RECLAMATION
Managing Water in the West

Technical Report No. SRH-2016-04

DRAFT Hydraulic and Revegetation Design of the Mendota Bypass – 30% Design

San Joaquin River Restoration Project
Mid-Pacific Region

U.S. Department of the Interior
Bureau of Reclamation

Oct 2015

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Technical Report No. SRH-2016-04

DRAFT Hydraulic and Revegetation Design of the Mendota Bypass – 30% Design

San Joaquin River Restoration Project
Mid-Pacific Region

prepared by

Blair P. Greimann, P.E., Ph.D., Hydraulic Engineer
Sedimentation and River Hydraulics Group, Technical Service Center, Bureau of Reclamation

Scott O'Meara, Ph.D., Botanist
Hydraulic Investigations & Lab Services, Technical Service Center, Bureau of Reclamation

Rebecca Kallio, P.E., M.S., Hydraulic Engineer
Sedimentation and River Hydraulics Group, Technical Service Center, Bureau of Reclamation

Citation:
Reclamation (2015). DRAFT Hydraulic and Revegetation Design of the Mendota Bypass – 30% Design, Technical Report No. SRH-2016-04, Prepared for San Joaquin River Restoration Project, Mid-Pacific Region, US Bureau of Reclamation, Technical Service Center, Denver, CO, October 2015.

U.S. Department of the Interior
Bureau of Reclamation **October 2015**

Peer Review Certification: This document has been peer reviewed per guidelines established by the Technical Service Center and is believed to be in accordance with the service agreement and standards of the profession. Questions concerning this report should be addressed to Timothy Randle, Group Manager of the Sedimentation and River Hydraulics Group (86-68240) at 303-445-2557.

PREPARED BY:

_______________________________________ DATE:____________

Blair Greimann, Ph.D., P.E.
Hydraulic Engineer, Sedimentation and River Hydraulics Group (86-68240)

_______________________________________ DATE:____________

Scott O'Meara, Ph.D.
Hydraulic Investigations & Lab Services, (86-68220)

_______________________________________ DATE:____________

Rebecca Kallio, P.E., M.S.
Hydraulic Engineer, Sedimentation and River Hydraulics Group (86-68240)

PEER REVIEWED BY:

_______________________________________ DATE:____________

Nathan Holste, M.S., P.E.
Hydraulic Engineer, Sedimentation and River Hydraulics Group (86-68240)

Section 5.3: Revegetation

_______________________________________ DATE:____________

Rebecca Seigle,
Ecologist, Fisheries and Wildlife Resources (86-68290)

Section 5.4: Irrigation

_______________________________________ DATE:____________

Roger Burnett,
Civil Engineer, Geology & Geotechnical Support (86-68320)

Contents

Table of Figures

Acronyms and Abbreviations

1D	one dimension
2D	two dimensional
ArcGIS	a Geographic Information System
ASCE	American Society of Civil Engineers
Bypass	Mendota Pool Bypass
cfs	cubic feet per second
Ch	chapter
Corps	U.S. Army Corp of Engineers
DH	drill holes
EM	Engineering Manual
Eq.	equation
ft	foot/feet
GRF	Gravelly Ford gage
HEC-GeoRAS	Hydrologic Engineering Centers River Analysis System extension for use in ArcGIS
HEC-RAS	Hydrologic Engineering Centers River Analysis System
ID	Identification
JBP	Fresno Slough into Mendota Pool are recorded by James Bypass
JSA	Jones and Stokes Associates, Inc.
LiDAR	Light Detection and Ranging
LWD	large woody debris
MEI	Mussetter Engineering Inc.
MEN	San Joaquin River near Mendota CA
NAD83	North American Datum National Readjustment

NAVD88	North American Vertical Datum of 1988
No.	number
NRCS	Natural Resources Conservation Service
Passage Memo	San Joaquin River Restoration Program Passage Memo, 2014
PLS	Pure Live Seed
prep	preparation
Project	Mendota Pool Bypass and Reach 2B Improvements Project
Reclamation	Bureau of Reclamation
RM	river mile
R/*W*	where *R* = radius of curvature and *W* = channel width
SJB	San Joaquin River Below Bifurcation
SJN	San Joaquin River at San Mateo Road near Mendota
SJR	San Joaquin River
SJRRP	San Joaquin River Restoration Program
SJRRW	San Joaquin River Restoration Daily Flow Model
SONAR	Sound Navigation and Ranging
SRH-1D	Sedimentation and River Hydraulics – One Dimension
SRH-2D	Sedimentation and River Hydraulics – Two-Dimensional
Settlement	Stipulation of Settlement
TSC	Technical Service Center
U.S.	United States
USBR	U.S. Bureau of Reclamation (Reclamation)
USGS	U.S. Geological Survey
WY	water year
yd	yard

Technical Report No. SRH-2016-04

Hydraulic Design of the Mendota Bypass

1 Introduction

The San Joaquin River Restoration Project Office of the Bureau of Reclamation (Reclamation) requested Reclamation's Technical Service Center (TSC) develop conceptual level designs for the compact bypass around Mendota Pool (Bypass) of the San Joaquin River (SJR) as described in the Bypass and Reach 2B Improvements Project (Project) [SJRRP, 2012b]. This analysis is 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.

The Settlement is based on two goals:

- **Restoration.—**To restore and maintain fish populations in "good condition" in the main stem of the SJR below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

- **Water Management.—**To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

The Bypass and the Project includes the construction, operation, and maintenance of the Bypass and improvements in the SJR in Reach 2B to convey at least 4,500 cubic feet per second (cfs) between levees. The Project area (Figure 1-1 and Figure 1-2) extends from approximately 0.3 miles above the Chowchilla Bypass Bifurcation Structure to approximately 1.0 mile below Mendota Dam; it comprises the area that could be directly affected by the Project. The Project may also indirectly affect nearby portions of Reach 2A and Reach 3. The Project area is in Fresno and Madera counties, near the town of Mendota, California. The Bypass and Reach 2B improvements defined in the Settlement are [Settlement Paragraph 11(a)]:

1. Creation of a bypass channel around Mendota Pool to ensure conveyance of at least 4,500 cfs from Reach 2B downstream to Reach 3. This improvement requires construction of a structure capable of directing flow down the Bypass and allowing the Secretary of Interior to make deliveries of SJR water into the Bypass when necessary;

2. Modifications in channel capacity (incorporating new floodplain and related riparian habitat) to ensure conveyance of at least 4,500 cfs in Reach 2B between the Chowchilla Bifurcation Structure and the new Mendota Pool Bypass channel.

The primary goals of this report are to document the hydraulic modeling results and present the 30% Design of the following features:

- Excavation of the Channel,
- Bed and Bank Erosion Protection,
- Revegetation, Irrigation, and
- Flow Reintroduction.

Appurtenant features, including fish ladders, fish barriers, control gates, and levees will be described in separate documentation and are integrated here by location and water surface elevations.

All elevations in this report are stated in feet (ft) and in the North American Vertical Datum of 1988 (NAVD88) vertical datum.

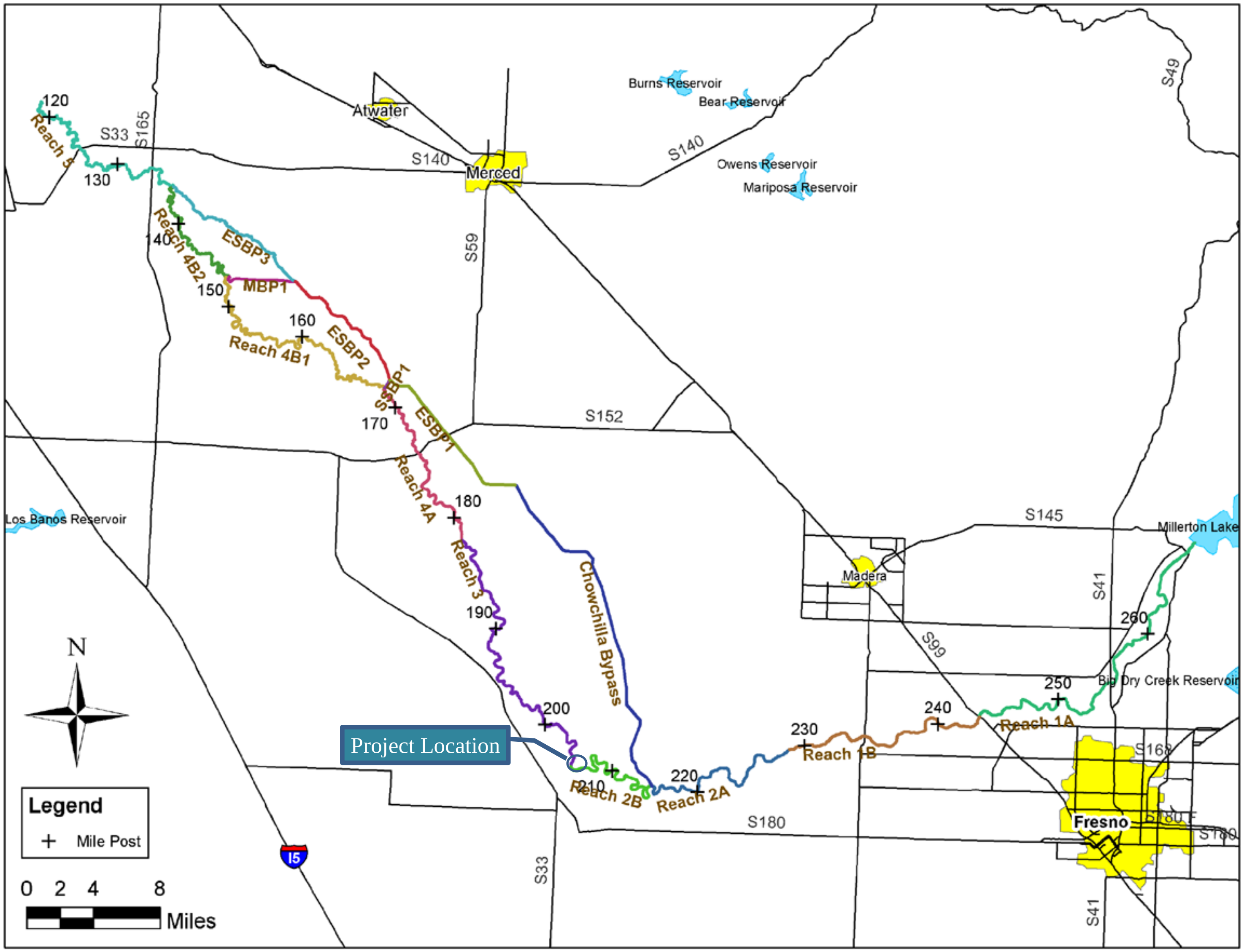


Figure 1-1. Overview of reaches associated with the SJRRP.

Figure 1-2. Mendota Bypass Project overview map.

2 Design Goals and Objectives

The overall design goals and objectives for the Project are described here and summarized below as project design criteria.

2.1 Fish Passage Objectives

Fish Passage Design Criteria Technical Memoranda [Passage Memo, SJRRP, 2014] describes the upstream fish passage strategy for the SJRRP to guide engineering modifications to structures within the SJR and Bypass between Friant Dam and the Merced River confluence. This document is used to guide the design of the hydraulic structures within the Bypass. The species of interest and passage criteria for each species are given in Figure 2-1, taken from the Reach 2B Project Description [SJRRP, 2012b].

In the Passage Memo, four categories were proposed for fish passage, labeled “A” through “D.” These categories range from the most inclusive to the most limited passage requirements defined for the SJR. Category A is the most inclusive and includes the adult and juvenile life stage of Chinook salmon, sturgeon, and other native fish. Category B is primarily focused on sturgeon and would provide for both adult and juvenile sturgeon passage, and possibly some other species. Category C was designed primarily to focus on the juvenile Chinook salmon passage requirements, while possibly providing for some other native fish passage. Category D was designed primarily to focus on the adult Chinook salmon passage requirements, while possibly providing for some other native fish passage.

Category A passage is assumed to require a nature-like fishway, which consists of constructed channel reaches with immobile structures usually made up of different sized rocks with smaller material. The rocks may or may not be grouted or concreted into place to help limit the amount of erosion from large storm events. Nature-like fishways have a wide variety of fish passage applications. Common configurations of nature-like fishways include rock ramps spanning a part or the entire width of the channel, step-pool or cascade-pool sequences, and bypass channels (roughened channels) around dams or drop structures. Overall, slopes of nature-like fishway structures commonly range from 2.5 to 6.5 percent [DFG, 2010]. One of the advantages of the nature-like fishway is the hydraulic diversity created that provides many pathways for smaller and weaker swimming fish along the margins of the channel. Another advantage is the structures work well for upstream and downstream passage of aquatic species. In addition, nature-like fishways are generally efficient at passing high flows, wood, and sediment.

Fish Passage Design Criteria

Species	Life-stage	Migration Timeframe	Frequency	Minimum Flow	Maximum Flow	Maximum Velocity [1]	Minimum Water Depth [2]	Maximum Jump Height [3]	Minimum Pool Depth
			years	cfs	cfs	fps	feet	feet	feet
Chinook salmon	Adult	Spring and fall pulse	All years except CL	115 [4]	4,500	4.0	1.2	1.0	[5]
	Juvenile (upstream)	Late spring diminishing flows	All years except CL	125 [6]	n/a	1.0	1.0	0.5	[5]
	Juvenile (downstream)	Nov-May	All years except CL	85 [7]	n/a	n/a	1.0	n/a	[5]
Steelhead	Adult	Spring and fall pulse	All years except CL	115 [4]	4,500	4.0	1.2	1.0	[5]
Sturgeon	Adult	Spring pulse	W and NW years	1,138 [8]	4,500	6.6	3.3	None – swim through	n/a
Lamprey	Adult	Spring pulse	All years except CL	125 [6]	4,500	[9]	[9]	[9]	n/a
Other native fish	Adult	Spring pulse	W, NW, and ND years	543 [10]	4,500	2.5	1.0	None – swim through	n/a

W = wet; NW = normal wet; ND = normal dry; CL = critical low

[1] Recommended velocities are for drop structures or structures with short longitudinal lengths. For structures with longer lengths (e.g., culverts and bifurcation structures under certain conditions), maximum velocities would be based on *Anadromous Salmonid Passage Facility Design* (NMFS 2008) and *Guidelines for Salmonid Passage at Stream Crossings* (NMFS 2001).

[2] Minimum water depth criteria based on 1.5 times body depth or 1 feet depth, whichever is greater.

[3] Maximum jump height criteria based on criteria in *Anadromous Salmonid Passage Facility Design* (NMFS 2008) and *Guidelines for Salmonid Passage at Stream Crossings* (NMFS 2001).

[4] Based on Exhibit B lowest flow in the fall spawning period (starts Oct 1) for the desired frequency; all Spring Pulse Flows are higher.

[5] Pool depths to be based on criteria in *Anadromous Salmonid Passage Facility Design* (NMFS 2008) and *Guidelines for Salmonid Passage at Stream Crossings* (NMFS 2001).

[6] Based on lowest flow within Exhibit B Spring Pulse Flow period for the desired frequency.

[7] Based on lowest flow within desired migration period for the desired frequency.

[8] Wet and normal wet years constitute 50% of years in the historical record. Based on an analysis of varying Restoration Flows management strategies (Reclamation 2010); flows with a 50% exceedance could range from 1,138 to 4,500 cfs.

[9] Lamprey designs to be based on criteria in *Best Management Practices for Pacific Lamprey* (USFWS 2010)

[10] Wet, normal wet, and normal dry years constitute 80% of years in the historical record. Based on an analysis of varying Restoration Flows management strategies (Reclamation 2010); flows with an 80% exceedance could range from 543 to 4,500 cfs.

Figure 2-1 - Fish passage criteria from SJRRP Reach 2B project description [SJRRP, 2012b].

One of the disadvantages of the nature-like fishway is the large footprint needed due to the low slope. If it is not designed properly, higher flow events can cause overtopping of the barriers and may wash out the resting pools. Additionally, large flood events can result in high maintenance costs to restore the barriers to their original configuration.

It is important to understand that typical average channel velocities, in the SJR at Reach 2B after levee setback, vary between 1 to 3 ft/s for flows between 100 and 4,500 cfs. Therefore, it is not practical to require that the velocities in the Bypass be lower than the naturally formed river, especially since the Bypass will have a slightly shorter length than the original river did at this location.

The final recommended minimum depths and maximum velocities for various categories of fish passage are given in Table 2-1. The juvenile upstream passage maximum velocity of 1 ft/s in culverts or 1.5 ft/s through passage facilities is not included because this is typically exceeded in the naturally formed channel and it will not be possible to reduce average channel velocities to below 1 ft/s. The advantage of constructing nature-like fishways is that there will be diversity of velocity across the section and there will likely be multiple resting areas and slower velocity regions that can be used for passage.

The design objective for the Bypass is to accomplish Category B passage for high flows (greater than 1,000 cfs) and Category C passage for low flows (less than 1,000 cfs) during passage of restoration flows. The Passage Memo recommends that a roughened channel nature-like fishway option be selected to meet Category A passage; however, it will not be possible to maintain greater than 3.3 ft of flow depth during low flows.

During deliveries to Mendota Pool, which happen infrequently only during flood flows or very dry years, a fish passage facility will be constructed around the compact bypass control structure and will accomplish Category C passage.

Table 2-1.—Fish passage design categories [Passage Memo, SJRRP, 2014]

Category	Minimum Depth (ft)	Maximum Hydraulic Jump Height (ft)	Maximum Recommended Design Velocity (ft/s)
A	3.3	0	2.5
B	3.3	0	4.0
C	1.2	1	2.5
D	1.2	1.5	4.0

2.2 Rearing Habitat Objectives

A description of juvenile Chinook salmon rearing habitat objectives for the SJRRP is described in a Rearing Habitat Design Objectives memo [SJRRP, 2014]. The Bypass may not be a primary location of rearing habitat, but there will be an effort to incorporate as much rearing habitat as possible into the design. The overall juvenile Chinook salmon rearing habitat design objectives for the SJRRP were as follows [SJRRP, 2014]:

- **Carrying Capacity.—**Provide adequate habitat quality and spatial extent to restore and maintain self-sustaining populations of Chinook salmon at an annual average adult return targets of 30,000 spring-run and 10,000 fall-run. This is a long-term objective that ties to the Settlement goals.

- **Temperature.—**Extend the duration of suitable rearing and migration temperatures for Chinook salmon in the spring to increase survival. This is a medium-term objective to be tackled once channel capacity exists.

- **Habitat Type Diversity.—**Restore natural diversity of in-channel (also known as main-channel or low flow channel), transitional zone, and seasonally inundated off-channel habitat, both spatially and temporally (i.e. at different flow levels or year-types), to increase life-history diversity, promote growth, reduce predation, facilitate outmigration, and increase survival. This is a long-term target to be accomplished with the site-specific projects, coarse sediment augmentation if needed, revegetation, and restored flow capacity.

- **Productivity.—**Increase primary and secondary production for a range of habitats within the SJRRP footprint, in order to promote higher prey densities, superior bioenergetics conditions, longer residence time, and increased growth. This is a medium-term target to be accomplished with site-specific project revegetation designs and passive restoration due to flows.

- **Vegetation Sustainability.—**Provide conditions for a self-sustaining native riparian community. This is a long-term goal to be accomplished with flow releases, invasive species removal, and site-specific and other projects.

- **Sediment Stability.—**Provide conditions for a stable channel with an overall sediment equilibrium on a reach by reach basis. This is a long-term goal to be accomplished with site-specific and other projects, but that may not be achievable in all locations.

- **Manage Unnatural Stranding.—**This is a medium-term target to be accomplished with site-specific projects. When it is in conflict with other objectives, such as productivity, it is lower priority.

To meet these objectives, three general habitat areas were assumed to be needed as shown in Figure 2-2.

