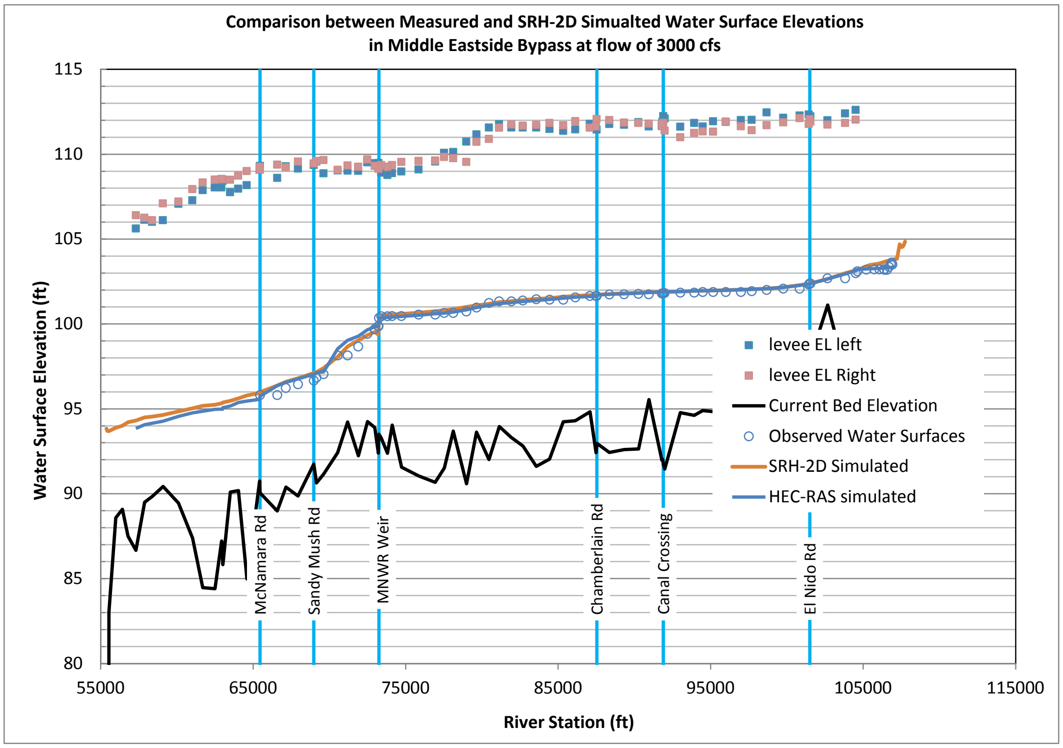

Figure 4-7. Observed and HEC-RAS and SRH-2D simulated profiles in MESB on 1/17/2011 at a flow of 3000 cfs.