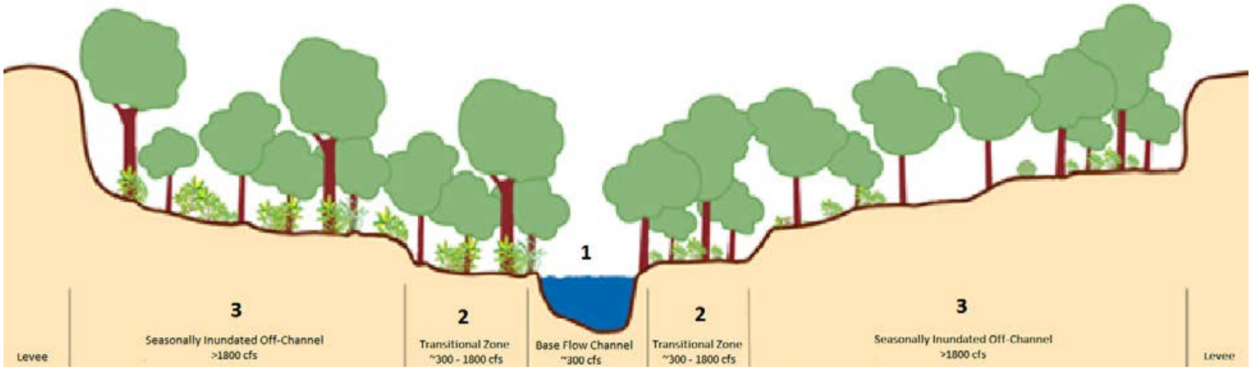


Figure 2-2.—Habitat areas identified in Habitat Rearing Objectives [SJRRP, 2014].

1. Base Flow Channel (Section 1)

    - Provides rearing habitat and migratory corridors during all years, at low flows, and during periods of elevated temperatures.

    - Widths minimized to keep temperatures low.

    - Fine structure, such as tules, to provide cover for juveniles, increasing survival, and keeping temperatures low.

2. Transitional Zone (Section 2)

    - Increases productivity and diversity of main channel habitats, reduces temperatures.

    - Forested in-channel shelves to optimize temperatures for late migrants.

    - Shelf habitat in the main channel that inundates at flows between 300-1,800 cfs; providing rearing habitat that optimizes food production, predator refuge, and migratory corridors.

    - Strategic planting of vegetation to narrow the channel, providing temperature benefits, channel stability, minimizing bank erosion, and sustaining bench inundation frequency.

3. Seasonally Inundated Off-Channel (Section 3)

    - Provides habitat diversity, escape from potential aquatic predators, and increased food and appropriate water temperatures and velocities for improved growth and survival.

    - Periodically inundated shallow aquatic habitat that contains appropriate features, such as large woody debris (LWD) and terrestrial vegetation, to provide juvenile Chinook salmon cover and refugia from predators, and high flows increasing juvenile salmon survival and reducing stress.

- Side channels to provide juvenile Chinook salmon adequate depths, velocities, temperature, food production, and potential migration routes with reduced predation, with increased inundation frequency, thereby increasing overall health and survival.

- More floodplain/wetland plants in the lower reaches of the Project footprint, as appropriate to site conditions, to increase primary and secondary productivity. Strategic planting of vegetation to maximize solar radiation in winter, increase water residence time, and reduce temperatures in spring after leaf-out.

- Functions primarily during flood control releases and during pulse flow releases > ~1,800 cfs depending on the specific location.

There are various channel features that can be categorized in the above habitat areas.

1. Base Flow Channel
    - Permanent main channel habitat
    - In channel shelves and narrow low flow channels
    - Multiple low flow channels
    - Perennial marsh
2. Transition Zone
    - Low floodplain surfaces adjacent to base flow channel
    - Split flow channel inundated just above base flow
3. Seasonally Inundated Off-Channel Habitat
    - Seasonally inundated floodplain
    - Seasonally inundated side channel
    - Seasonally inundated depressions

2.3 Conveyance of Flows for Restoration, Flood and Diversion Operations

The SJRRP will restore perennial flow to Reach 2B, whereas prior to the SJRRP, the upstream end of Reach 2B only received water under flood release scenarios. The SJRRP will also increase the flow capacity of Reach 2B to 4,500 cfs. The original design capacity of Reach 2B was 2,500 cfs and currently is limited to 1,120 cfs [SJRRP, 2015] because of concerns of water seepage and levee stability.

The restoration flow schedules for Reaches 2 and 3, as defined by the Settlement, are given in Figure 2-3 and Figure 2-4, respectively. However, the actual flows in the reach will also be influenced by flood operations, which can increase or decrease flows in a given year. Hydrologic simulation is necessary to develop a full range of hydrologic scenarios which will be used to analyze the performance of the floodplain design. A RiverWare hydrologic model was developed by the TSC [Reclamation, 2012b]. The RiverWare model uses historical tributary and inflow data and operates the San Joaquin system consistent with the Settlement.

The RiverWare simulated flows under SJRRP for the period using the historical inflows from 1923 to 2003 is shown in Figure 2-5 for the stream gage SJR, which is located at the upstream end of Reach 2B. The highest flows are limited to 4,500 cfs in Reach 2B. The flow is zero more than 10 percent of the time in Reach 2B during the month of May. This is because there is a forecast component in the RiverWare model in which a 90 percent flow forecast is used to choose the water year type for the month of May, meaning that in 90 percent of the years the flow volume would be greater than that forecast. The forecast component is necessary to represent the uncertainty water managers will have when releasing water in the early spring. The water year type can be critical-low, critical-high, dry, normal-dry, normal-wet and wet. Whereas after May, a more accurate water forecast is available and more flow will generally be available for restoration flows. The 99 percent exceedance flow is zero for all months because in critical-low years there is zero restoration flow available.

There are four basic flow scenarios involving restoration flows, flood flows, and water deliveries that will typically occur in Reach 2B:

- In critical-low to normal-wet water year types, restoration flows will proceed through Reach 2B and irrigation deliveries and diversions will occur in Mendota Pool with no interaction between the Restoration Flows in Reach 2B and Mendota Pool.

- In wet water year types, flood releases from Pine Flat Reservoir may be bypassed to the SJR via Fresno Slough and Mendota Pool. Due to capacity restrictions downstream of Reach 2B, the addition of these flows further restricts the amount of flow that can enter Reach 2B, and more SJR flows will be diverted into the Chowchilla Bypass to compensate. Some portion of the SJR flows is anticipated to perform as restoration flows in Reach 2B, but the flood management agencies will have ultimate discretion in directing flood flows.

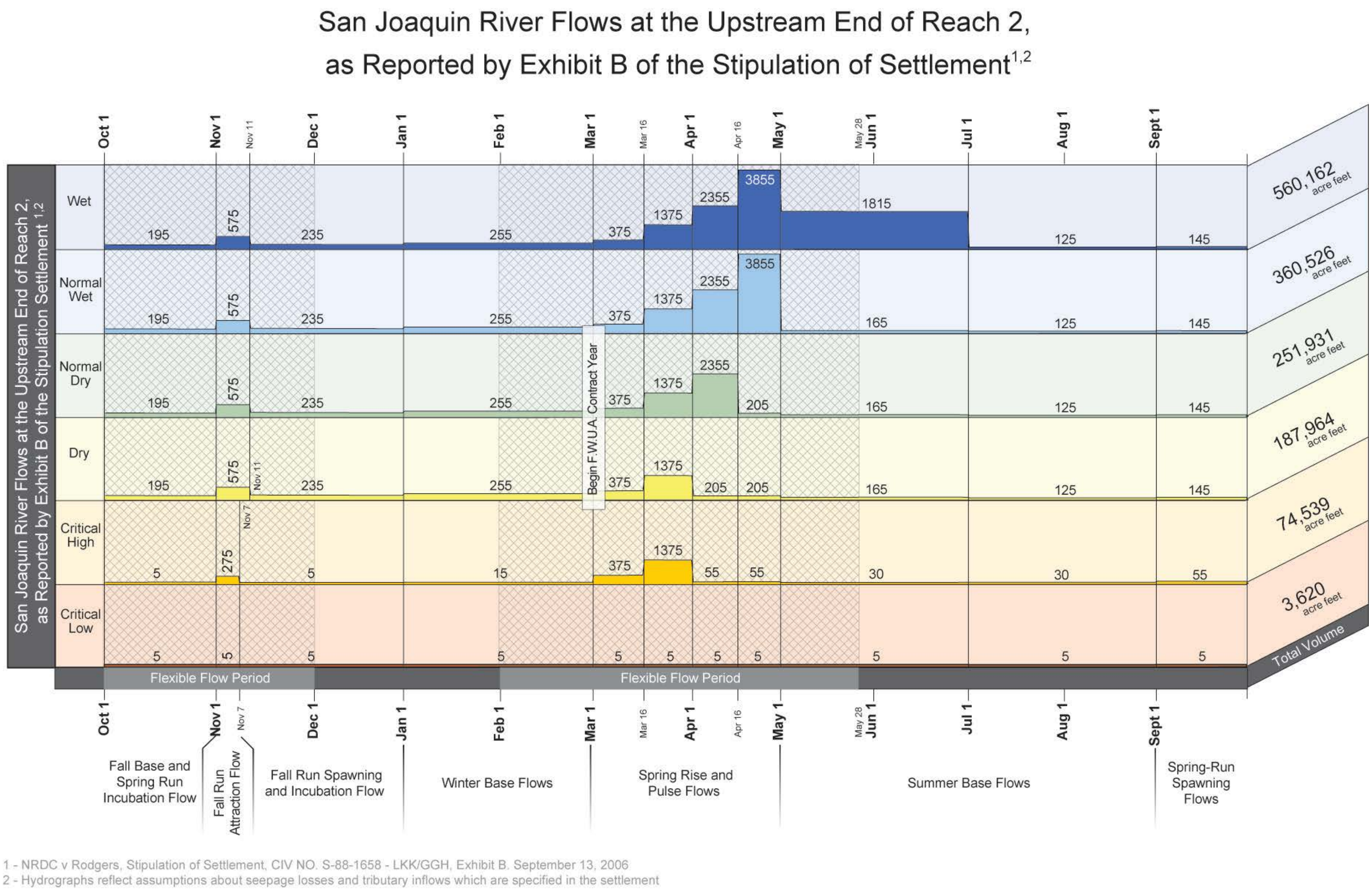


Figure 2-3.—San Joaquin River flows at upstream end of Reach 2 as reported in Exhibit B of Stipulation of Settlement.

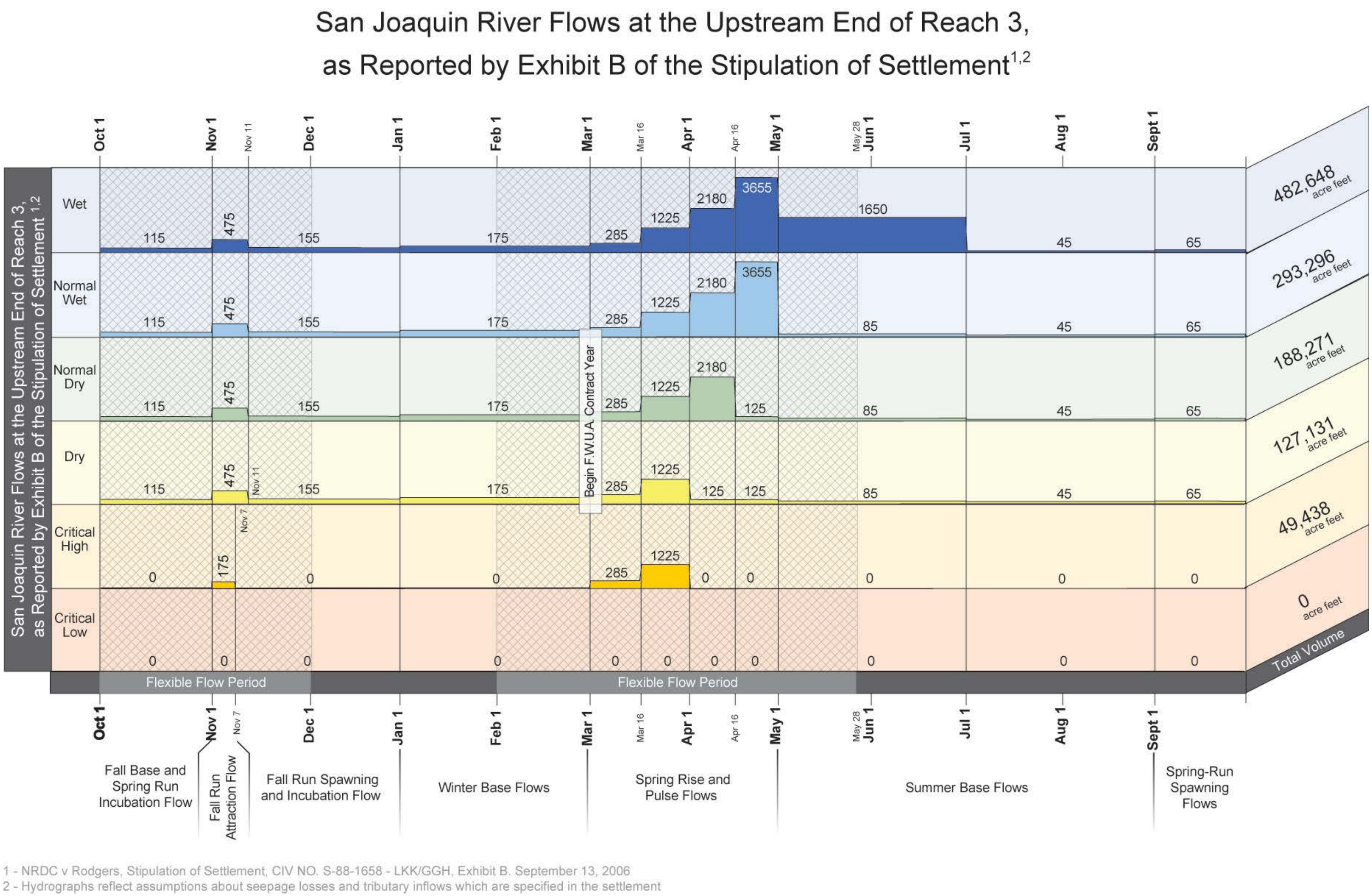


Figure 2-4.—San Joaquin River flows at upstream end of Reach 3 as reported in Exhibit B of Stipulation of Settlement.

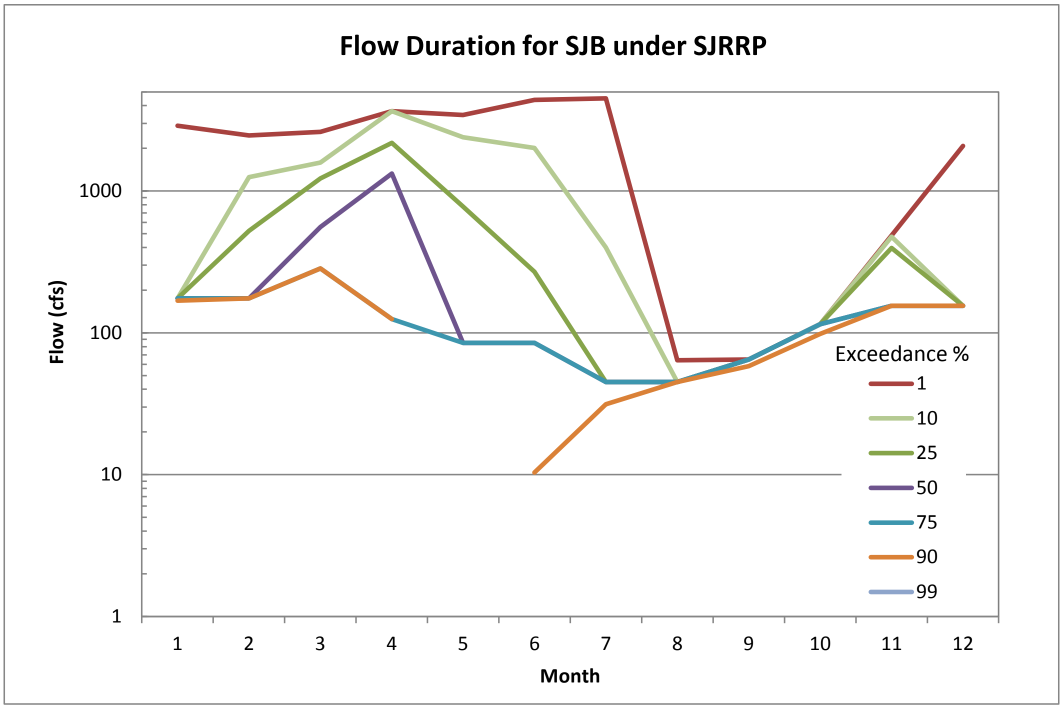


Figure 2-5.—Simulated monthly flow duration at SJR (stream gage at upstream end of Reach 2B) under the SJRRP. The 99 percent exceedance is 0 for all months and not shown on log-scale plot.

- In normal-wet to wet water year types, flood releases from Millerton Lake may be diverted from Reach 2B into the Chowchilla Bypass as well as to Mendota Pool where they can be used to fulfill water contracts or by legal water rights holders while alleviating pressure on the flood system. Some portion of these flows is anticipated to perform as Restoration Flows in Reach 2B, but the flood management agencies will have ultimate discretion in directing flood flows.

- In all water year types, water can also be released from Millerton to make water deliveries to Mendota Pool where they can be used to fulfill water contracts or used by legal water rights holders.

To meet these flow scenarios, the hydraulic system should be able to achieve the flow conditions shown in Table 2-2 while still meeting fish passage criteria to the extent possible. There are three potential water operations conditions: 1) Restoration, 2) Flood, and 3) Delivery to Mendota Pool (Delivery), and then there are two potential combinations of the three operation conditions: 1) Restoration and Delivery and 2) Flood and Delivery. The values shown in Table 2-2 are intended to span the range of potential operations and not resolve all potential intermediate operational scenarios. The flow schematic is shown in Figure 2-6.

Table 2-2.—Range of Design Conditions for Flow Operations for the Mendota Bypass Project. Values Shown Represent Discharge in cfs

Scenario	Reach 2B	Bypass	Reach 2B Below Bypass	Fresno Slough	Reach 3 Above Bypass	Reach 3 Below Bypass
Restoration	45-4,500	45-4,500	0	0	0-600	45-4,500
Flood	45	45	0	4,455	4,455	4,500
	4,500	4,500	0	0	0	0
Delivery to Mendota	0-2,500	0	0-2,500	0	0-600	0-600
Restoration /Delivery	2,595	45	2,500	0	45-600	45-645
	4,500	2,000	2,500	0	0-600	2,000-2,600
Flood/Delivery to Mendota	4,500	2,000-4,500	0-2,500	0	0	2,000-4,500
	2,500	2,500	2,500	4,500	4,500	4,500

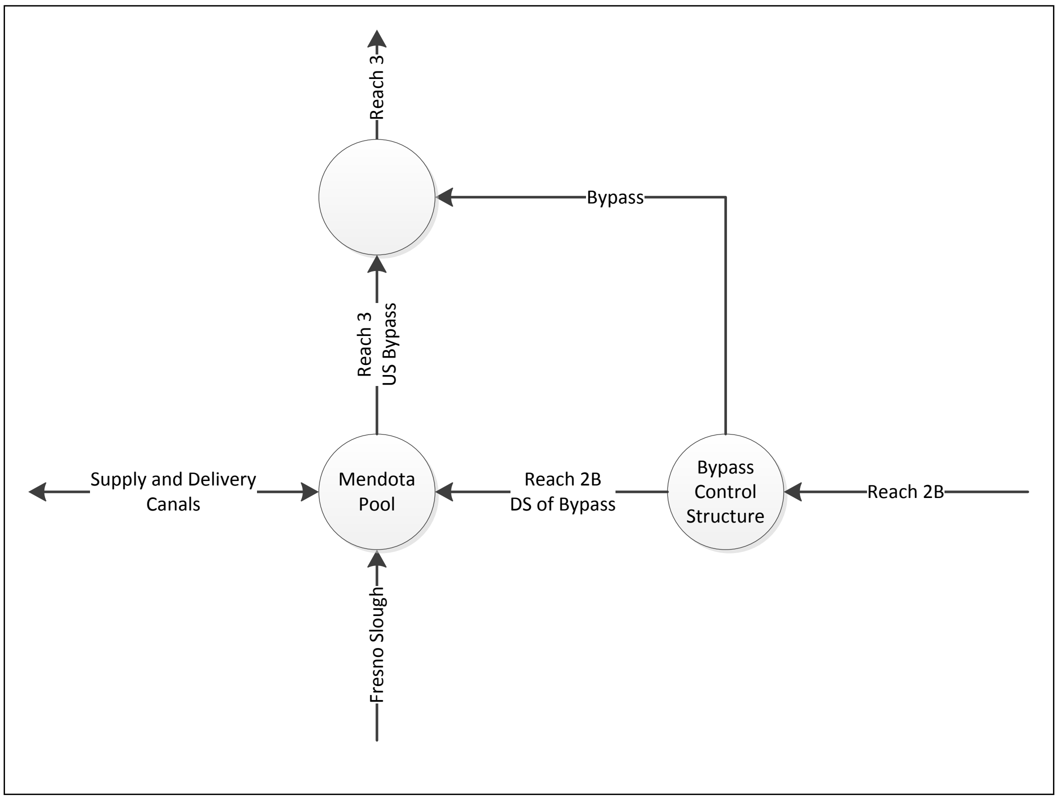


Figure 2-6.—Flow schematic of Bypass Project.