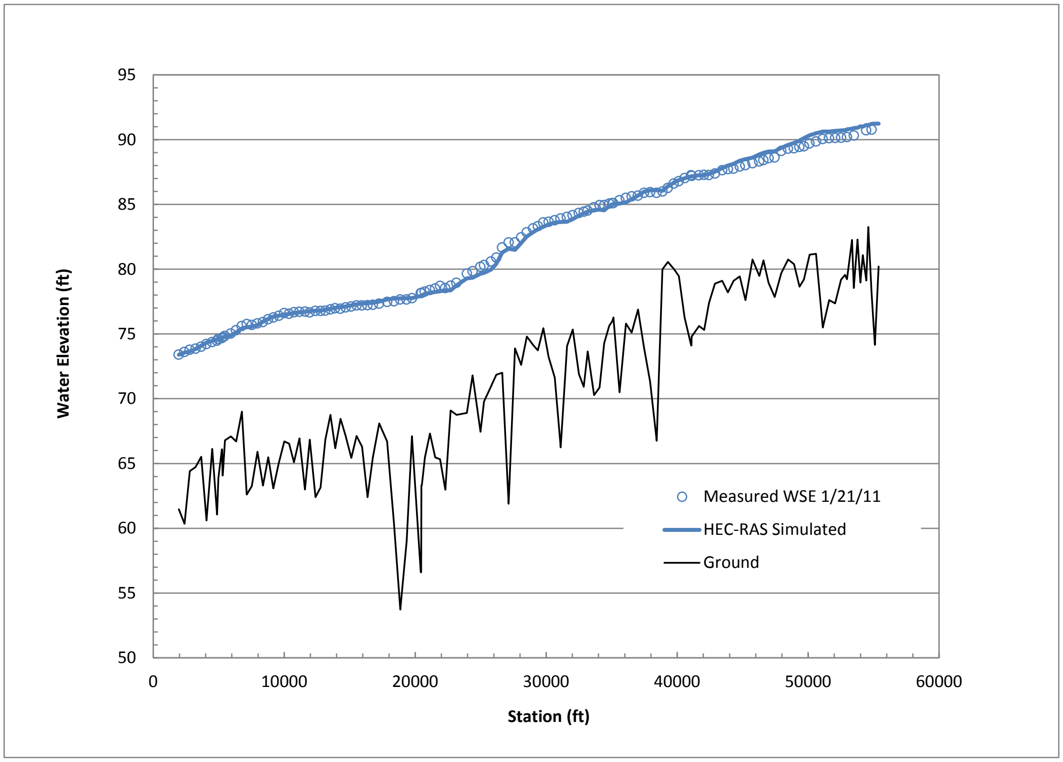

Figure 4-8. Observed water surface elevation (WSE) on 1/21/2011 at a flow of 1893 cfs compared to HEC-RAS simulated profiles in LESB.

4.2 Two-Dimensional Model

The model input includes a mesh that represents channel topographic features, channel roughness delineated in each cell of the mesh, upstream flows, downstream water surface elevations for various flow scenarios, and some model input parameters (e.g., such as starting and ending simulation times, and time steps).

Three separate SRH-2D models were generated: Middle Eastside Bypass, Lower Eastside Bypass and the Mariposa Bypass.

4.2.1 Middle Eastside Bypass Mesh

The computational mesh was generated using the Surface Water Modeling System software (SMS) Version 10.1. The following website link provides more information for the software: http://www.aquaveo.com. The mesh contains elevation information at each node and roughness data for each cell. The mesh was bounded in the lateral direction by the levees on both sides.

The cell size of the mesh was varied based on the location of the cell in reference to the channel. In the lateral direction (cross-stream), 10 mesh cells were used in the main channel, which equated to mesh spacing of approximately 15 ft in the transverse direction to the flow. A spacing of about 20 feet was used in the floodplains. In the longitudinal direction, the cells were limited to approximately 30 feet. A smaller dimension in the lateral direction is used to capture the more rapidly changing topography transverse to the stream flow compared to longitudinal direction. Examples of the mesh are given in Figure 4-9, Figure 4-10, and Figure 4-11 for the upper, middle and lower section of the MESB.

The mesh consists primarily of quadrilaterals in the main channel with triangles in the floodplains. Side channels were delineated in ARC GIS and imported to SMS as polyline shapes, which were used as feature arcs in SMS. The mesh cell density was increased along the channel boundary by redistributing the vertices along the boundary with a spacing approximately 12 ft. Mesh cells within the side channels are triangles. Approximately 190,000 cells were used in the mesh for the middle eastside bypass, of which about 120,000 cells are triangles.

Elevation values for the mesh were calculated with the existing topographic data and Alternative 2 topographic data. Existing conditions topographic data were from LiDAR data acquired in 2007 and existing conditions bathymetric data collected in 2011. The final topographic models for each subreach were created in NAD83 State Plane CA III, NAVD88 ft.

Alternative 2 topographic data includes a 50-ft wide low flow channel excavated into the existing low channel of the Middle Eastside Bypass, which is now approximately 150-ft wide. The terrain elevations were assigned to each node of the mesh (Figure 4-12).

Figure 4-9. Example of mesh near the upstream boundary of the eastside bypass

Figure 4-10. Example of the mesh in the middle reach.