2.4 **Sediment Transport**

The primary objective of the sediment transport conditions is to prevent undesirable bed erosion or deposition in Reach 2B and the adjacent Reaches 2A and 3. This is often described as a sustainable channel or stable channel since the transport of sediment into the Project reach should match the transport of sediment out of the reach. Some immediate erosion and deposition is expected due to the large increase in peak flows within Reach 2B and the construction of the Bypass, but there should be no long-term erosion and deposition within the reach that is undesirable.

To be a sustainable channel, sedimentation at structures should be minimized and there should be no longer term dredging required near structures and within the channel. When structures restrain the morphology of the channel, some maintenance at grade control or bank protection locations will be required. The first goal is to develop a sustainable channel design, but if this cannot be done, the selected design should minimize anticipated maintenance.

2.5 Subsidence

There is active subsidence occurring in Reach 2B and in reaches downstream [Reclamation, 2012c]. The design goal is to account for the direct and indirect effects of subsidence at structures and in the channel profile design. Also, part of the design goal is that future subsidence will not threaten channel sustainability or structure stability. The current subsidence rates, along with the potential total subsidence if these rates were to continue for a given period of time is provided in Table 2-3.

Table 2-3.—Current Subsidence Rates Near Reach 2B along the San Joaquin River

River/Bypass Reach: (River Mile(RM)/Mile Post to RM/Mile Post)	Subsidence Rate (ft/yr)	Projected Total Subsidence in 25 yrs (ft)
Reach 2B (RM 216.3 to RM 210.0)	0.10	2.50
Reach 2B (RM 210.0 to RM 207.0)	0.15	3.75
Reach 2B (RM 207.0 to RM 204.0)	0.20	5.00
Reach 3 (RM 204 to RM 200.2)	0.20	5.00
Reach 3 (RM 200.2 to RM 196.9)	0.10	2.50
Reach 3 (RM 196.9 to RM 194.9)	0.20	5.00
Reach 3 (RM 194.9 to RM 188)	0.30	7.50
Reach 3 (RM 188 to RM 184.5)	0.20	5.00
Reach 3 (RM 184.5 to RM 182.7)	0.30	7.50
Reach 3 (RM 182.7 to RM 182.0-Sack Dam)	0.40	10.00

2.6 Vegetation

Vegetation objectives were suggested by ESA [ESA 2012], and a modified version of them follows:

- Short-term Goals (Years 1 to 10):
  - Maintain suppression of invasive plants to limit impacts to habitat and competition with native species
  - Revegetate newly created channel to provide sediment stability
  - Establish widespread beneficial vegetation within the bypass floodplain, uplands, and channel margins to enhance habitat diversity and inhibit invasive weed colonization
  - Manage flows through the Bypass to promote establishment and growth of native riparian vegetation
  - Use woody species to encourage channel and floodplain complexity

- Long-term Goals (Years 10 to 30):
  - Contiguous expanses of multi-tiered native vegetation within the bypass (target acreage to be determined following more detailed revegetation design of the selected alternative)
  - Areas of natural riparian recruitment where sediment is deposited or vegetation removed by natural processes to promote continual habitat succession
  - Natural recruitment and addition of LWD to the channel and floodplain
  - Well established and sustainable ecosystem including a mosaic of herbaceous, shrub, and tree communities

2.7 Design Objectives Summary

Project design objectives for the Bypass are consistent with the SJRRP goals that are to pass and support Chinook salmon fisheries, and to manage flows in a manner that minimizes impacts to water delivery.

The goal of the Project is to bypass the Mendota Pool with a system that promotes and maintains Chinook salmon migration. Essential design objectives, based on the more detailed goals, objectives, and desired conditions described above, are listed as:

- For the Bypass, accomplish Category B passage for high flows (greater than 1,000 cfs) and Category C passage for low flows (less than 1,000 cfs) during passage of restoration flows.

- During deliveries to Mendota Pool, which happen infrequently only during flood flows or very dry years, a fish passage facility will be constructed around the Bypass control structure and will accomplish Category C passage.

- Promote survival of the species through development of appropriate and sustainable habitat.

- The Bypass should convey at least 4,500 cfs. This improvement requires construction of a structure capable of directing flow down the bypass and allowing the Secretary of Interior to make deliveries of SJR water into Mendota Pool when necessary.
- Maintain current flood conveyance capacities in Reach 3.
- Minimize both construction and maintenance cost.
- Create a sustainable stream profile that minimizes long term sediment imbalances within the project area.

3 Hydraulic Studies

The hydraulic data and analysis used to support the hydraulic design is described in this section.

3.1 Description of Hydraulic Model

The above water topography used in the hydraulic model is based upon 2008 LiDAR mapping that was recently developed for CDWR in the North American Vertical Datum of 1988 (NAVD88). The below water topography is based upon several different bathymetric surveys listed in Table 3-1 performed by California Department of Water Resources (CDWR) and Reclamation.

Table 3-1.—Dates of Bathymetry Surveys

Reach	Date of Bathymetric Survey
2A	March-April 2010 (CDWR)
2B	March, August, September, 2009 (CDWR) April 2010 (Reclamation)
3	March, August, September, 2009 (CDWR) April 2010 (Reclamation)

The HEC-RAS model for Reach 2B under project conditions was described in Attachment D – Hydraulics Modeling Memo of the Project Description [SJRRP, 2012b]. The HEC-RAS model used for existing conditions in Reach 3 is documented in Tetra Tech [2013]. The hydraulic roughness values were calibrated to observed water surfaces collected in 2010 and 2011 as part of this study.

The HEC-RAS model for the Bypass was developed using HEC-GeoRAS 10.2 and appended to the downstream end of the Reach 2B model. HEC-GeoRAS 10.2 is an extension to ArcGIS 10.2 and available for download at: http://www.hec.usace.army.mil/software/hec-georas/. ArcGIS 10.2 is a geographic information system (GIS) for working with maps and geographic information (https://www.arcgis.com). The channel excavation tools within HEC-RAS were used to create the initial excavated channel through the Bypass.

The hydrology, hydraulic and sediment transport have been analyzed in Reclamation [2015]. The hydraulics in the Bypass have been updated to reflect the current grading plan and structural design. The cross section layout used in the hydraulic model in the Bypass is given in Figure 3-1.

The roughness in the low flow channel of the Bypass was assumed to be 0.035, the first stage of the floodplain was assumed to have a roughness of 0.08, and the second stage of the floodplain was assumed to have a roughness of 0.12. The upland was assumed to have a roughness of 0.06. There is considerable uncertainty regarding the roughness in the Bypass because it is not fully possible to estimate the future dynamics and vegetation growth within the Bypass. The estimates are intended to be for the case far into the future after the vegetation has reached a relatively stable state.

There are two basic hydraulic conditions in the Bypass: 1. The Bypass Control Structure Gates will be fully open and Restoration flows are passing through the Bypass, and 2. The Bypass Control Structure Gates will be partially closed with both Restoration Flows and Delivery Flows occurring.

3.2 Restoration Flows in the Bypass

Restoration flows will occur primarily when the Bypass Control Structure gates are fully open. The water surface profiles for this condition are given in Figure 3-2. Example cross sections and the associated water surface elevations are given in Figure 3-3, Figure 3-4, and Figure 3-5, for cross section numbers 3200, 2200, and 1200, respectively.

The channel velocities for flow between 50 and 4,500 cfs are given in Figure 3-6. The channel velocities increase on the downstream end of the reach for flows below 2,000 cfs. After incision into Reach 2B and deposition in Reach 3 occurs the velocities will be more uniform throughout the Bypass.

The channel depths for flows between 50 and 4,500 cfs are given in Figure 3-7. The channel depths are greater than 1.2 ft for all flows above 100 cfs.

The inundation depth in the Bypass as estimated from HEC-RAS is given in Figure 3-9 and Figure 3-10 for flows of 2,000 and 4,500 cfs respectively.

3.3 Delivery Conditions

It is difficult to determine the frequency with which deliveries to Mendota Pool from the San Joaquin River will occur. The historical frequency is not necessarily a reliable indication because of shifts in operational rules for the Delta-Mendota Canal flows, the changes in operations caused by the SJRRP itself, and potential changes in the precipitation amount and distribution caused by climate change. The only two years in which deliveries from the San Joaquin River occurred since Friant Dam's completion in 1942 have occurred in the last 3 years.

The water surfaces in Reach 2B will be significantly higher under delivery conditions because the water surface elevation will need to be sufficient to reach the pool elevation which is typically between 154 and 154.5 ft. It is necessary to compute the water surface elevations in Reach 2B because a portion of the Reach 2B levees will be constructed as part of this design. Their construction will be combined with the regrading of Columbia Canal, which is located along the north side of the Bypass and Reach 2B. The levees in Reach 2B will be designed to the case when all 4,500 cfs is passed through Mendota Dam as this will create the highest water surface condition in Reach 2B.

Two water surface profiles in Reach 2B for the case of 4,500 cfs being routed through Mendota Pool are given in Figure 3-11. The lower water surface profile is based upon the current topography as defined from the surveys described in the previous section.

The upper profile is intended to provide the design condition for the levees so that if 5 ft of subsidence occurs at Mendota Pool, the levees will still have 3 ft of freeboard. The 5 ft of subsidence is the design criteria taken from Table 2-3.

1

Figure 3-1.—Cross section layout in Bypass.

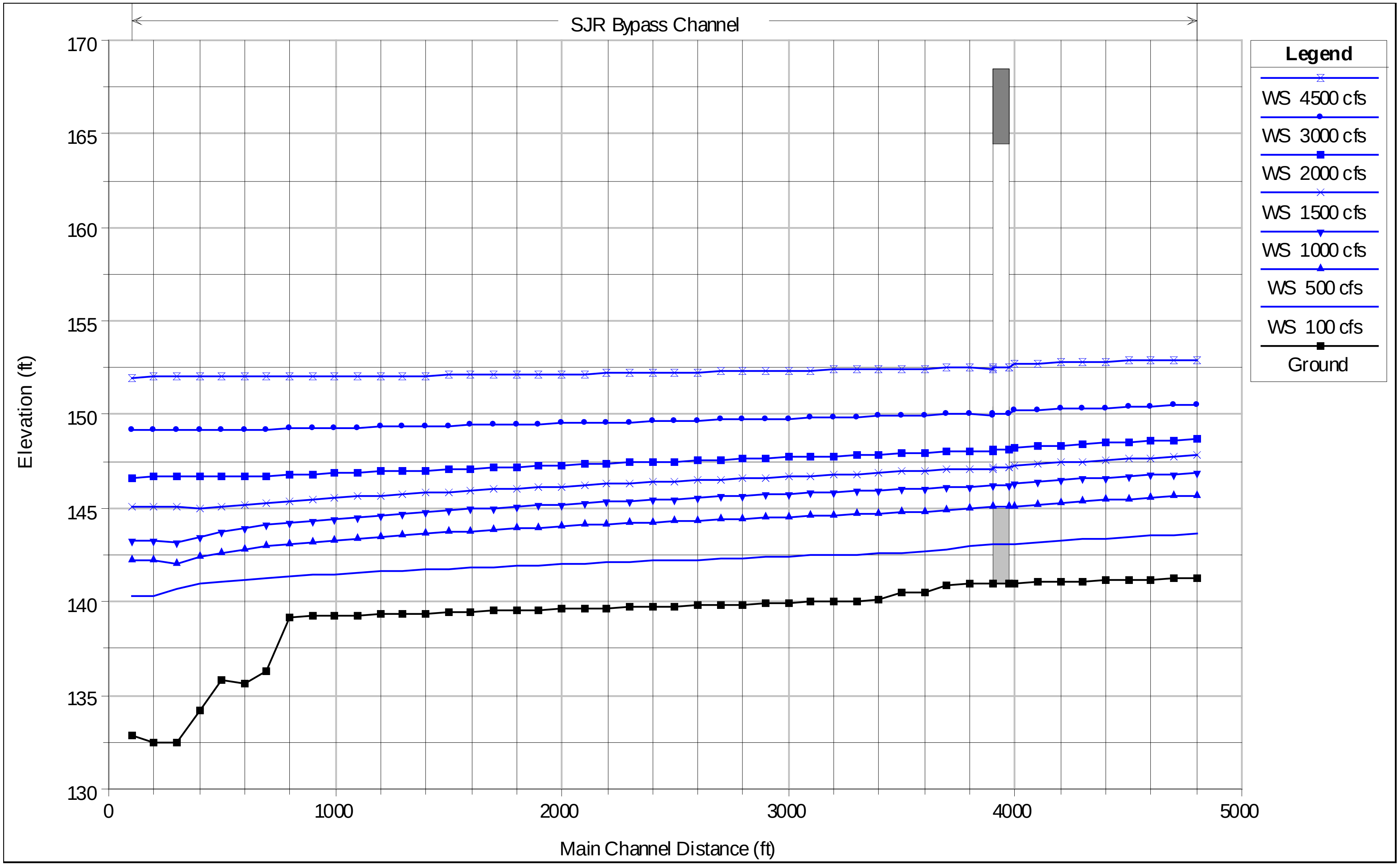


Figure 3-2.—Water surface profile in Bypass for flows between 100 and 4500 cfs.

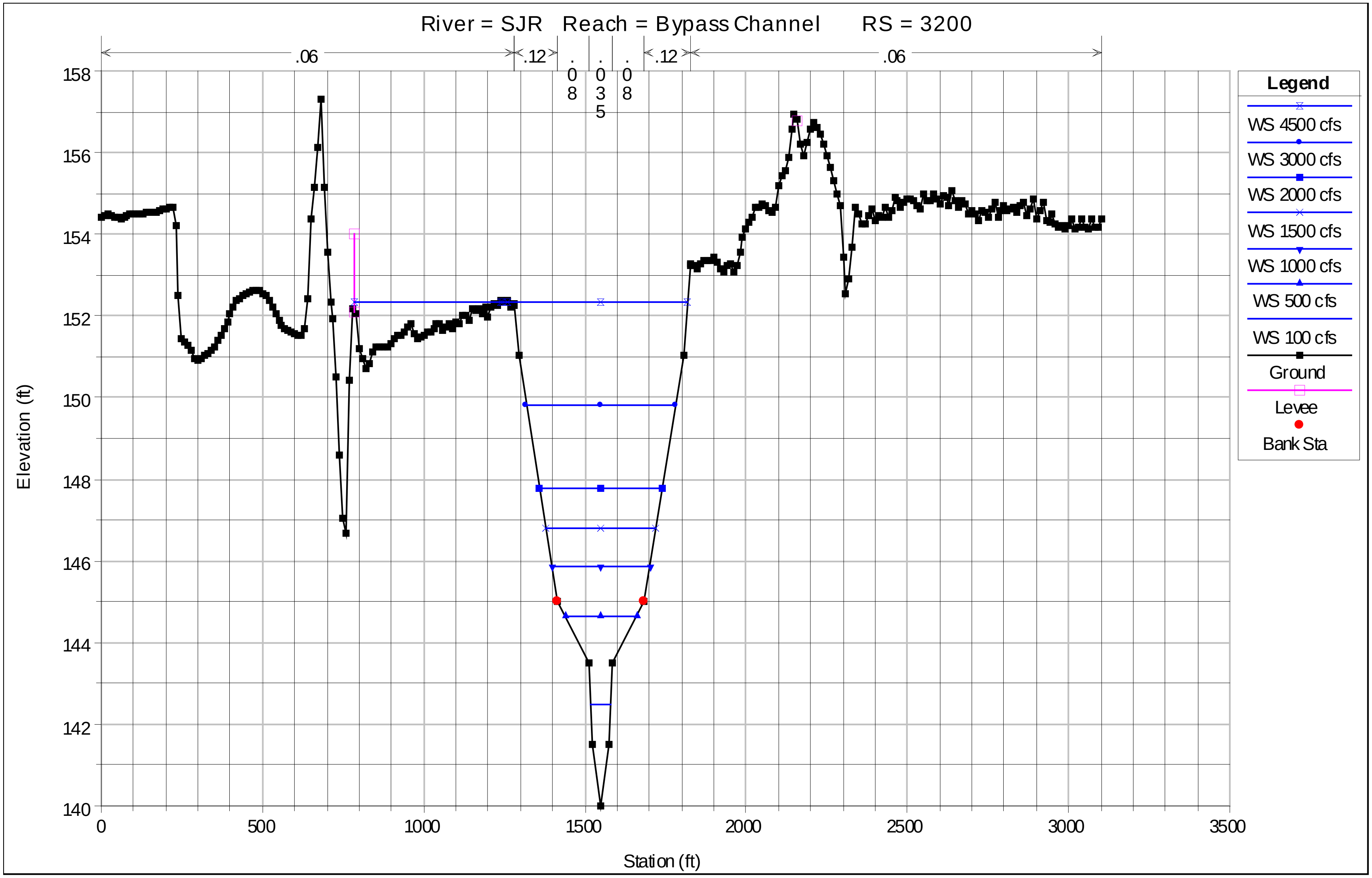


Figure 3-3.—Cross section 3200 in Bypass showing water surfaces.

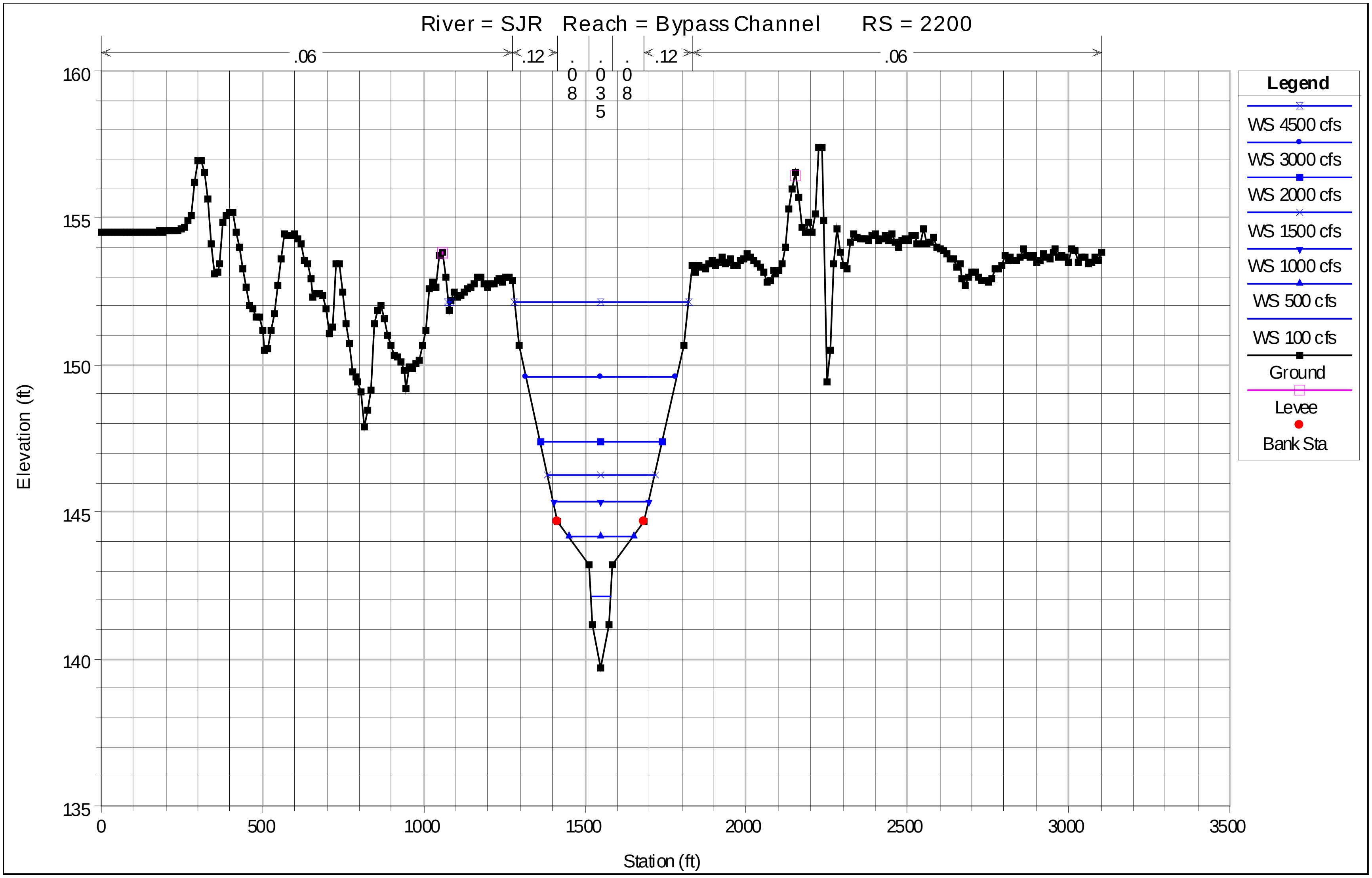


Figure 3-4.—Cross Section 2200 in Bypass showing water surfaces.

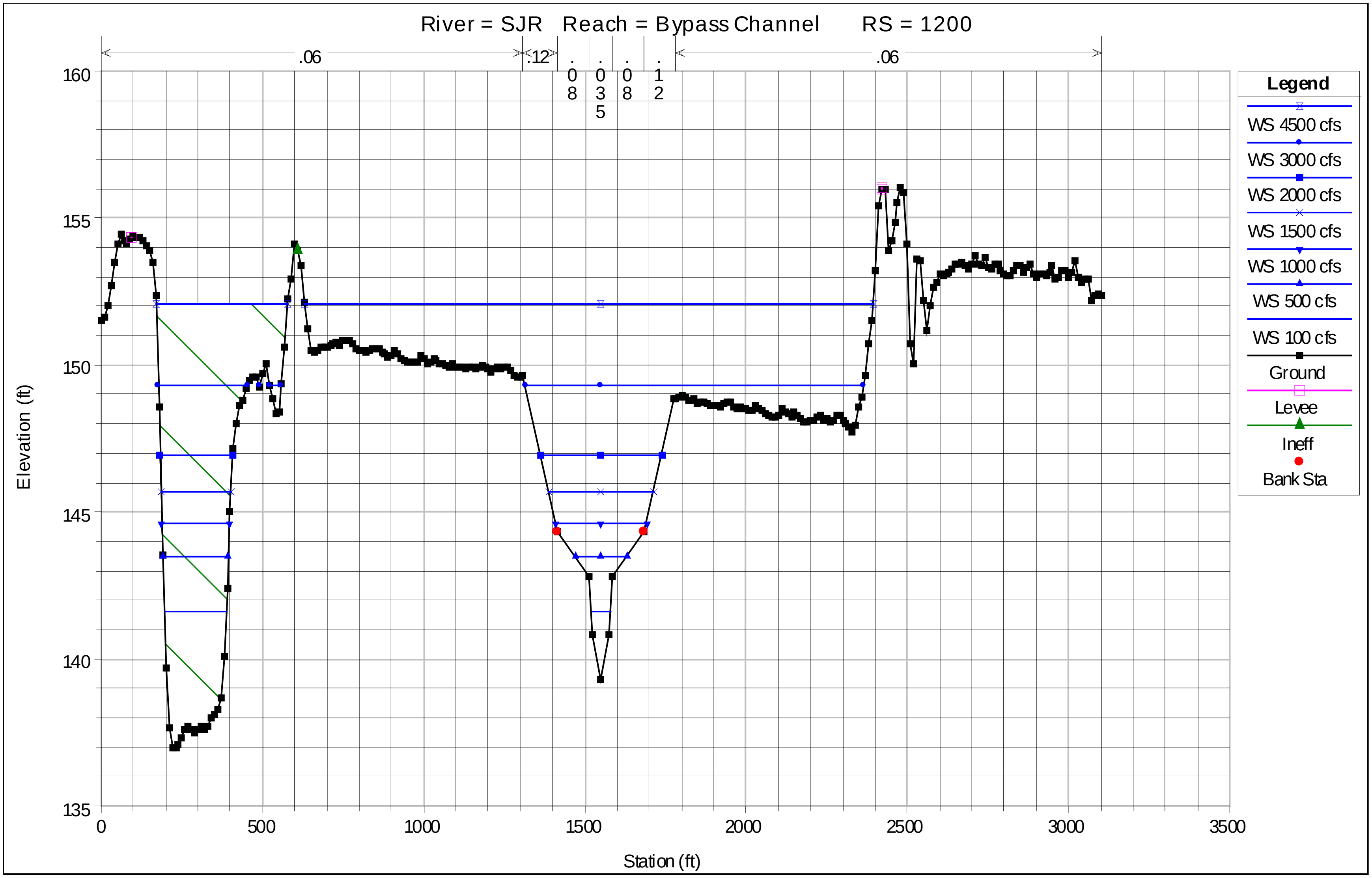


Figure 3-5.—Cross section 1200 in Bypass showing water surfaces.

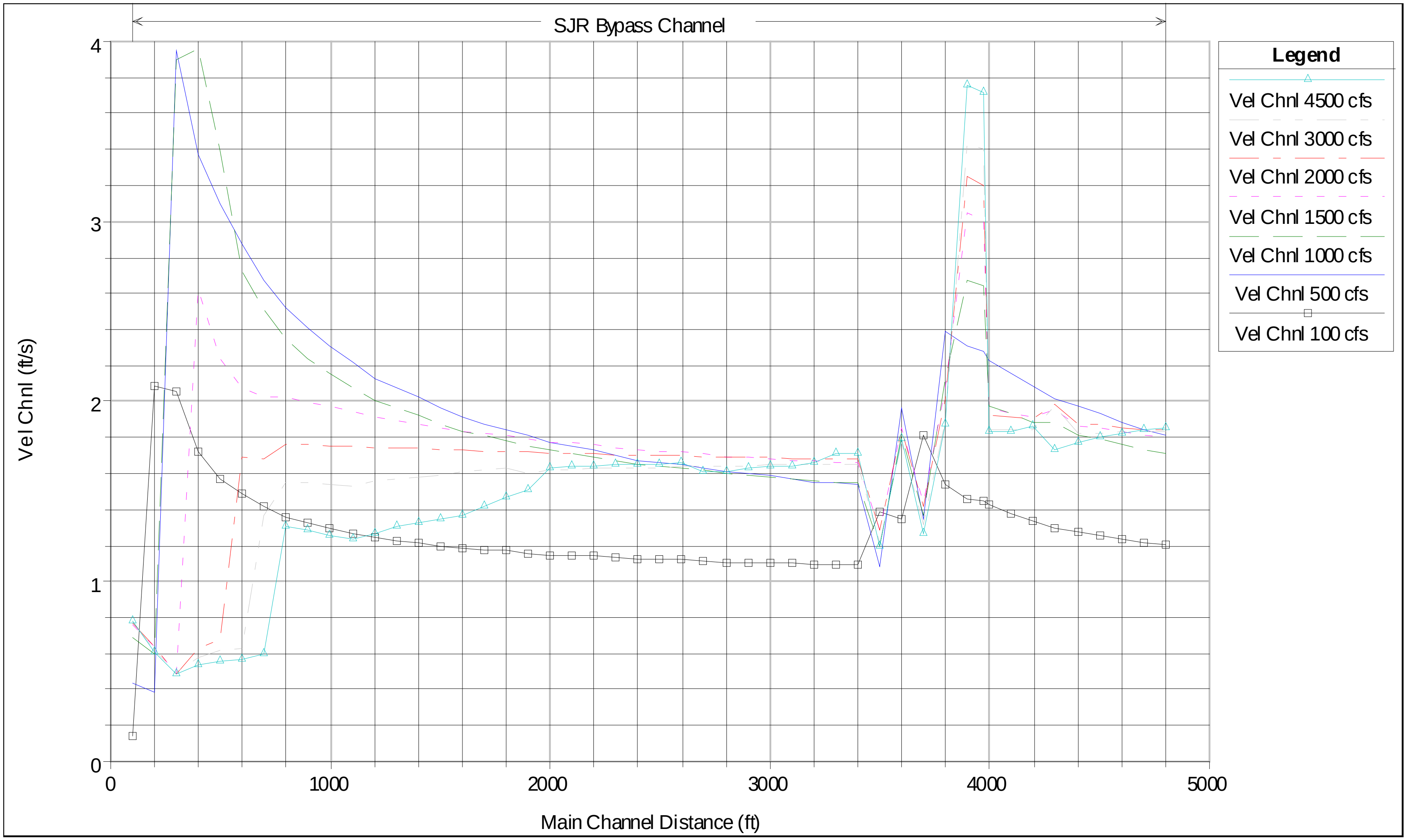


Figure 3-6.—Average channel velocity in Bypass for flows between 100 and 4500 cfs.

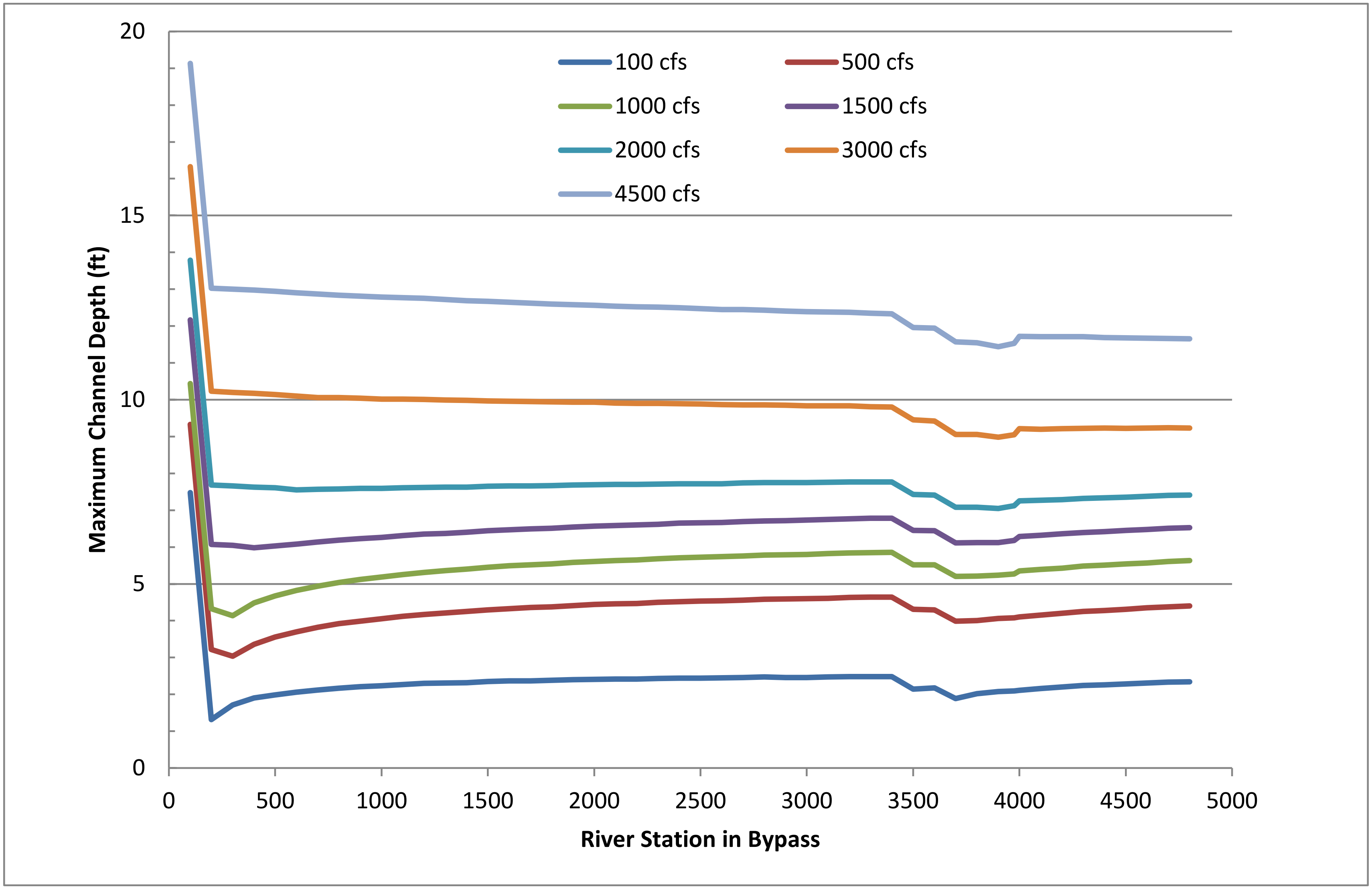


Figure 3-7.—Channel depth in Bypass for flows between 100 and 4500 cfs.

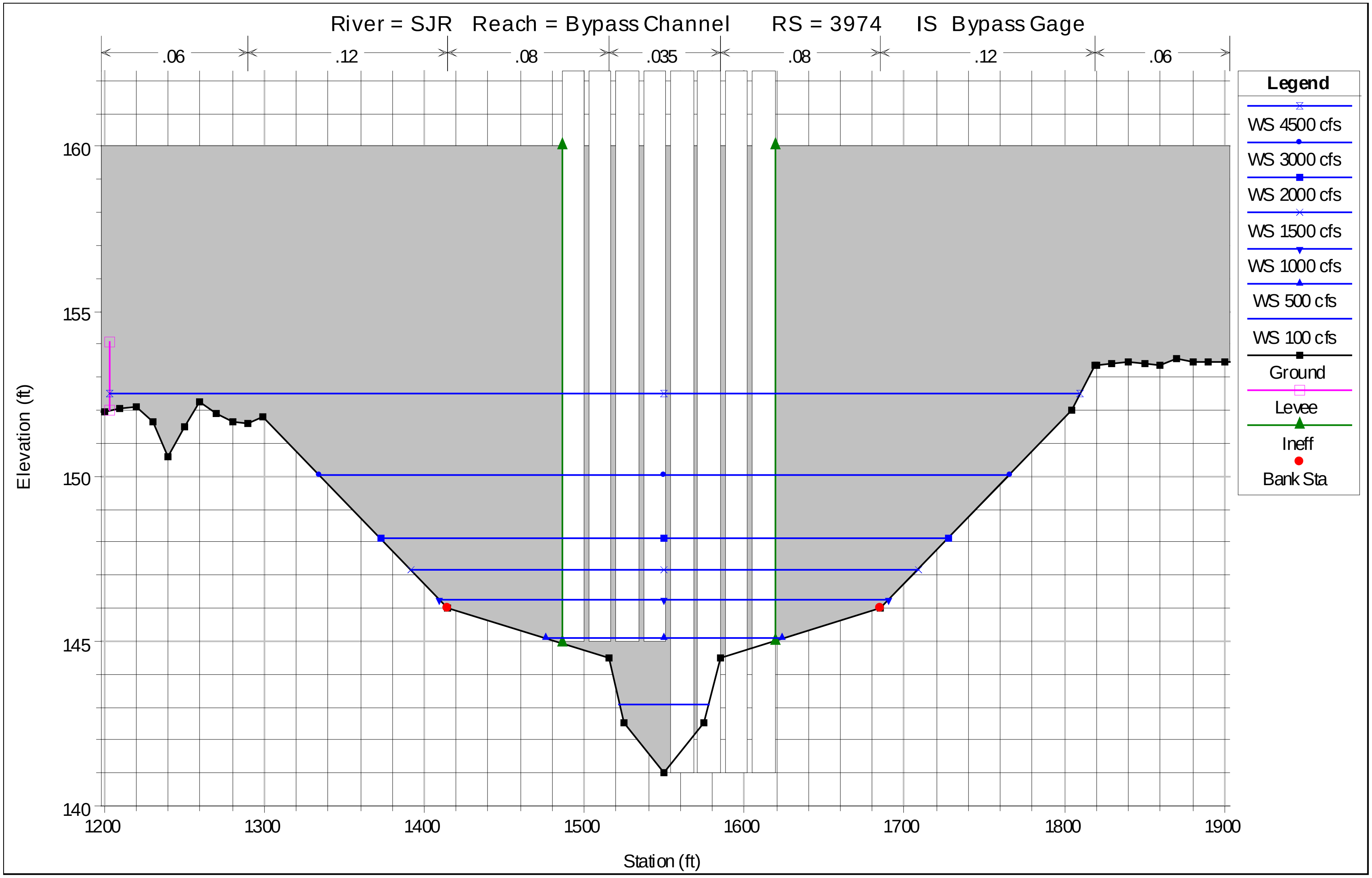


Figure 3-8.—Water surfaces at control structure at head of the Bypass. The gate openings are given and the structure and abutments are shown in gray.

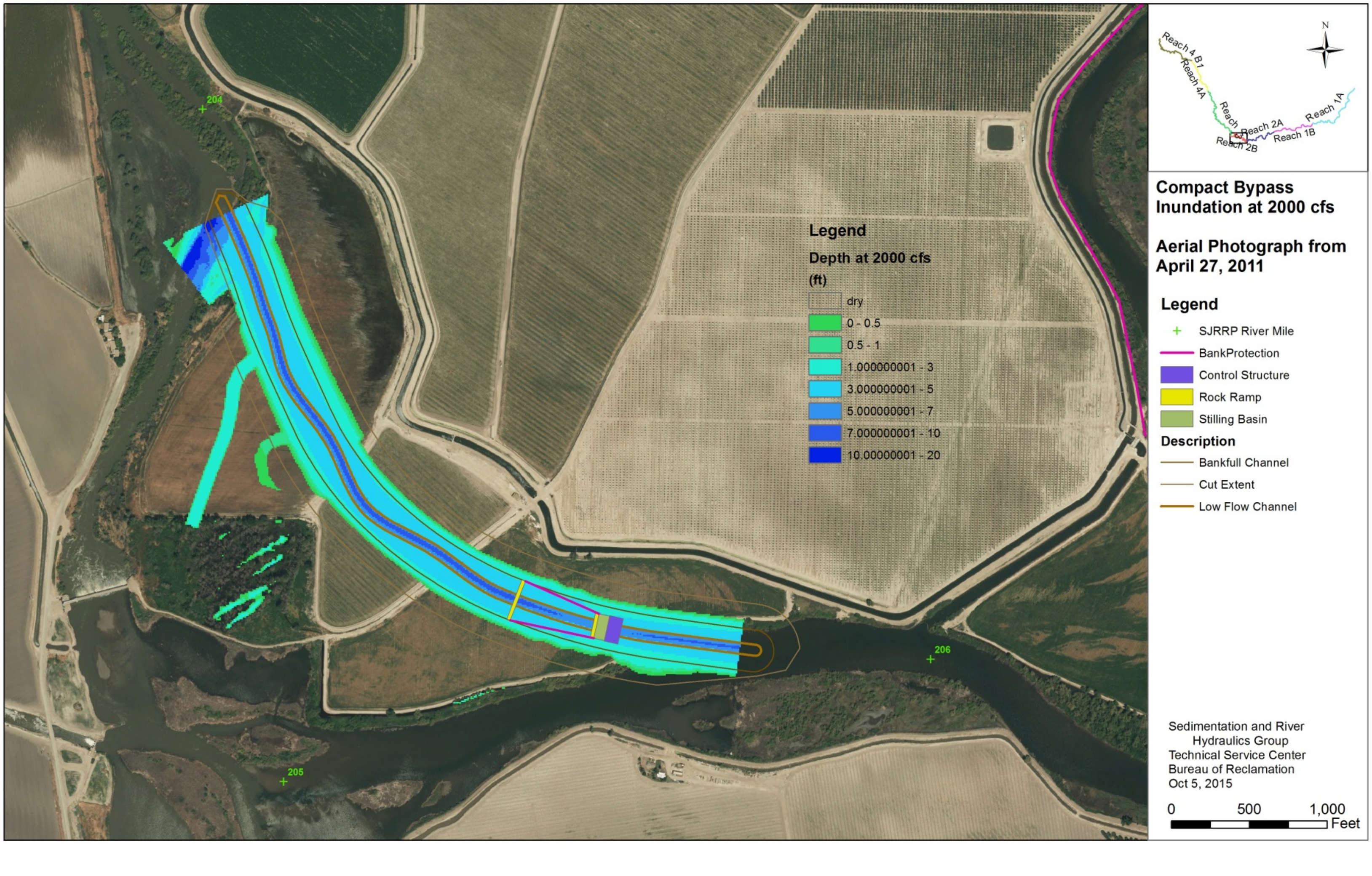
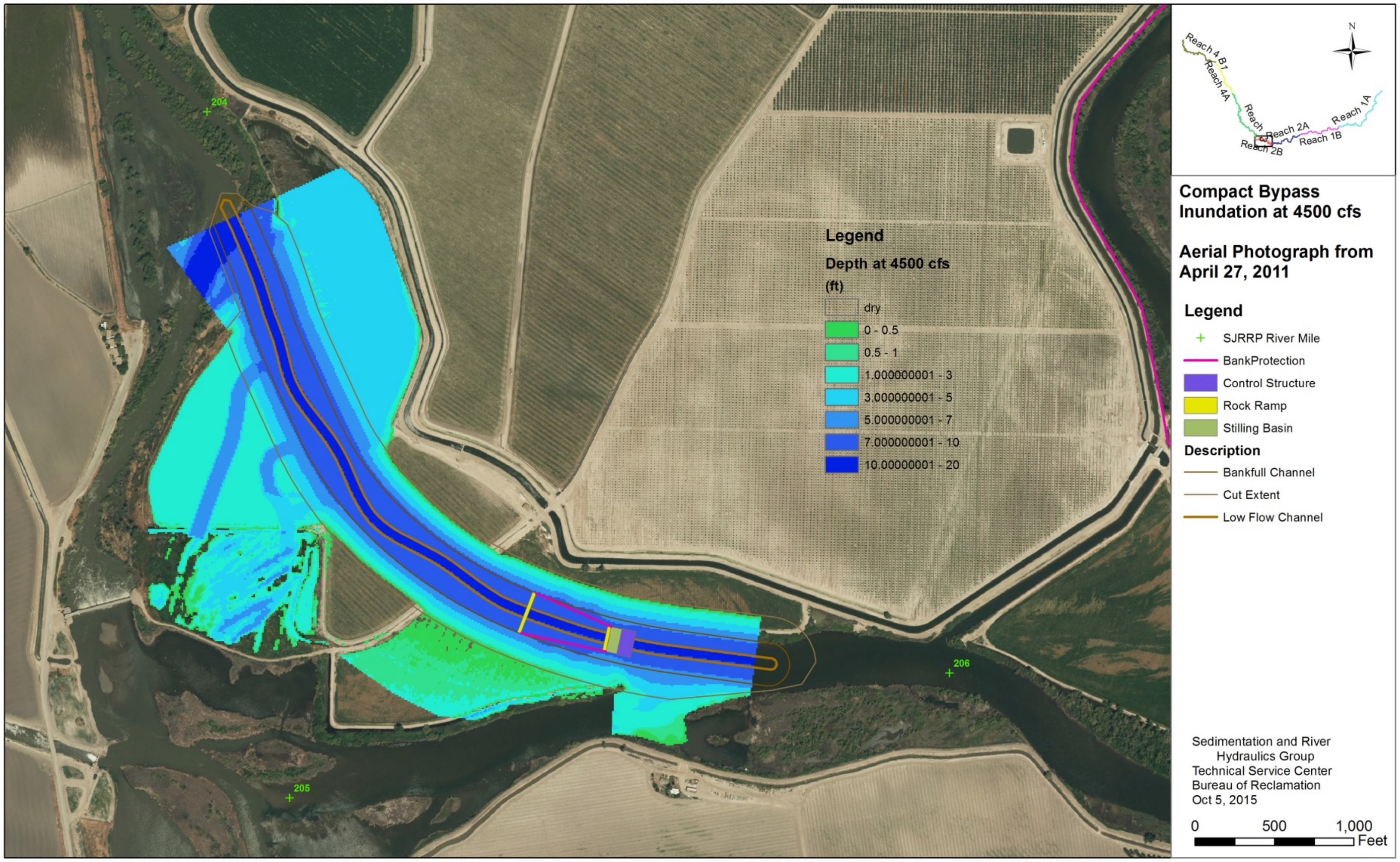


Figure 3-9.—Water depths in Bypass for a flow of 2000 cfs.