Figure 4-11. Example of the mesh at the downstream boundary. Two green node strings were used to set downstream boundary conditions.

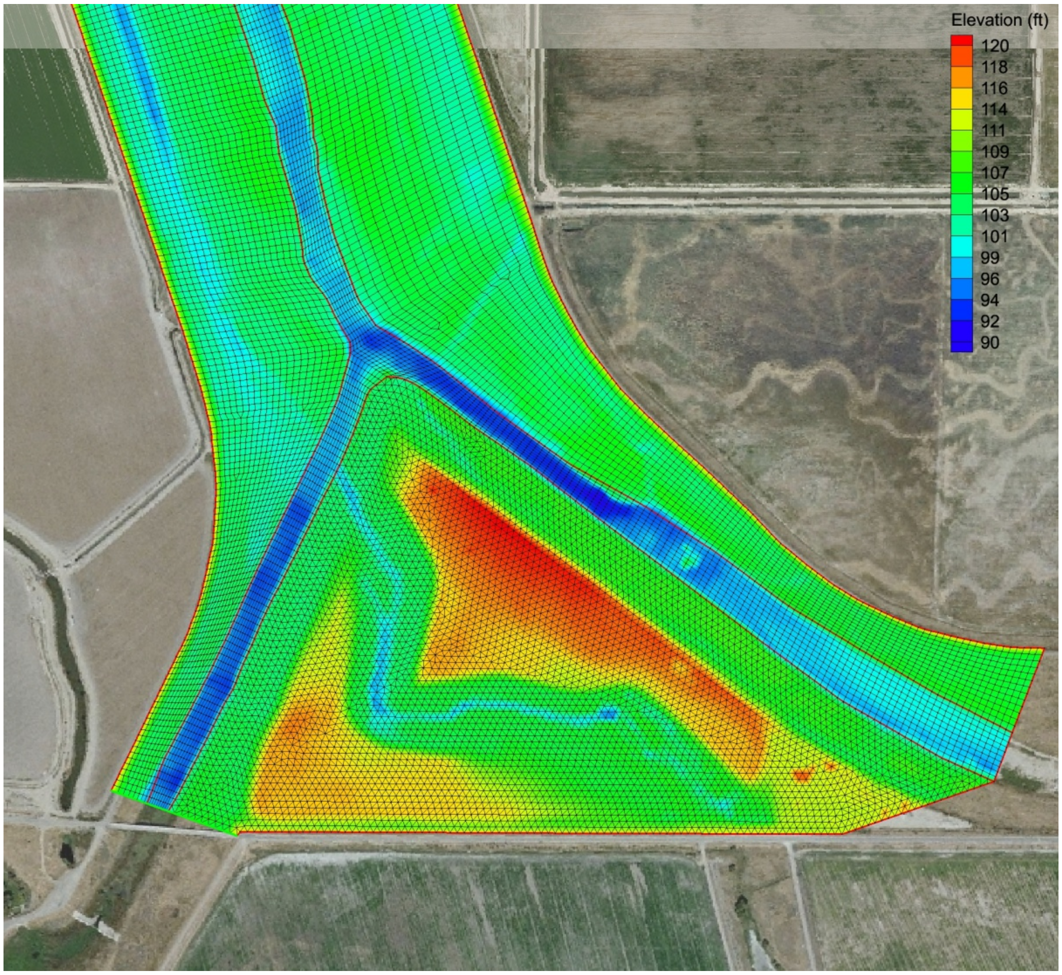

Figure 4-12. Example of numerical mesh showing bed elevations as derived from the terrain surface

4.2.2 Roughness Zones

Flow resistance is calculated using the Manning's roughness equation in which the Manning's coefficient (*n*) is used as one of the model inputs. There is little vegetation within the Eastside Bypass and the Manning's roughness calibrated in the 1D HEC-RAS model was used for the 2D numerical simulation. Under existing conditions, a uniform Manning's roughness of 0.035 was used for the main channel with bare soil and a value of 0.045 was used for the floodplain with minor vegetation.