1

Figure 3-10.—Water depths in Bypass for a flow of 4500 cfs.

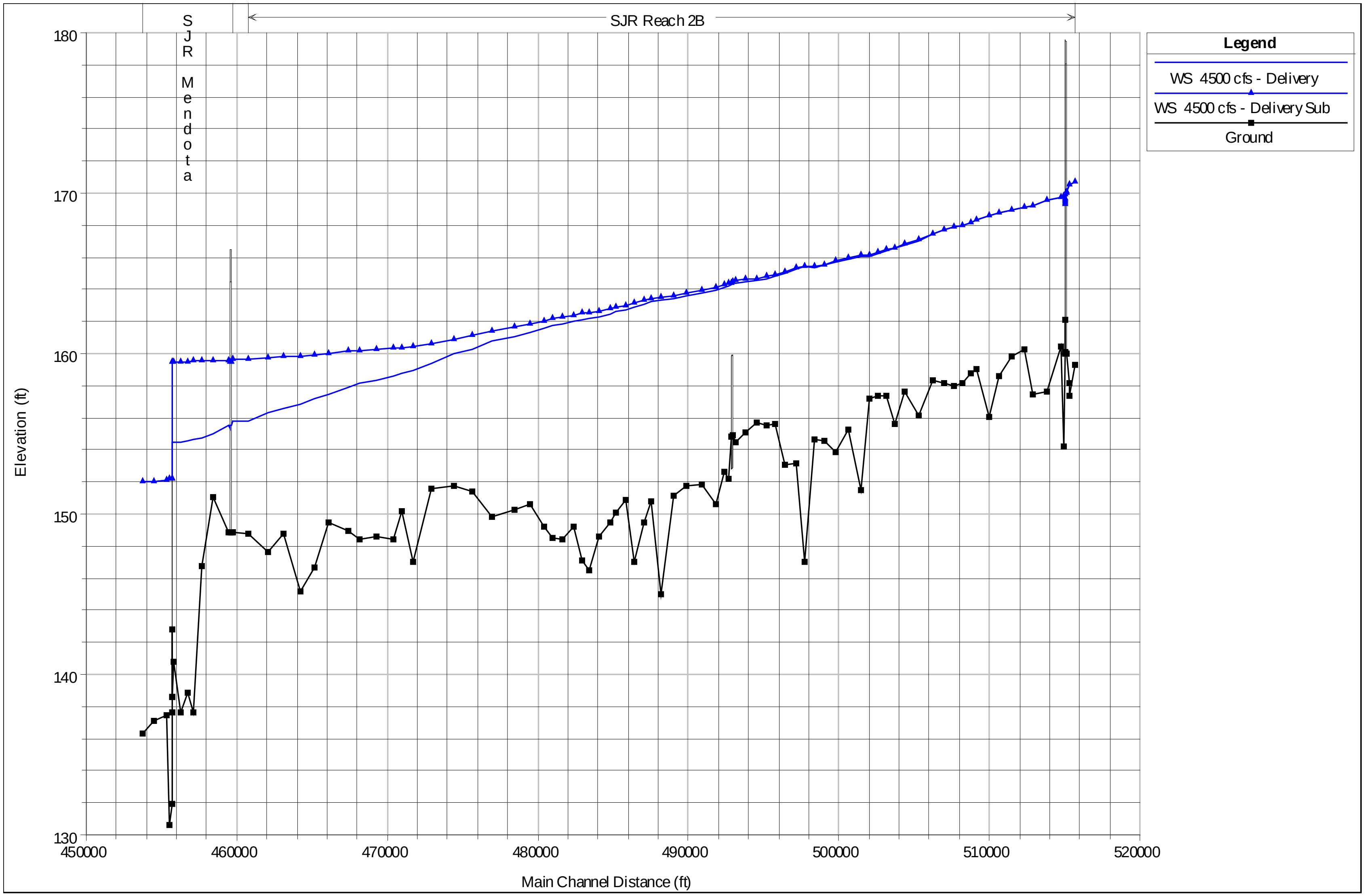


Figure 3-11.—Water surface profile in Reach 2B for Delivery Conditions with current topography and assuming that the water surface required for delivery rises 5 ft relative to ground surface to account for subsidence.

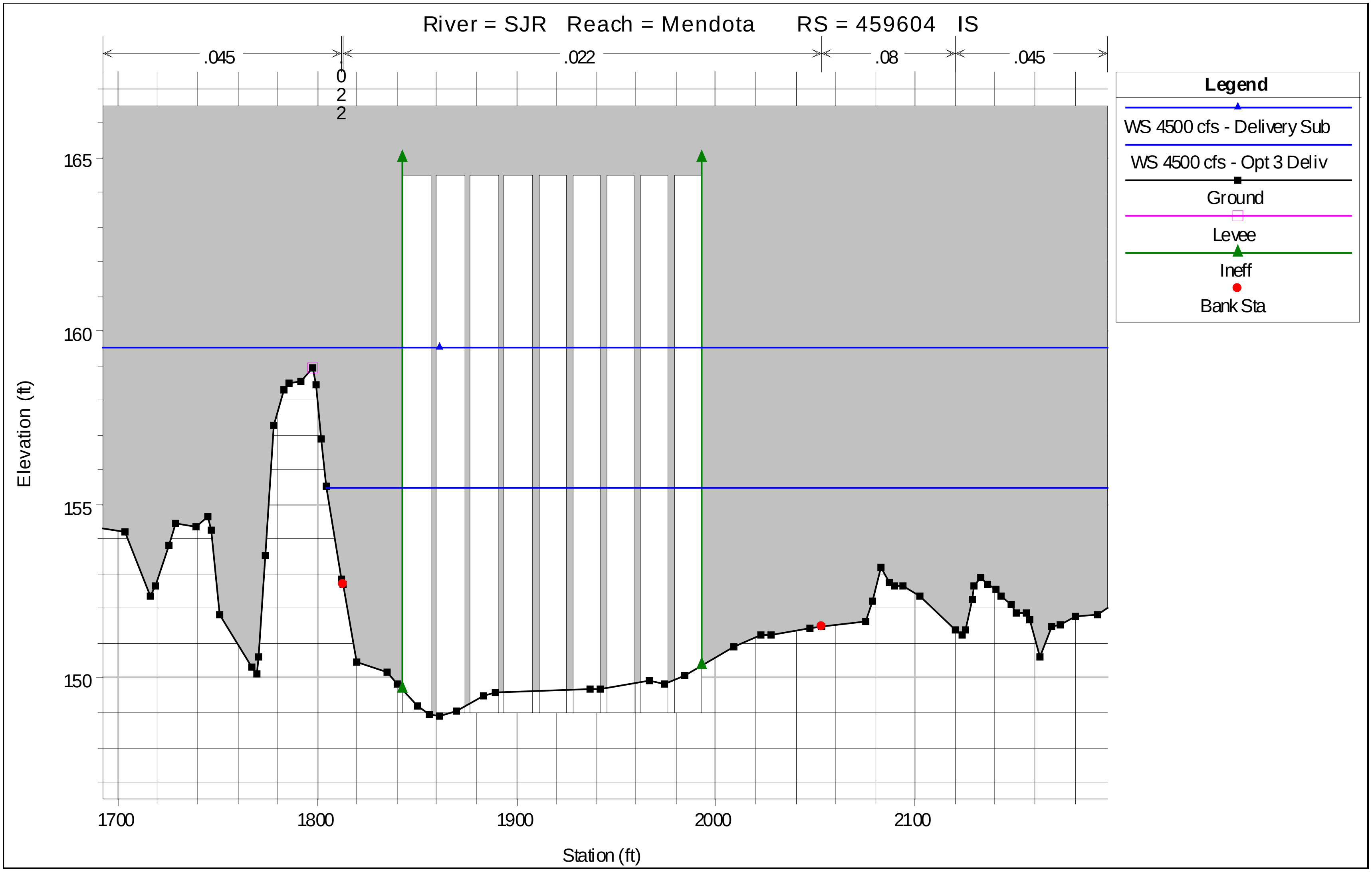


Figure 3-12.—Cross Section at Mendota Pool Control Structure.

4 Revegetation Background Data

4.1 Site History

The earliest available photographs of the site were taken in 1937 (Figure 4-1), after the construction of Mendota Dam (built in 1871), and suggest the area had already been influenced by both the dam and agricultural practices to some extent. The photos depict several relatively large areas of dense vegetation, particularly along the southern border near the river channel. In contrast, other large areas in the central and northwestern portions appear to be sparser and may have been cleared for grazing. A small isolated open water area can also be seen, potentially implying a connection to the floodplain prior to the creation of the dam and/or an effect of the dam in elevating groundwater levels in this area.

More recent color aerial photography (Figure 4-2) shows patterns of soil color variation similar to the bare/vegetated pattern in the northwestern portion of the project area. This may indicate there are areas with soil or hydrologic conditions that are potentially less favorable for woody vegetation.

Figure 4-1.—Aerial photograph of Bypass project area from 1937. Compact Bypass project area is in red.

Figure 4-2.—Aerial photograph of Bypass project area from 2014.

4.2 Site Conditions

4.2.1 Soils

Currently available soils information includes USDA Natural Resources Conservation Service soil classification maps, geotechnical soil borings, and field soil measurement points. The northwestern third of the property is currently inaccessible for surveys, and further soil sampling is planned for the project area that will be used to refine the vegetation species composition and layout in future drafts of the design. Existing soils classifications are presented in Figure 4-3 and summarized in Table 4-1.

The Madera area soil survey identifies five different soil series within the project area:

- Chino loam – slightly saline-alkali (CgaA)
- Chino loam – moderately saline- alkali (CgbA)

- Columbia loamy sand (CoA)
- Grangeville fine sandy loam – slightly saline-alkali (GbA)
- Wunjey very fine sandy loam – strongly saline-alkali (WxA)

Figure 4-3.—Soil series for Compact Bypass project area.

The soils in the Bypass are generally stratified alluvial deposits from granitic parent materials with 0 to 1 percent slopes. Drainage is moderate to poor, attributed partially to a lowered water table from groundwater pumping; drainage may be slower if groundwater becomes shallower. Salinity levels in the riparian planting zone may only be problematic in the Wunjey series, which normally contain an excess of salts and alkali. Water holding capacity is low to moderate and rooting zones are deep to very deep.

Table 4-1.—Soil series characteristics summary for the Compact Bypass.

Soil Series	**Chino loam**	**Chino loam**	**Columbia loamy sand**	**Grangeville fine sandy loam**	**Wunjey very fine sandy loam**
Map Unit	CgaA	CgbA	CoA	GbA	WxA
Texture	loam, silty clay loam	loam, silty clay loam	loamy sand, stratified sand to silt loam	fine sandy loam, sandy loam, stratified loamy sand to silt loam	very fine sandy loam, stratified very fine sandy loam to silt loam
Drainage	poor	poor	poor	poor	well-drained
Water Capacity	moderate	moderate	low	moderate	low
Salinity	slight to moderate	moderate to strong	not specified	slight to moderate	strong
Erosion Hazard	moderate	moderate	moderate	slight	slight

Geotechnical boring data is currently preliminary and located at the perimeter of the Bypass project area associated with proposed structure locations. Classifications are generally sandy loam with a minor representation for loam, consistent with the NRCS series.

Hand-augured central boring and composite samples, as well as EM38 readings were taken at three points within the southern boundary of the Bypass project area. The borings were approximately 5 ft deep. Sample locations were located within the Grangeville fine sandy loam (Sample 4), Chino loam moderately saline-alkaline (Sample 5), and Chino loam slightly saline-alkaline (Sample 6) mapping units. These data are summarized in Table 4-2. Soil data sheets for these points, including EM38 measurements are included in Appendix D.

Table 4-2.—Hand-augured central boring and composite soils data summary for the Compact Bypass project area.

Sample	**Texture**	**Moisture**	**pH**	**ECe (dS/m)**
4	silt loam, fine sandy loam	very moist - nearly dry	7.5-8.0	1.5-3.2
5	loam, silt loam, fine sandy loam	very moist - moist	6.8-7.5	1.8-5.4
6	loam, fine sandy loam, loamy sand	very moist - dry	6.8-7.1	1.1-1.5

Soils data collection is ongoing and may inform refinements to the final revegetation design.

4.2.2 Hydrology

Luhdorff et al. (2011) estimates groundwater elevations within the Bypass from 90 to 140 ft. The bed of the excavated baseflow channel ranges from 141 to 139 ft, suggesting that groundwater depths may be as much as 50 ft below the channel elevations. For the purpose of the revegetation design, it is assumed that once the channel is excavated (up to 10 ft deep) and flows are initiated in the Bypass, the groundwater elevation will be relatively consistent with the baseflow elevation across the riparian areas. This would put the depth to groundwater at a maximum of 10 to 15 ft within the riparian planting zones, which is within the range of suitability for establishment. Most of the channel will be within 5 ft of the groundwater elevations. Although this scenario is unlikely to describe the actual groundwater elevations with a high degree of accuracy once the Bypass is fully functional, it is considered adequate for the design stage and there are no special considerations with groundwater elevations at this time.

4.2.3 Vegetation

Currently, the project area is entirely agricultural and without substantial native species present. Native vegetation adjacent to and upstream of the Bypass has been identified in the course of several monitoring efforts. Plant community mapping surveys have documented California bulrush marsh, riparian bank herbs, button willow thickets, black willow thickets, Oregon ash groves, saltgrass flats, California mugwort brush, creeping wildrye grassland, and Fremont cottonwood forest vegetative alliances. Other reported habitats included Valley Foothill riparian, elderberry savannah, riparian scrub, willow scrub, annual grassland, and other various herbaceous and aquatic habitats.

Invasive vegetation has been documented upstream of the Bypass (Meadows et al., 2015). Species of concern include giant reed (*Arundo donax*), red sesbania (*Sesbania punicea*), Chinese tallow (*Sapium sebiferum*), edible fig (*Ficus carica*), and tamarisk (*Tamarix* spp.).

5 Design Description

The following elements of the 30% Bypass Design are described in this section:

- Excavation of the Channel,
- Bed and Bank Erosion Protection,
- Revegetation,
- Irrigation, and
- Schedule.

Perhaps the most critical design decision for the Bypass is the sill elevation of the flow control structure that will be placed at the upstream end of the Bypass. The elevation of the structure will define the slope in the Bypass and the slope in Reach 2B, upstream of the Bypass. The slope will then be the dominant variable determining the hydraulic and sediment transport characteristics of those reaches. To determine the elevation of the flow control structure that best meets project objectives, two options were analyzed in Reclamation (2015b). The option selected in the report was Option 2, which had the lower sill elevation of the two options (a sill elevation of 141.5 ft). The 30% design made the following changes from the Option 2 of the Conceptual Design (Reclamation, 2015b):

1. The low flow channel now has a slight sinuous pattern. The sinuous pattern is to promote the development of a more complex habitat within the Bypass.

2. The elevation of the control structure is at 141 ft instead of 141.5. The decrease in elevation will reduce the need for grade control within the Bypass.

3. The grade control structures are moved to just downstream of the flow control structure instead of at the end of the Compact Bypass. They will be integrated into the hydraulic dissipation of the control structure at the upstream end of the Bypass.

4. The cross section is slightly altered to eliminate the small terraces and instead create gradual transitions in elevation. The gradual transitions will be easier to revegetate.

5.1 Channel Excavation

The current slope of the reach upstream, Reach 2A, is 0.00035, and the slope of Reach 3 is 0.00021 (Reclamation, 2009). The bed slope of Reach 2B is variable, with the portion immediately upstream of the Mendota Pool having a much smaller slope than the most upstream portion of Reach 2B. The change in slope is due to the sediment that has deposited behind Mendota Dam, which was originally built prior to 1900 and more than 100 years of sedimentation has occurred behind the dam. The natural stream slope in the lower portion of Reach 2B was likely similar to the slope in the upper portion of Reach 2B prior to the construction of the dam.

Reclamation (2015b) recommended a sill elevation of the upstream control structure of 141.5 ft. The sill elevation was decreased to 141 ft to reduce the need for grade control in the Bypass. Further reduction in the sill elevation is not recommended for two reasons: (1) the amount of deposition within the Bypass in the first few years after flows introduction could become excessive. Significant, but tolerable deposition is already expected after flows are introduced in the Bypass, but lowering the sill further could create enough deposition that would impede the operation of the flow control structure or fish passage facilities. (2) Reach 2B will become steeper than Reach 2A and therefore could potentially incise throughout the reach. In the current design, the slopes of Reach 2B and 2A are approximately equal (within 3%).

The design elevations at the beginning and ending of each Reach are given in Table 5-1. The existing and design profiles along the stream centerline in Reach 2A through the upper portion of Reach 3 are given in Figure 5-1 and the design profiles for the Bypass are given in Figure 5-2. Note that the grading of the levees are not shown in the two figures and that the levees will tie into the control structure.

The slope in the Bypass is slightly higher than the slope in Reach 2B or Reach 3, and therefore two grade control structures are necessary. These grade control structures are described in Section 5.2.2.

The typical cross section of the excavation is shown in Figure 5-3. The low flow channel is approximately 70 ft wide and has an average depth of approximately 3 ft deep. It is designed to contain approximately 200 cfs. The overbank transverse slope toward the low flow channel is 0.015 (67H:1V) and a flow of 1200 cfs is designed to have about 1 foot of depth in the overbank. The overbank transverse slope increases to 20H:1V at a distance of 135 ft from the center of the channel cut. The floodplain cross section is intended to produce a range of channel depths regardless of the flow.

Because the entrance to the Bypass is located approximately 7 ft below the current thalweg of Reach 2B, a pilot channel will be constructed to create a smoother transition between Reach 2B and the Bypass channels (Figure 5-2). The pilot channel will be 70 ft wide with 2H:1V side slopes excavated within Reach 2B, upstream of the junction between the Bypass and San Joaquin River. The excavation will be performed just prior to the reintroduction of high flows to the Bypass so that sediment does not refill the channel. Some of the material excavated from the pilot channel could be placed in the bed of the Bypass low flow channel to a max depth of 1 foot.

The channel will likely evolve in time and a sediment transport and mobile bed simulation was performed using SRH-1D to estimate the bed change over time (Reclamation, 2015b). The simulation did not include the construction of the pilot channel. Approximately 2 to 3 ft of deposition occurred in the Bypass in the first year when flows are routed into the Bypass (Figure 5-6). Sediment would fill the low flow channel and cause large amounts of deposition in the floodplain. The pilot channel should decrease the magnitude of this deposition, but large amounts of deposition are still expected in the Bypass in the first few years after flows are allowed to enter. There is up to 7 ft of deposition in Reach 3 immediately below the Bypass that gradually decreases to zero deposition approximately 1 mile downstream of the Bypass. Most of the deposition occurs in the pool in Reach 3, immediately downstream of the Bypass. Further downstream in Reach 3, the model predicts erosion within Reach 3 because despite the additional sediment being supplied from Reach 2B, there was historically a net deficit of sediment supplied to this reach. There is some uncertainty regarding this deficit because the supply of sand from Fresno Slough has not been measured.

The river bed elevation within the Bypass is expected to erode back to the original design elevations by year 5. By year 25, the Bypass is expected to erode 1 to 2 ft because the overall trend in Reach 3 is erosional and the erosion may progress into the Bypass. The erosion in the Bypass is a primary reason why grade control is suggested in the upper portion of the Bypass. As mentioned previously, there is some uncertainty regarding the sediment supply to Reach 3 and therefore the extent of the erosion in Reach 3 is uncertain. If Reach 3 remains relatively stable, then the Bypass will remain relatively stable.

The estimated stable channel elevations from the long term sediment transport simulation are given in Table 5-1. The Bypass reach is slightly steeper than Reach 2B or Reach 3 and therefore, some grade control may be necessary in the design. This is discussed in Section 5.2.2 titled “Grade Control”.

A significant portion of floodplain deposition is expected to occur, which may increase the flow necessary to inundate the floodplain. However, the deposition is also expected to increase the complexity of the floodplain habitat. Separate flood channels are expected to form and some vegetation may be eroded or buried, but it is expected that this process will actually be beneficial to the habitat in the Bypass in the long term.

Approximately 400,000 tons of sediment is expected to erode from Reach 2B within the first 5 years. The pilot channel is estimated to between 70,000 and

90,000 tons, so it is only a small portion of the total amount expected to be eroded from Reach 2B.

Table 5-1.—Assumed stable channel elevations for various reaches as estimated by long term (25-yr) sediment transport simulations. Elevations are given to nearest foot.

	Upstream Elevation (ft)	**Downstream Elevation (ft)**	**Reach Design Slope (-)**
Reach 2A	186	161	0.00035
Reach 2B	161	141	0.00036
Bypass Reach	141	139	0.00050
Reach 3	139	116	0.00023

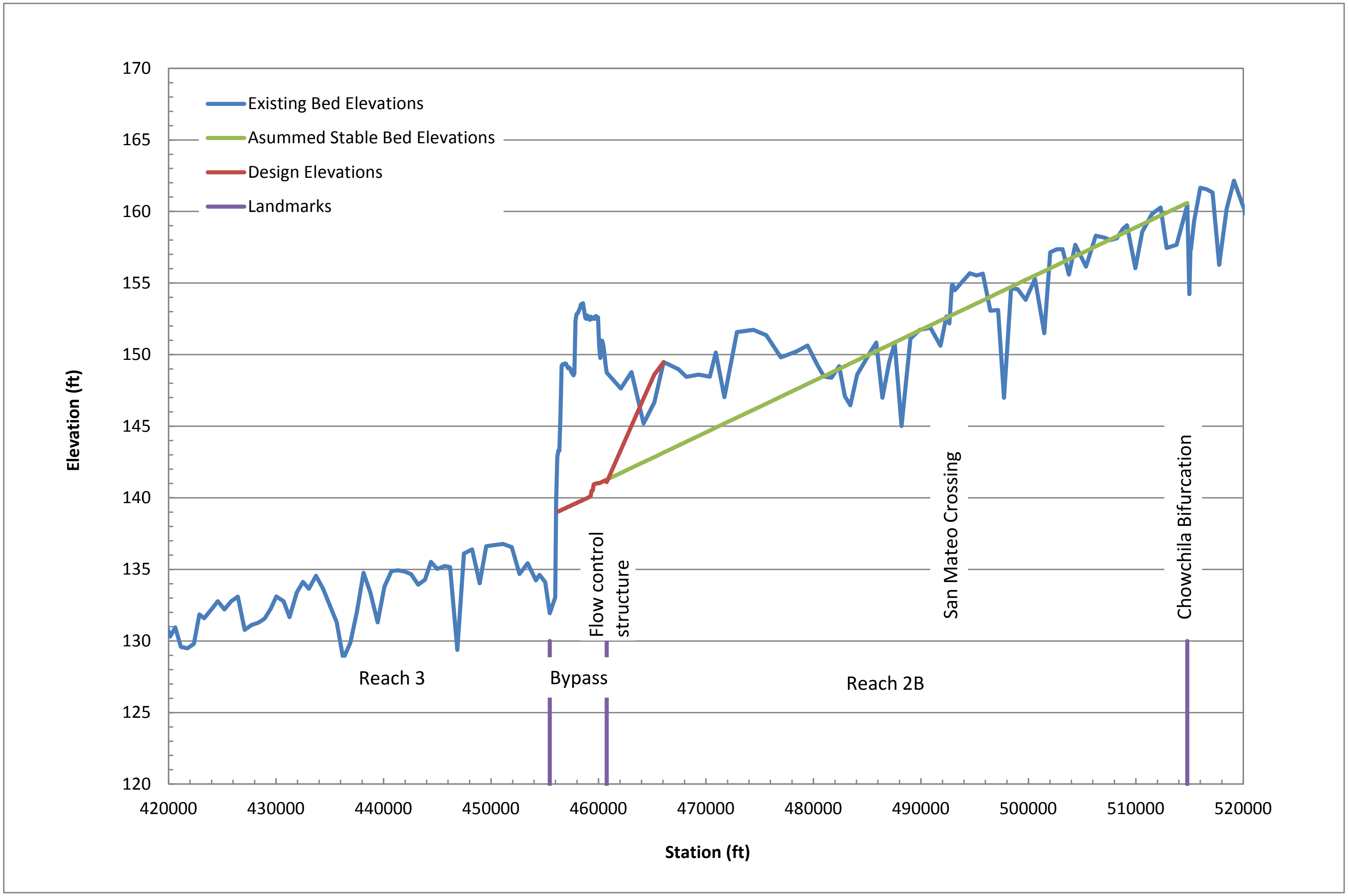


Figure 5-1.—Existing and Design Profiles in Reach 2B through Compact Bypass.

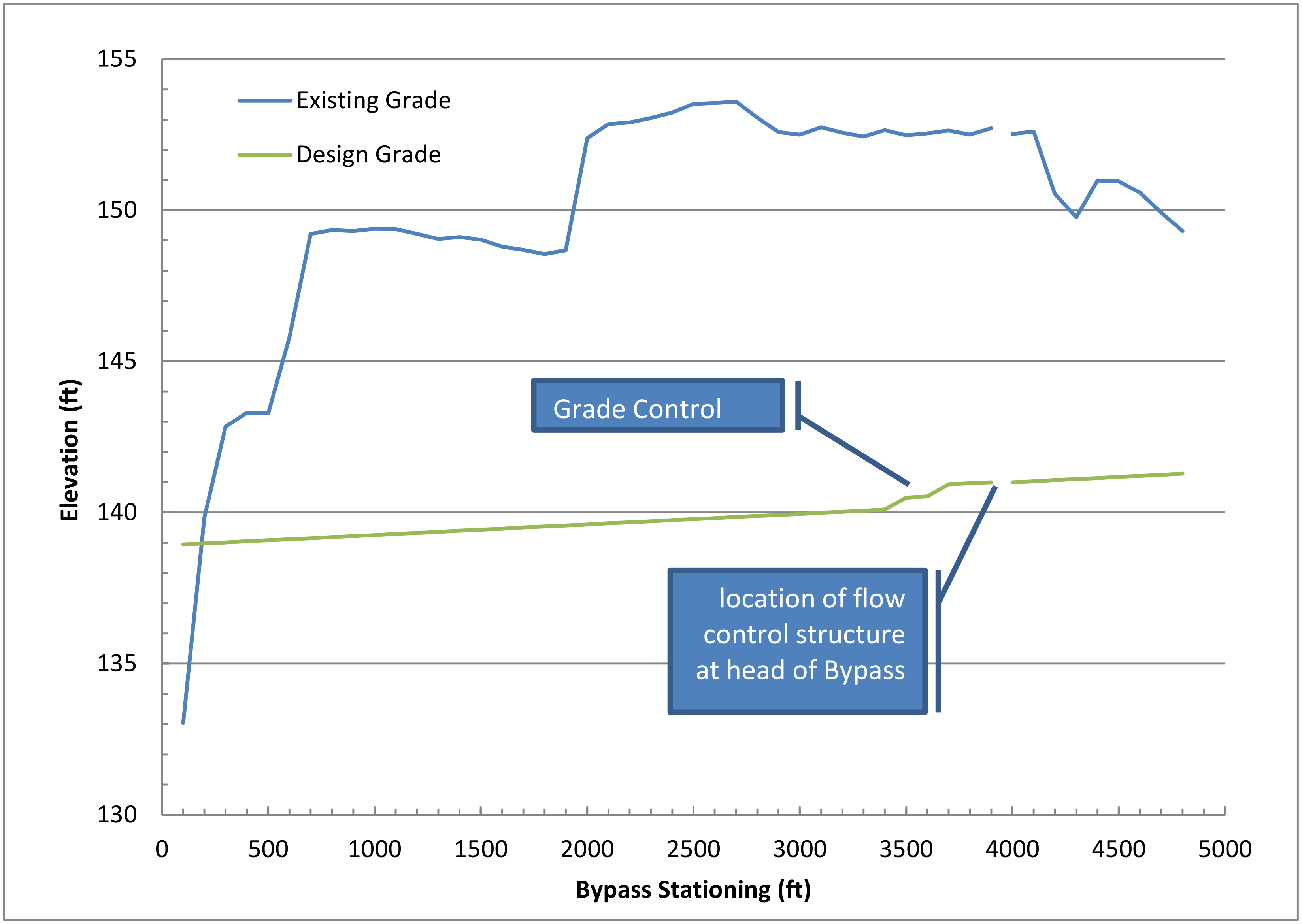


Figure 5-2.—Existing and Design Profiles in Compact Bypass.

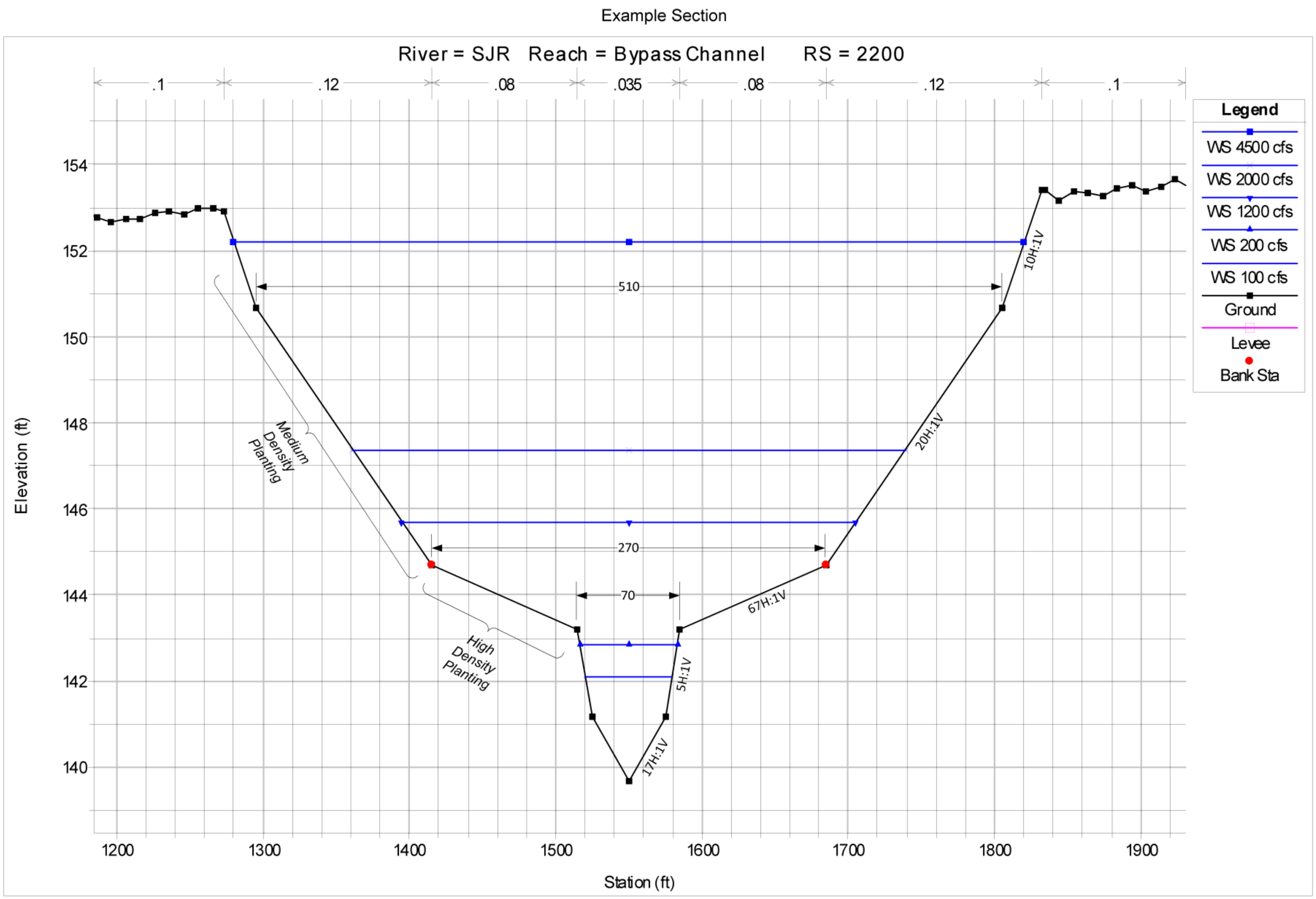


Figure 5-3.—Typical cross section in Compact Bypass.

Figure 5-4.—Planview Layout of Bypass including approximate flow control and grade control location.

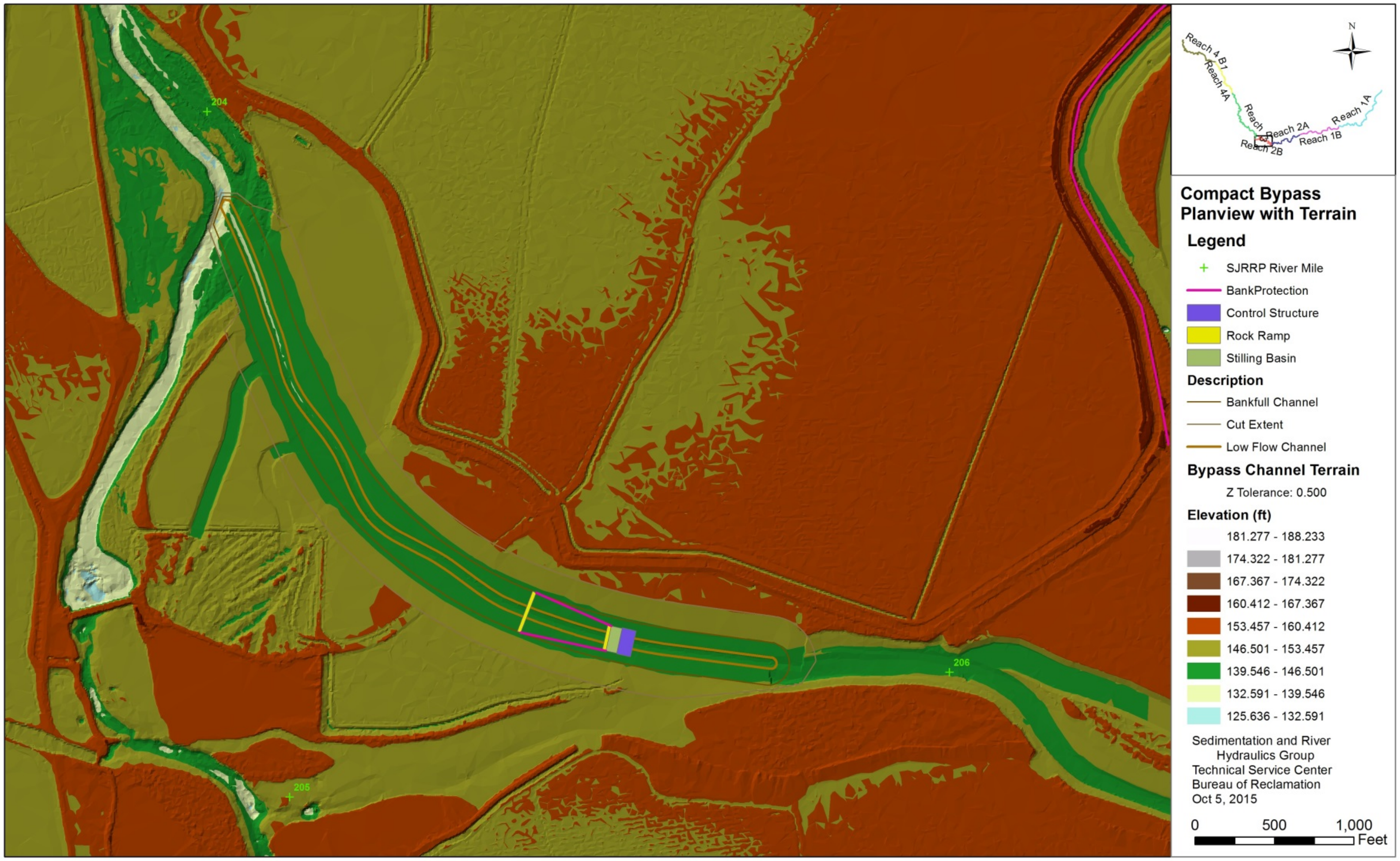


Figure 5-5.—Planview of Bypass showing modified terrain.

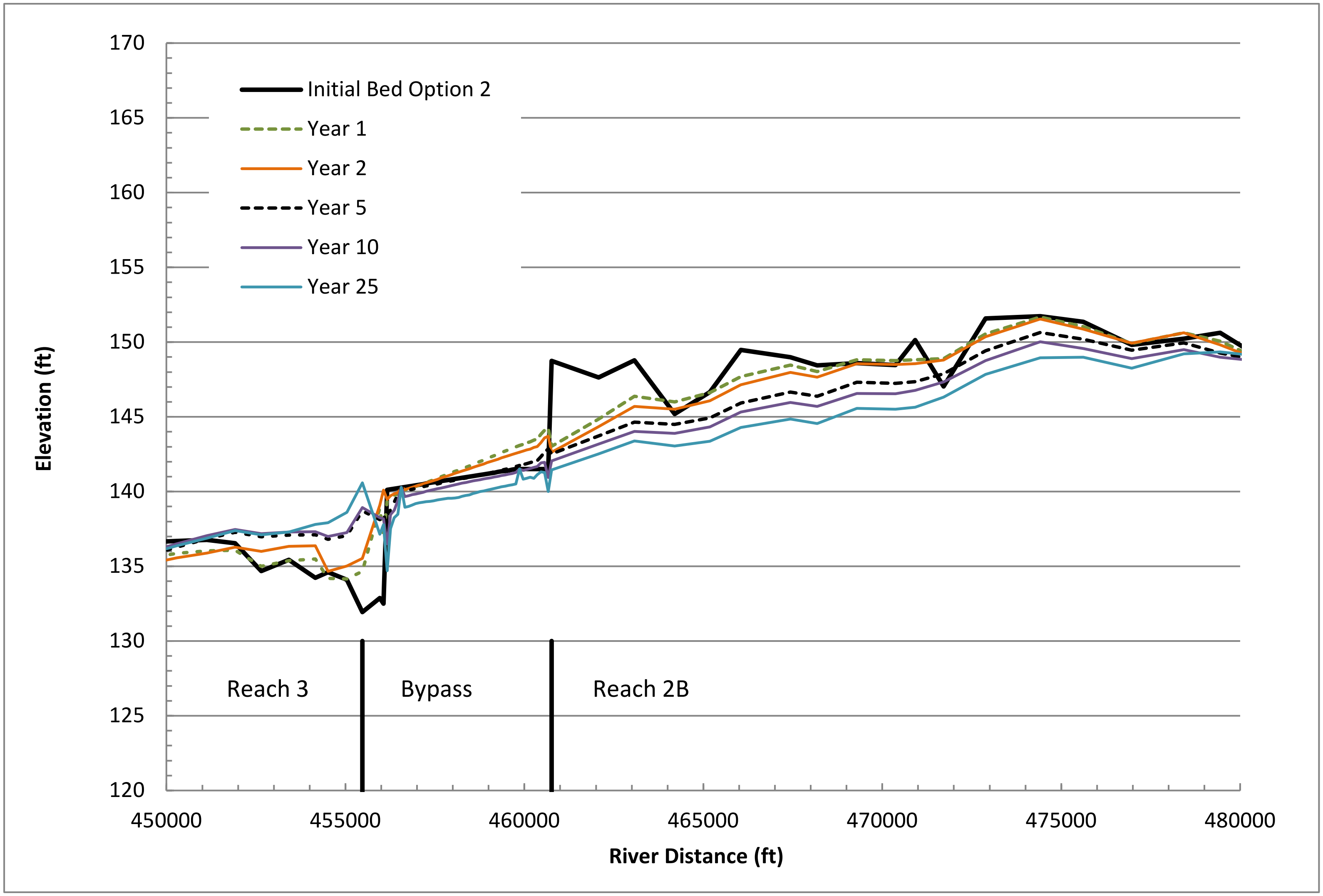


Figure 5-6.—Evolution of bed profile assuming Option 2 bed profile and no excavation of pilot channel. Option 2 is similar to the current 30% design with differences specified in Section 4.