4.2.3 Upstream and Downstream Boundary Conditions

Discharge was used as the upstream boundary condition, which were based on the Settlement and flood flows. Additionally, the January 2011 field survey discharges (Table 4-2) were used as calibration cases.

Water surface elevation at each discharge was used as the downstream boundary condition, which was taken from the HEC-RAS model.

4.2.4 Calibration

A comparison between the observed water surfaces, the HEC-RAS simulated results, and the SRH-2D simulated results is shown in Figure 4-7 for the Middle Eastside Bypass for the flow on January 17, 2011. The computed average difference between the observations and simulated SRH-2D results is shown in Table 4-3. The simulated results for the SRH-2D and HEC-RAS are very similar. The main advantage in using SRH-2D is that it generally calculates more accurate depth averaged velocities throughout the model domain compared to the 1D model.

Table 4-3. Comparison between Measured and SRH-2D Simulated Water Surface Elevations for the data collected on January 17, 2011.

Date	Flow (cfs)	Average Difference (ft)	Standard Deviation (ft)	Root Mean Square (ft)
January 17, 2011	3000	0.13	0.17	0.21

5 Initial Concepts Considered

There were five initial Alternatives analyzed in this document (Table 5-1). The development of the initial concepts is described in SJRRP (2010). There is considerable floodplain, channel, and levee modification required for each alternative. A description of the floodplain, channel, and levee modification for the Bypasses (Middle Eastside, Lower Eastside, and Mariposa Bypasses) and Reach 4B1 for each alternative is discussed in this chapter.

5.1 Alternative 1

Alternative 1 increases the capacity of Reach 4B1 to 4500 cfs and passes most all restoration flow into Reach 4B1. The Bypass system is not used to convey restoration flow. There were three different levee alignments considered in Reach 4B1 for Alternative 1. The same main channel alignment was used for all the options, and the total channel length of Reach 4B1 following the existing river alignment is 21 miles with the bed elevation dropping from 95 to 75 feet.

The levee alignment options are shown in Figure 5-1 and a description of the alignments is given below. The area enclosed by the various alignments is given in Table 5-2. Only Options B through D are viable options for Alternative 1 as discussed in the Hydraulic Analysis Section (Section 6). The Option A levee alignment is used for Alternatives 3 and 4.

> **Option B**: This is considered the minimum levee setback necessary to convey 4500 cfs and maintain a minimum level of riparian habitat. The levees are setback a minimum of 250 ft from the edge of the channel so that levee maintenance would be minimized. Some side channels would be constructed, but on a limited basis. The channel would be primarily a single thread channel. The levees are typically 1300 to 2000 ft apart.
>
> **Option C**: Option C is considered an intermediate levee setback between Option B and D that would contain a minimum of 4500 cfs. The levees are typically 3500 to 5500 ft apart, though the distance between them decreases to about 2500 ft at the downstream end of the reach.
>
> **Option D**: Option D is considered a maximum levee setback that would reconnect historical side channels and restore a significant portion of the complex channel network of the San Joaquin that existed prior to the advent of intensive agricultural production. A 1937 aerial photograph of a portion of the San Joaquin is given in Figure 5-2. Figure 5-3 shows the same reach in 2004. The levees under Option D are typically 5000 to 11000 ft apart, though the width between them decreases to about 2500 ft at the downstream end of the reach.

For each levee option, a considerable amount of earthwork would be required in Reach 4B1 to restore channel conveyance, floodplain connectivity, and prevent fish stranding. At this stage of alternative development, two example areas were chosen to design these features and the location of these areas is given in Figure 5-4 and Figure 5-5.

For options B to D, it was assumed that the existing levees would be removed to approximately the surrounding floodplain elevations. This material would be used to grade the floodplain so that the floodplain slopes away from the levees and toward side channels or the main channel. The cut and fill was balanced in each alternative to minimize material being imported to or exported from the reach. However, it is likely not possible that a significant portion of the existing levee material could be used to construct new levees. This is because most of the material would be needed as fill in the floodplain and the material may not be appropriate for levee construction.