5.2 **Bed and Bank Erosion Protection**

There are three features necessary to control bed and bank erosion immediately downstream of the flow control structure:

1. Energy dissipation
2. Grade control
3. Bank protection

It should be emphasized that the bed and bank erosion protection measures will only permanently stabilize the river in the vicinity of the flow control structure and siphon crossing. The vast majority of the Bypass will not be stabilized with permanent material such as rock and concrete. Instead, the revegetation and flow reintroduction plan will create a corridor that will function similar to other non-stabilized reaches of the San Joaquin River. The revegetation plan is described in Section 5.3. The justification for not stabilizing the majority of the channel is that channel velocities are typical of the other portions of the San Joaquin. The velocities in the majority of the Bypass are less than 2.5 ft/s and natural vegetation will be sufficient to stabilize the banks on a long term basis (Gray and Sotir, 1996; Reclamation, 2015).

5.2.1 Energy Dissipation

Immediately downstream of the control structure, an energy dissipation structure will be necessary to prevent scour when the gates are partially closed. *Reclamation Engineering Monograph No. 25* (EM No. 25, Reclamation, 1984) is used to design the stilling basin size. Figure 6 and 7 within the Monograph can be used to estimate the length of stilling basin required to dissipate the hydraulic jump. The assumed quantities are given in Table 5-2, which is for the case when there are deliveries to Mendota Pool under subsided conditions and there is 4500 cfs being passed down the Bypass. It is assumed that only the 4 gates with the lower sill elevation are being operated. Therefore, the width of gate opening is only 56 ft.

The basin length using Figure 6 of the monograph gives 57 ft while that using Figure 7 gives 65 ft. A basin length of 75 ft is recommended to account for uncertainty in the computation and so that uniform flow conditions will exist downstream of the stilling basin. The basin length may also need to be adjusted based upon the location of the fish ladder that will be adjacent to the stilling basin.

The basin will be recessed approximately 2.5 ft below the sill elevation of the upstream gates according to the criteria in Reclamation [1984] which requires the downstream lip to be equal to 0.2* D_w, where D_w is the tailwater depth. There are two sets of gates, one at an elevation of 141 ft and another set at 145 ft. The basin will also have a transverse slope to the basin so that deepest part of the basin is on the right side of the channel, similar to the gates. The lip at the downstream end will have a 4H:1V slope to bring the downstream basin elevation up to the channel elevation.

Table 5-2. Stilling Basin Design Input Variables and Results.

Input Quantities	**Variable**	**Value**	**Units**
Flow	Q	4500	Cfs
WSE upstream	Z1	161	ft
Width	W	56	ft
Discharge Coefficient	Cd	0.8	
Sill Elevation	Zsill	141.0	ft
Tailwater computed from HEC-RAS model			
Tailwater Elevation	Z2	152.4	ft
Conjugate Depth			
Velocity	V	28.7	ft /s
Depth	D1	2.8	ft
Froude	Fr1	3.0	
Conjugate Depth	D2	10.7	ft
Basin Length from Figure 6 of EM No. 25			
Basin Length/D1	Lb/D1	20.24	
Basin Length	Lb	57	ft
Basin Length from Figure 7 of EM No. 25			
Tailwater depth	D_w	11.4	ft
Basin Length/D2	Lb/D2	6.1	
Basin Length	Lb	65	ft
Final Recommended Basin Length	**Lb**	**75**	**ft**

5.2.2 Grade Control

There are two grade control structures. The most upstream one will begin immediately downstream of the flow control structure. The siphon crossing is located upstream of the second grade control structure so that the grade control structure also serves to protect the siphon crossing. Each will have approximately 0.4 ft of bed elevation drop across it.

Each structure will have a maximum downstream slope of 0.04 and be a minimum of 25 ft in length in the streamwise direction.

The references used to design the grade control are: *Rock Ramp Design Guidelines* (Reclamation, 2007) and *EM1110-2-1601* (U.S. Army Corps of Engineers, 1994).

<u>Rock Size</u>

The size of the rock is determined by using the following equation from *EM1110-2-1601* (U.S. Army Corps of Engineers, 1994).

$$D_{30} = \frac{1.95 S^{.555} q^{2/3}}{g^{1/3}} \qquad \text{Eq 1}$$

where,

S = bed slope
q = flow per unit width (cfs/ft)
g = acceleration of gravity (ft^2/s)

The input and results for this equation are given in Table 5-3. The unit discharge is computed assuming that the channel width is 270 ft, which is the width of the bankfull channel. The D50 is computed using recommendations from Lagasse (2006) that state D50 = 1.2*D30.

If rounded rock is used the diameters need to be increased by 25 percent as recommended in *EM1110-2-1601*. The recommended gradations for the rock ramp are given in Table 5-4. Vandalism and/or theft of the stones could be a serious problem when the channel is dry for extended periods because large rock is relatively rare in this region. *EM1110-2-1601* recommends a minimum weight of the median size material of 80 lb to prevent theft and vandalism and therefore the rock size should be of sufficient size to prevent vandalism, at least without the use of heavy equipment.

Table 5-3.—Data for sizing of material in rock ramps.

Variable	Value	Units
S	0.04	-
q	16.7	ft^2/s
g	32.2	ft/s^2
Flow Concentration Factor	1.25	-
D30 - angular	0.78	ft
D50 angular	0.98	ft

Table 5-4.—Recommended gradations for grade control, assuming angular rock. Using riaprap classes found in Lagasse et al. (2006). Assumed specific weight of 165 lb/ft^3.

Class III Riprap	***Percent Lighter by Weight***						
	15		***50***		***85***		***100***
	Min	***Max***	***Min***	***Max***	***Min***	***Max***	***Min***
Weight (lb)	32	93	120	210	310	510	1100
Equivalent Diameter (in)	7.3	10.5	11.5	14	15.5	18.5	24

Filter

No filter fabric will be used, but a granular filter should be included beneath the material in the rock ramp. The filter material is designed according to the *Rock Ramp Design Guidelines* (Reclamation, 2007). The filter recommendations in Reclamation (2007) are:

$$\frac{D_{50,Filter/Riprap}}{D_{50,Base}} < 40 \qquad \text{Eq 2}$$

$$5 < \frac{D_{15,Filter/Riprap}}{D_{15,Base}} < 40 \qquad \text{Eq 3}$$

$$\frac{D_{15,Filter/Riprap}}{D_{85,Base}} < 5 \qquad \text{Eq 4}$$

Because the ramp will be excavated into a silty/sandy material, two filter layers may be necessary. The upper filter (Layer 1) will be mostly gravel material and the lower filter (Layer 2) will be mostly sand size. The recommended gradations using the above criteria are in Table 5-5.

Table 5-5.—Filter gradations for grade control structures.

	Percent Lighter by Weight						
	15		***50***		***85***		***100***
	Min	***Max***	***Min***	***Max***	***Min***	***Max***	***Max***
Filter Layer 1 Diameter (mm)	7	9	10	14	59	82	100
Filter Layer 2 Diameter (mm)	0.2	0.3	0.3	0.4	1.6	2.3	4

<u>Bed Scour</u>
There will be some scour downstream of each structure and the methodology of Bormann and Julien (1991) was used to compute the expected scour downstream of the grade control structures. The scour depth, y_s, is computed as:

$$y_S + d_p = \frac{0.611}{[g\sin(\phi+\beta')]^{0.8}} \frac{q^{0.6} U_0}{{d_{90}}^{0.4}} sin(\beta') \qquad \text{Eq 5}$$

The parameter β' is the maximum side angle of scour hole and is computed as:

$$\beta' = 0.316 \sin\lambda + 0.15 \ln\left(\frac{d_p + Y_0}{Y_0}\right) + 0.13 \ln\left(\frac{Y_t}{Y_0}\right) - 0.05 \ln\left(\frac{U_0}{\sqrt{gY_0}}\right) \qquad \text{Eq 6}$$

The diffused distance to the maximum scour depth, L_s, is computed as:

$$L_S = 1.861 \left[\frac{\sin\phi}{g(s-1)\sin(\phi+\beta')}\right]^{0.8} \frac{{Y_0}^{0.6}{U_0}^{1.6}}{{d_s}^{0.4}} \qquad \text{Eq 7}$$

where:

d_p = height of grade control structure (m)
ϕ = submerged angle of repose of bed sediment = 25 degrees = 0.436 radians
d_s = sediment size (m)
U_0 = jet velocity of water entering tail water (m/s)
Y_0 = thickness of jet entering tailwater (m)
Y_t = tailwater depth (m)

β' = maximum side angle of scour hole
γ, γ_s = specific weight of water
ρ, ρ_s = mass density of water
s = specific gravity of sediment = 2.65
g = acceleration of gravity = 9.8 m^2/s

The variables are also defined in Figure 5-7. The input variables and resultant scour downstream of the grade control structures are given in Table 5-6. The computed scour depth is 4.8 ft. The recommended scour depth at this stage is modified based upon the results from the bank protection scour to be more conservative.

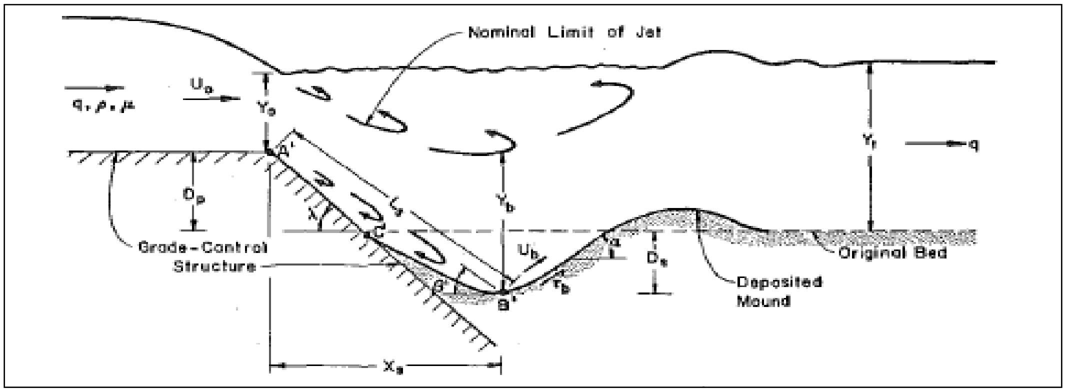


Figure 5-7.—Scour downstream of grade control figure from Borman and Julien (1991).

Table 5-6.—Input and output variables for scour computation downstream of the grade control structures.

Variable	Value	Units
U_0	15.5	ft2/s
Y_0	11.4	ft
Y_t	11.4	ft
U_0	4	ft/s
d_{90}	0.0033	ft
d_p	0.4	ft
y_S	4.8	ft
L_S	29	ft

The predicted scour from the grade control is less than the scour predicted along the bank protection structure. It is recommended that the scour depth from the bank protection (7.5 ft) be used for design purposes until further verification that the scour will be significantly less.

<u>Layer Thickness and Transverse Width</u>

The layer thickness of the rock ramp is set at 3 ft or 1.5 * D100, slightly greater than recommended in Reclamation (2007), which recommends the thickness to be equal to the D100. The layer thickness is increased because it is expected that the structure will initially be buried by sand and that there will be significant loss of material following the introduction of flows to the Bypass. There will be an additional 7.5 ft of scour protection on the downstream toe to account for the scour on the downstream side. The thickness of each filter layer should be 0.75 ft as recommended in HEC11 (Federal Highways Administration, 1989). The cross section of a typical grade control structure profile is given in Figure 5-8.

The rock ramp will span the width of the bankfull channel, which is 270 ft wide and transitioned into the bank protection that is placed from the flow control structure to the rock ramp.

The rock ramp will have an inset low flow channel to ensure that minimum depth criteria are met, which will be 1.2 ft of depth at a flow of 50 cfs.

<u>Maintenance</u>

There is expected to be some loss of rock material after each high flow, and additional rock material may need to be placed after high flow events.

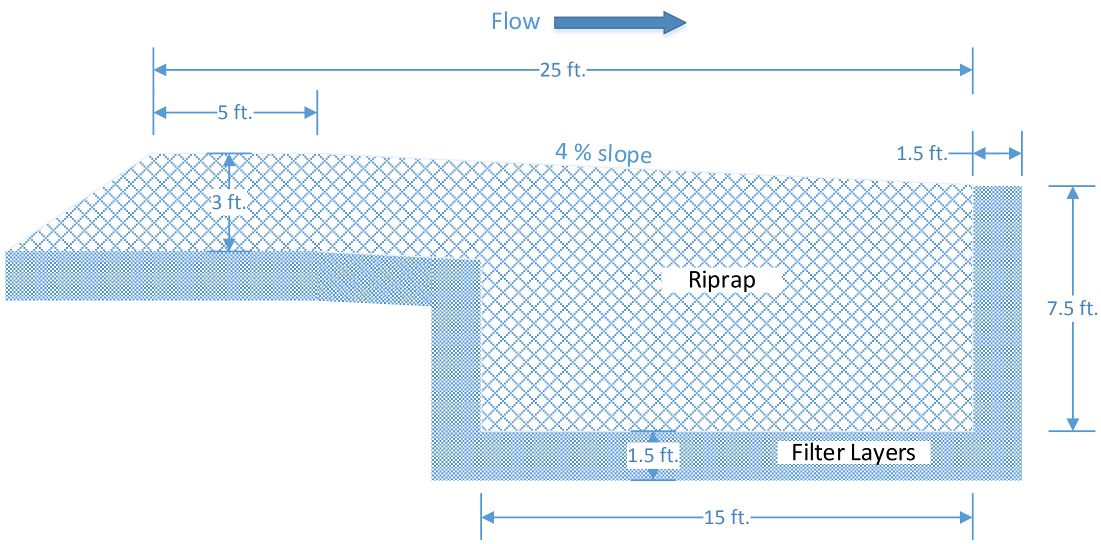


Figure 5-8.— Conceptual profile section of grade control structure.

5.2.3 Bank Protection

Downstream of the siphon crossing, no engineered bank protection is recommended. However, there will also be bank protection provided from the stilling basin to the downstream grade control structure on the both sides of the channel to prevent flanking of the grade control, which equates to about 500 ft of bank protection on either side.

<u>Rock size</u>

The bank protection will consistent of approximately the same size of rock material as the grade control. The riprap size was also checked against the methods recommended in EM-1110-2-1601 “Hydraulic Design of Flood Control Channels” (USCOE, 1994) for bank protection and it was found to be smaller than the material specified for the rock ramps. At this stage of design it is recommended to use the same material for the bank and rock ramp.

If a filter is deemed necessary, the same filter material can be used for the bank protection as the grade control structures.

Scour

Several methods for computing the scour at the base of the bank protection are described below.

Neill

The depth of scour below thalweg elevation, d_s, is predicted by Neill (1973) as reported in Reclamation (1984):

$$d_s = Zd_i\left(\frac{q_f}{q_i}\right)^m \quad \text{Eq 8}$$

where:

m = exponent varying from 0.67 for sand to 0.85 coarse gravel
d_i = bank full depth
q_i = bank full discharge
q_f = design discharge per unit width
Z = 0.5 for straight reach, 0.6 for moderate bend, 0.7 severe bend

This method was not used in the final design estimate because the uncertainty in choosing the bank full discharge in this braided river. We choose Z = 0.6 for a moderate bend.

Lacey

The scour equation of Lacey (1930) as reported in Reclamation (1984) is:

$$d_s = Z0.47\left(\frac{Q}{f}\right)^{1/3} \quad \text{Eq 9}$$

where:
Q = Flow rate in channel at design discharge (ft^3/s or m^3/s)
f = $1.76\sqrt{d_{50}}$
Z = 0.25 for straight reach, 0.5 for moderate bend, 1.25 for vertical rock bank
d_{50} = mean grain size in mm

We choose Z= 0.5 for moderate bend.

Blench

The scour equation of Blench (1969) as reported in Reclamation (1984) is:

$$d_s = Z \frac{q_f^{2/3}}{F_{bo}^{1/3}} \qquad \text{Eq 10}$$

where:

q_f = design discharge per unit width

F_{bo} = $1.75 d_{50}^{\,0.25}$

d_{50} = mean grain size in mm

Z = 0.6 for straight, 1.0 for moderate bend, 1.25 for vertical rock bank or wall.

We choose Z = 1 for moderate bend as recommended in Reclamation (1984).

EM1601

The COE manual EM1601 (COE, 1994) recommends using the following equation:

$$d_s = S_f Z d_m - d_f \qquad \text{Eq 11}$$

where:

d_m = average depth in the crossing upstream of the bend.

d_f = depth of thalweg at bend

S_f = Safety Factor = 1.14

Z = factor based upon radius of curvature to width ratio

= $3.37 - 0.66 \ln(R/W)$ for sand bed

= $3.37 - 0.7 \ln(R/W)$ for gravel bed

The radius of curvature is approximately 3000 ft for the Bypass and the assumed topwidth is the bankfull topwidth of 270 ft.

Recommended Scour

The results of the scour computation are in Table 5-7. The recommended design scour is taken as the average scour estimated from the four methods and rounding to the nearest half foot.

Table 5-7.—Design scour estimates for bank protection in Bypass.

Location	**Design Scour Estimates (ft)**				
	Neill (1973)	Lacey (1930)	Blench (1969)	EM1601	**Design Scour**
Bypass	6.6	3.6	11	8.7	7.5

Layout and Layer Thickness

The bank protection will be placed as a rock filled trench that extends from the stilling basin to the downstream most rock ramp along both sides of the channel. The rock filled trench will transition between the outside of the Bypass control structure to the bank full channel location as defined in Figure 5-4. The volume of the trench was estimated by assuming that the rock extends from the trench elevation to 7.5 ft below the Bypass thalweg which would equate to approximately 13.5 ft height. The layer thickness was assumed to be 2 ft or 1 * D100. An additional 50% is added to account for stone loss and irregular placement because the material will be launched during scour events. The total volume necessary is 73 ft^3/ft placed within the trench.

The trench in which the rock is placed will be 5 ft deep and have a bottom width of 14.5 ft with 1.5H:1V side slopes. The rock will be placed along the base and up one side of the slope. The trench will be backfilled with the excavated soil and the Riprap can be covered with 1 foot of topsoil as shown in Figure 5-9.

There may also be a filter required to prevent loss of soil through the riprap. Two filter layers may be required as was the case with the rock ramps. The filter thickness for each layer is recommended to be 0.5 ft in this case.