To analyze the flow hydraulics in the reach it was necessary to modify the existing terrain map to incorporate these features. The location of the side channels and levee removal is shown in Figure 5-4 for example Area 1 and Figure 5-5 for example Area 2. These two example areas were chosen as representative reaches of Reach 4B1. These areas represent about a 1/3 of the total area of Reach 4B1. Only the side channels for Option D are shown. Side channels are also incorporated into the other levee options, but only if they are fully encompassed within the levees. The side channels are intended to have approximately 1 foot of water at a flow of 150 cfs. In the final design, the side channel may be varied so that some become active at different flow values. Example cross sections for Option D are shown in Figure 5-6 and Figure 5-7. It is likely that the side channels would be excavated below groundwater elevations in many locations.

It would be necessary to remove vegetation within the existing channel if a continuous flow path is required in Reach 4B1. Based upon an analysis of the aerial photography, it was estimated that 30 acres of wetland and riparian plant species would have to be removed regardless of the Levee Alignment. An example of the vegetation areas that would be removed is given in Figure 5-8 and a photograph of the vegetation is given in Figure 5-9.

5.2 Alternative 2

For Alternative 2 a 50-ft wide low flow channel would be excavated into the existing low flow channel of the Middle Eastside and Mariposa Bypass, which is now approximately 150-ft wide. The excavation depth would vary between 0 ft and 7 ft deep and some of the excavation would be below groundwater elevations. Some of the barrow pits within the bypass would be filled in with the material excavated from the low flow channel. The channel design features are shown in Figure 5-10.

The river profile before and after excavation is given in Figure 5-11 and typical cross sections are given in Figure 5-12. The inset low flow channel is shown within the larger low flow channel and the floodplain is relatively flat. This 50-ft wide channel would have a transverse slope so that fish passage is ensured at all flows above 50 cfs. The design slope of the low flow channel is 0.00024, which is slightly higher than the original design slope of 0.00022 in the Bypass according to the as-built drawings. The average slope of Reach 4A is also approximately 0.00022. The depth of the excavation would vary between 0 ft to 8 ft to maintain the 0.00024 slope. The construction of the low flow channel would significantly decrease water surface elevations during flows less than approximately 2000 cfs. The length of the channel in the Bypass from the end of Reach 4A to the beginning of Reach 4B2 is 13.8 miles and the bed elevation drops from 95 to 75 feet. The approximate volume of excavation within the Middle Eastside and Mariposa Bypass is 600,000 yd^3.

The construction of the low flow channel is necessary for a variety of reasons:

1. Limit sediment deposition in the Middle Eastside Bypass;
2. Lower water surface elevations in the bypass at low flows to limit seepage outside levees;
3. Improve connection of the channel with groundwater supplies; and
4. Develop a benched channel within the low flow to promote hydraulic variability for fish habitat.

Even though the Bypass reach is slightly more steep than Reach 4A, the difference in elevation over the length of the Bypass considering slopes between 0.00022 and 0.00024 would only be 1.3 feet. The bed erosion repercussions of lowering the Mariposa Bypass Control Structure's sill and removing structures are analyzed in Section Future Geomorphology and Sediment Transport using a mobile bed sediment transport model.

The revised channel bed invert in the Bypass also necessitates that the sill of the Mariposa control structure be lowered to allow for fish passage through the structure. It was also assumed that the drop structure at the downstream end of the Mariposa Bypass would be removed because there is no drop in water surface at the end of the bypass with the excavated channel and the structure would not be necessary. The MNWR weir would be removed and the road crossings would be elevated to pass at least 4500 cfs.

Two options are considered to mitigate the impact of rising flood elevations: a levee rise and levee setbacks. The existing and setback levee alignment options are given in Figure 5-1. The setback alignment is referred as the MNWR alignment refers to the Merced National Wildlife Refuge and the levee setback is intended to encompass the Lone Tree Unit of that refuge.

5.3 Alternative 2-LESB

Alternative 2-LESB uses the Lower Eastside Bypass to route Restoration flows instead of the Mariposa Bypass and Reach 4B2. There would be minor amounts of channel grading recommended in the Lower Eastside Bypass as shown in Figure 5-13. The main significant change required within the reach would be a removal or modification of the grade control structure just downstream of Dickinson Ferry Road, approximately 3 miles downstream of the Eastside Bypass Control Structure. The total volume of material that would need to be removed from the Lower Eastside Bypass is approximately 70,000 yd^3. This is in addition to the material that would need to be removed from the Middle Eastside Bypass as described in Alternative 2, which is estimated to be approximately 450,000 yd^3.

It is also recommended that two bays of the Eastside Bypass Control Structure are lowered approximately 4.4 ft to an elevation of 82 ft (Figure 5-14).

5.4 Alternative 3

Alternative 3 will convey up to 475 cfs into Reach 4B1 with restoration flows larger than this conveyed in the Middle Eastside and Mariposa Bypass.

Levee Option A is used to contain the flows within the channel. This roughly follows the existing Levee alignment with improvements to contain the design flow. The maximum flow capacity with this alignment is considered to be approximately 1500 cfs, which was the original design capacity of this reach when the bypass system was constructed in the 1960s. However, the levees would only be improved to contain 475 cfs. The levees are typically 250 to 400 ft apart in this option.

5.5 Alternative 4

Alternative 4 will convey up to 1500 cfs into Reach 4B1 with restoration flows larger than this conveyed in the Middle Eastside and Mariposa Bypass.

Levee Option A is used to contain the flows within the channel. This roughly follows the existing Levee alignment with improvements to contain the design flow. The maximum flow capacity with this alignment is considered to be approximately 1500 cfs, which was the original design capacity of this reach when the bypass system was constructed in the 1960s. The levees are typically 250 to 400 ft apart in this option

Table 5-1. Initial Alternatives Analyzed.

Channel/ Structure	Alternative 1 Main Channel Restoration	Alternative 2 Bypass Restoration	Alternative 2 - LESB Lower Eastside Bypass Restoration	Alternative 3 Bypass All Pulse Flows	Alternative 4 Split Pulse Flows and Restore Both
San Joaquin River Flows	Up to 4,500 cfs (all Restoration Flows)	At least 475 cfs of Flood Flows	At least 475 cfs of Flood Flows	Restoration Flows up to 475 cfs	Base and fall pulse flows; some spring pulse flows
Bypass System Flows	Flows greater than 4,500 cfs	All flows up to 16,500 cfs	All flows up to 16,500 cfs	Flow greater than 475 cfs	Flow greater than Reach 4B capacity
Fish Routing	Reach 4B1 and 4B2	Middle Eastside Bypass, Mariposa Bypass, Reach 4B2	Middle and Lower Eastside Bypass	Reach 4B1, Middle Eastside Bypass, Mariposa Bypass, Reach 4B2	Reach 4B1, Middle Eastside Bypass, Mariposa Bypass, Reach 4B2
Habitat	SJR	Bypass	Bypass	SJR and Bypass	SJR and Bypass
Reach 4B Headgates	Simple Gate	Simple Gate	Simple Gate	Construct gates and roughened channel fishway	Construct gates and roughened channel fishway
Merced NWR Options for Fish Passage	None	Remove Weir	Remove Weir	Remove Weir	Remove Weir
Eastside Bypass Control Structure	No Change	Fish Passage	Notch Center Bays	Fish Passage	Fish Passage
Mariposa Bypass Control Structure	No Change	Notch Center Bays	No Change	Notch Center Bays	Notch Center Bays
Mariposa Drop Structure	No Change	Remove Drop Structure	No Change	Remove Drop Structure	Fish Passage
San Joaquin River Reach 4B1 Levee Alignments	B, C, D	A	A	A	A
Middle Eastside and Mariposa Bypass Levee Alignments	Existing	Existing or Setback	Existing or Setback	Existing	Existing
Lower Eastside Bypass Levee Alignments	Existing	Existing	Existing	Existing	Existing