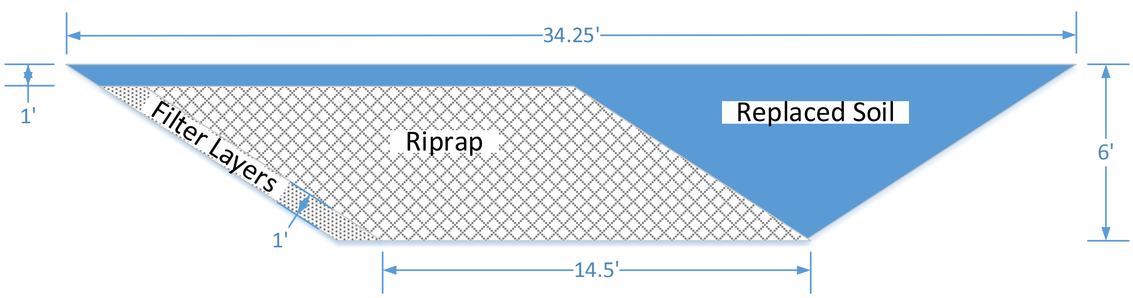


Figure 5-9.—Conceptual cross section of riprap filled trench.

Maintenance

There should be minimal maintenance of the bank protection because it will be excavated into a trench and is likely not to be significantly exposed. If significant exposure occurs the riprap bank should be inspected and material added if necessary.

5.3 **Revegetation**

Active revegetation within the bypass will be intensive as there will be no existing plant communities within the excavated channel. Dense vegetation will need to be established before the channel is connected to river flows in order to stabilize soils and meet design specifications. Irrigation will be necessary to establish woody species, and ultimately the layout of irrigation lines will be the basis for planting locations.

5.3.1 Site Preparation

Because the primary riparian revegetation areas will be in the newly constructed bypass, preparing the site for planting will likely be minimal. The top 12-18 inches of topsoil should be scraped and stockpiled, then replaced on the bypass excavated surface (except for the low flow channel) at the completion of the construction phase. Other processes to facilitate installation of the irrigation system may be necessary, and may also potentially be incorporated into the construction effort.

5.3.2 Planting Materials

At least two years lead-time is anticipated to obtain sufficient seed and planting stock for the revegetation of the bypass. Local sources of plant material are preferred due to adaptations to site conditions, providing better potential for establishment success. However, sourcing plant materials from a variety of different parent populations helps to increase intraspecific genetic diversity, which is also an important component of long-term sustainability.

A local nursery will be required to propagate sufficient numbers of woody planting materials and potentially much of the required seed. Existing nurseries in the area may be able to provide at least some of the required quantities, but lead time and budget for setup and maintenance of a nursery specific to the project (and future SJRRP projects) may be necessary. Coordination with local landowners will be integral to this process.

Use of commercially available planting materials may also be necessary due to constraints in budget, time, or other logistics. However, local sources of plant material are generally preferred due to adaptations to local conditions, providing the best possible establishment success.

5.3.3 Species Selection

The suite of species selected for planting for the conceptual design varies by elevation above summer baseflow, and are delineated into three zones: High Density Riparian, Mid-Density Riparian, and Upland (Figure 5-10). Further segregation of planting categories and composition is anticipated once soil conditions are better understood, but would likely incorporate heavier shrub and/or herbaceous species in areas in lieu of tree plantings to account for less favorable riparian environments. Therefore, the proposed species selection is assumed to be a conservative estimate for propagation, planting, irrigation, and maintenance costs.

Revegetation species zones:

1. High Density Riparian - Areas with elevations in the range of 0 to 2 ft above summer baseflow elevations (21.9 acres) will likely support emergent wetlands and flood tolerant woody species (Table 5-8). This zone may be inundated for extended periods during wet years or high summer flow events. This zone will be heavily planted with woody shrubs and trees to maximize shading and other fish habitat characteristics, as well as provide competitive understory cover to enable a diverse influx of species as the vegetative community matures.

2. Mid-Density Riparian - All floodplain areas with potentially suitable soils and elevations within a range of 2 to 8 ft above summer baseflow elevations (33.3 acres) were selected as potentially suitable for riparian recruitment (Table 5-9). Vegetation for this category includes woody shrubs and trees but is more diverse in species and structure than the High Density Riparian zone, with patches of open herbaceous, cluster of shrubs, tree groves, and intermixed areas to provide multi-species habitat and promote system stability (pollination, trophic levels, etc.).

3. Upland - Areas with elevations greater than 8 ft above summer baseflow (72.3 acres) are not likely to support riparian vegetation development and recruitment (Table 5-11 and Table 5-12). These areas will be seeded primarily with a diverse mix of forbs and grasses, with a minor component of shrubs and trees and will not receive irrigation. The purpose of revegetating the upland areas is primarily to stabilize soils and prevent invasive species colonization, and may provide some habitat component. Further modification of plantings in this zone for secondary species habitat is under consideration.

Species planting densities are averages over the entirety of the particular zone, and actual planting locations will not be even distributions of all species at the stated composition percentage (see Section 5.3.4).

Both the High and Mid-Density Riparian zones will be planted with woody species in rows along irrigation lines. Between rows, herbaceous species will be seeded with alternating swaths of grasses and forbs to facilitate weed management with selective herbicides.

Figure 5-10.—Revegetation species planting zones.

Table 5-8.—Irrigated species for revegetation: Zone 1 High Density Riparian.

Common Name	*Scientific Name*	Veg Type	Composition (%)	Density (plants/acre)	Total Plants
Fremont cottonwood	*Populus fremontii*	Tree	15	82	1,796
Gooding's willow	*Salix gooddingii*	Tree	15	82	1,796
box elder	*Acer negundo*	Tree	10	55	1,205
Oregon ash	*Fraxinus latifolia*	Tree	10	55	1,205
red willow	*Salix laevigata*	Tree	10	55	1,205
yerba mansa	*Anemopsis californica*	Forb	5	27	591
common buttonbrush	*Cephalanthus occidentalis*	Shrub	5	27	591
baltic rush	*Juncus balticus*	Tule	5	27	591
California blackberry	*Rubus ursinus*	Shrub	5	27	591
sandbar willow	*Salix exigua*	Shrub	5	27	591
arroyo willow	*Salix lasiolepis*	Shrub	5	27	591
shining willow	*Salix lucida ssp. Lasiandra*	Tree	5	27	591
blue elderberry	*Sambucus nigra ssp. caerulea*	Shrub	5	27	591

Table 5-9.—Irrigated species for revegetation: Zone 2 Mid-Density Riparian.

Common Name	*Scientific Name*	Veg Type	Composition (%)	Density (plants/acre)	Total Plants
creeping wildrye	*Elymus triticoides*	Grass	15	83	2,764
red willow	*Salix laevigata*	Tree	10	55	1,832
shining willow	*Salix lasiandra var. lasiandra*	Tree	10	55	1,832
arroyo willow	*Salix lasiolepis*	Shrub	10	55	1,832
box elder	*Acer negundo*	Tree	5	27	899
narrow-leafed milkweed	*Asclepias fascicularis*	Herb	5	27	899
coyote brush	*Baccharis pilularis*	Shrub	5	27	899
buttonbush	*Cephalanthus occidentalis*	Shrub	5	27	899
blue wildrye	*Elymus glaucus*	Grass	5	27	899
valley oak	*Quercus lobata*	Tree	5	27	899
golden currant	*Ribes aureum*	Shrub	5	27	899
Califoria wildrose	*Rosa californica*	Shrub	5	27	899
California blackberry	*Rubus ursinus*	Shrub	5	27	899
Gooding's willow	*Salix gooddingii*	Tree	5	27	899
blue elderberry	*Sambucus nigra ssp. caerulea*	Shrub	5	27	899

Table 5-10.—Herbaceous species for seeding between irrigation lines: Zones 1 and 2

Common Name	Scientific Name	Veg Type	Composition (%)	PLS*/acre (lb.)	Total PLS* (lb.)
meadow barley	*Hordeum brachyantherum*	Grass	40	25	624.0
Creeping wildrye	*Elymus triticoides*	Grass	30	10	187.2
dwarf barley	*Hordeum depressum*	Grass	30	25	468.0
Douglas' sagewort	*Artemisia douglasiana*	Forb	30	2	37.4
Great Valley gumweed	*Grindelia camporum*	Forb	40	2	49.9
Western goldenrod	*Euthamia occidentalis*	Forb	30	0.5	9.4

*PLS = Pure Live Seed

Table 5-11.—Planted species for revegetation: Zone 3 Upland

Common Name	*Scientific Name*	Veg Type	Composition (%)	Density (plants/acre)	Total Plants
creeping wildrye	*Elymus triticoides*	Grass	15	41	2,964
narrow-leafed milkweed	*Asclepias fascicularis*	Forb	5	14	1,012
valley oak	*Quercus lobata*	Tree	5	14	1,012
golden currant	*Ribes aureum*	shrub	5	14	1,012
California wildrose	*Rosa californica*	shrub	5	14	1,012

Table 5-12.—Seeded species for revegetation: Zone 3 Upland

Common Name	Scientific Name	Veg Type	Composition (%)	PLS*/acre (lb.)	Total PLS* (lb.)
quail bush	*Atriplex lentiformis*	Forb	10	9	65
western goldenrod	*Euthamia occidentalis*	Forb	10	0.1	1
small fescue	*Festuca microstachys*	Grass	10	1	7
purple needlegrass	*Stipa pulchra*	Grass	10	10	72
yarrow	*Achillea millefolium*	Forb	5	0.5	2
Spanish lotus	*Acmispon americanus var. americanus*	Forb	5	5	18
Great Valley gumweed	*Grindelia camporum*	Forb	5	0.5	2
telegraph weed	*Heterotheca grandiflora*	Forb	5	4	15
tomcat clover	*Trifolium willdenovii*	Forb	5	0.5	2

*PLS = Pure Live Seed

5.3.4 Plant Layout

Specific distribution, clustering, and within-zone plant guilds and associations will be further refined when more detailed soil data is available. Mixed species implementation and high planting densities will provide a buffer for uncertainty in species survival and adaptation as well as serve to establish a diverse vegetation community and canopy structure.

Planting density was set at 545 plants per acre for the irrigated zones: 16 ft spacing between irrigation lines to allow for equipment access and 5 ft spacing along irrigation lines to maximize density. Forbs and grasses will be planted as plugs or transplants under irrigation in order to encourage structural diversity. Upland areas will be broadcast seeded or drilled with incorporation as necessary.

5.3.5 Planting Implementation

Woody species will need to be planted by hand and should not require special equipment. Screens or cardboard containers will be installed to minimize browsing damage and herbicide overspray. Plantings will correspond with irrigation line emitters spaced 5 ft along lines and 16 ft between.

Areas between irrigation lines, as well as the upland areas and base-flow channel will be left fallow for two years following the installation of woody species. This will allow weeds, particularly aggressive perennial species, to germinate and be controlled with mechanical and chemical methods. Weed control prior to planting generally increases the success of riparian revegetation by reducing competition and pushing the system past the early successional stages.

These areas will be seeded and planted after the two year weed suppression period. The upland areas will be a combination of seeding and planting of plugs and containerized species; areas between irrigation lines will be seeded only. Seeded sites may require seedbed preparation and potentially incorporation after seeding depending on the existing conditions and method. The layout and irrigation system is designed to allow standard agricultural seeding equipment to be utilized.

The base-flow channel will also be seeded with a grass cover crop to prevent invasive species colonization until flows are initiated in the channel.

5.3.6 Monitoring and Maintenance

Monitoring and maintenance will be conducted for 10 years following revegetation: Yearly for the first 3 years, then every other year up until year 7, and a final assessment at year 10 (total of 7 monitoring years). This may ultimately be incorporated into a larger overall monitoring program for SJRRP revegetation efforts. Development of specific monitoring protocols will be based on the goals of the project and will key on habitat metrics. These would potentially include a field-survey of successful plant establishment (live vs. dead), vigor (growth rate, photosynthetic measurements, etc.), and coverage (stem density or canopy cover) for desired species, and invasive species occurrences as well as aerial or satellite imagery analysis, GIS integration, vegetation transects, vegetation quantification plots, and other potential tasks. Monitoring reports should include recommendations for adaptive management strategies to be applied as data become available.

Soil moisture, sediment transport, and hydrologic changes may also be monitored, and would likely be part of a larger effort to assess the overall performance of the bypass per the rearing habitat objectives.

5.3.7 Invasive Species

Management of invasive species will be critical, especially during the short term (minimum of 3 years) to ensure that the desirable vegetation dominates the landscape and provides habitat diversity, productivity, and sustainability. Selective herbicides may be used in seeded areas and glyphosate formulations or other herbicides safe for application within the drip-line of woody species and within the floodplain may be used to keep irrigated areas clear of competing vegetation. All herbicides must be applied in accordance with the label and by a certified applicator as required.

Integrated methods for weed suppression are typically more economical and effective than any one method used alone. Mechanical control (tillage, hand removal, etc.) may be an option for small or contiguous patches, and mowing can also be effective for some species. Other innovative techniques for promoting native vegetation over invasive species may be explored. This will be particularly important in the upland areas where no irrigation will occur.

Known weeds in the vicinity of the project area and potential upstream sources of invasives include scarlet wisteria (*Sesbania punicea*), giant reed (*Arundo donax*), edible fig (*Ficus carica*), tree of heaven (*Ailanthus altissima*), Chinese tallow (*Triadica sebifera*), tamarisk (*Tamarix* spp.), and blessed milkthistle (*Silybum marianum*).

Weed control efforts are integrated into the site preparation stage to knock down the first flushes that will come up between irrigation lines and in the upland areas after soil disturbance. Two years of well-timed cultivation and herbicide application should reduce the amount of aggressive, early germinating species that are well adapted to disturbance and could be problematic competitors for natives.

5.3.8 Herbivory

Herbivore damage to newly planted or germinated vegetation can be alleviated with screens, chemical deterrents, or other exclusion methods. Mowing can also be used to eliminate cover for rodents and small mammals that may cause damage to planted species.

5.3.9 Schedule

All plantings should be completed within one season following excavation of the bypass and irrigation system setup. An overall schedule including the excavation and flow reintroduction schedule is given in Table 5-22. Seeding is typically done in the late fall or winter to maximize use of seasonal precipitation and first-year growth. Warm season grasses may do better with spring or early summer seedings, especially if seed predation is an issue. Woody cuttings and transplants should be installed in the winter or early spring.

All plantings and seedings will ultimately be more successful if coordinated with natural precipitation. This will be more critical for the upland zone where no irrigation will occur, whereas irrigated areas may produce successful establishment with less sensitivity to timing.

5.3.10 Vegetation Evolution

Vegetation within the bypass is expected to change in composition and structure from the initial planting effort over time. There is a good deal of uncertainty as to what the equilibrium state will look like due to a variety of factors (climate, soils, hydrology, sediment transport, etc.) that are difficult to predict. Initial revegetation efforts are designed to introduce enough desirable vegetation into the system in order to make valuable habitat the most likely outcome, although it cannot be guaranteed without persistent monitoring, maintenance, and potentially reseeding or replanting some areas.

Succession of disturbed areas without intervention can vary widely, but generally initiates with herbaceous annuals, typically weedy species, then evolves towards perennial grasses, forbs, and finally to a multi-tiered structure with understory, woody shrubs, and trees given suitable riparian conditions. By installing native shrubs and trees in the bypass, the landscape will progress more rapidly towards a mature stage with diverse structure and dense canopies.

Flows through the bypass will have a significant effect on how the vegetation evolves. Episodic scouring flows will be necessary to propagate cottonwoods and willows, and maintaining sufficient groundwater levels is critical for support of all riparian species within the bypass. Extended periods of below-normal groundwater levels may shift the vegetation community towards a less robust and more herbaceous/woody scrub type of system with lower habitat value.

Other maintenance activities such as weed suppression and irrigation also have the potential to substantially shape the evolution of vegetation in the bypass. Although invasive species might decline over time naturally if native species are able to gain a foothold, they will likely persist as a significant proportion of the community and lower overall habitat quality.

5.4 Irrigation

5.4.1 Water Requirements

The riparian corridor alongside the bypass channel area will require irrigation for a period of 3 to 5 years. This restoration area encompasses 55 acres of over 28,500 new riparian plants. This section describes the irrigation water requirements of these riparian species. The monthly irrigation requirement (F_g) was calculated by

$$F_g = \frac{(ET_C - P_e)}{I_e} \quad \text{Eq 12}$$

where ET_C is the crop evapotranspiration, P_e is the effective precipitation, and I_e is the irrigation efficiency. Crop evapotranspiration was calculated by:

$$ET_c = K_c ET_o \quad \text{Eq 13}$$

where $K_c$the crop coefficient and ET_o is the reference crop evapotranspiration (in/day). The crop coefficient integrates the effect of characteristics that distinguish typical field crop from the grass reference, therefore different crops have difference $K_c$values. In addition to using different $K_c$values for different crops, $K_c$values for a crop changed between months to account for crop development stages and variation in climate. Crop coefficients for willows were taken from Gazal et al. (2006) (Table 5-13).

Table 5-13.—Willow monthly crop coefficients (K_c).

Crop	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Willows	0.18	0.23	0.23	0.32	0.35	0.38	0.41	0.43	0.46	0.47	0.49	0.50

The Natural Resources Conservation Service (NRCS) National Engineering Handbook Part 623 Chapter 2 method was used for P_e in this design (NRCS National Engineering Handbook, 1993). A common irrigation efficiency for micro-spray irrigation ranges between 80 to 95 percent. This study assumed a conservative 85 percent irrigation efficiency. ET_o monthly values (inches) and precipitation were obtained from the Department of Water Resources, California Irrigation Management Information System (CIMIS) at station name Los Banos # 56 (Figure 5-11, Table 5-14). The monthly values reported have been averaged from June 28, 1988 to September 21, 2015.

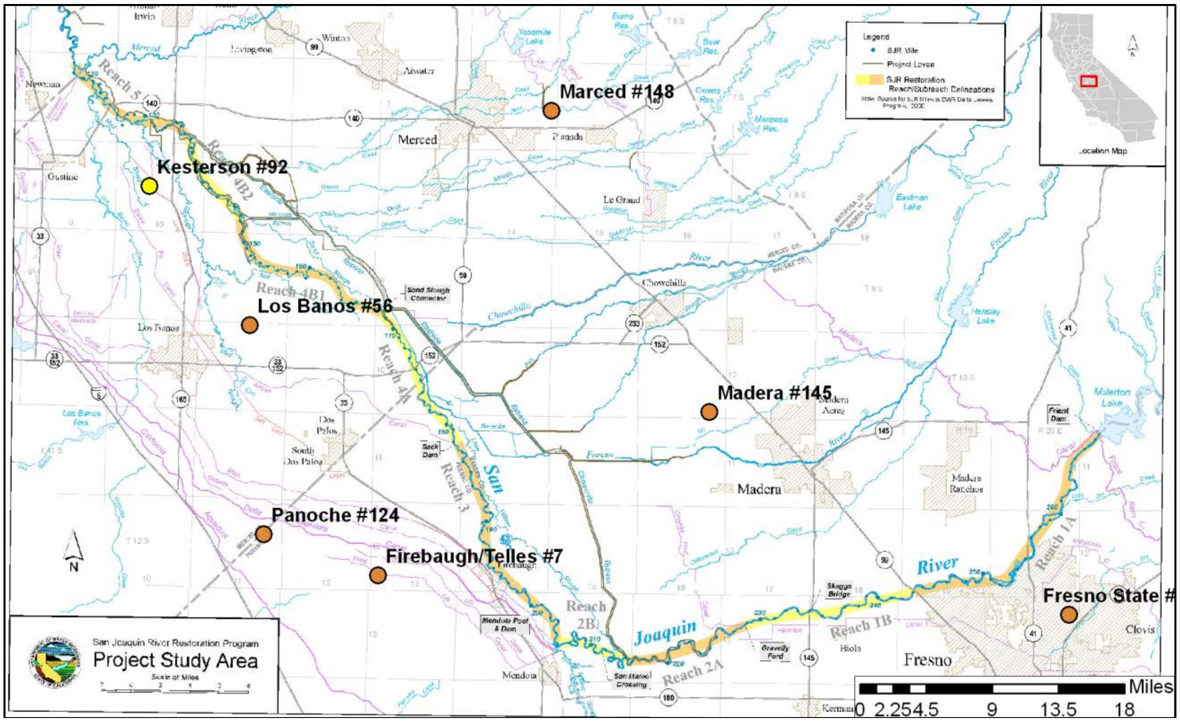


Figure 5-11.—Location of CIMIS stations near the project location.

Table 5-14.—Monthly ETo values in inches at station #56 Los Banos from September 21, 2015.

Type	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
ETo (in)	1.18	2.03	3.83	5.60	7.60	8.46	8.22	7.49	5.61	3.79	1.86	1.08	56.75
P (in)	1.64	2.09	1.58	0.61	0.37	0.09	0.01	0.02	0.12	0.56	0.76	1.29	9.14

5.4.2 Soils Data

The irrigation water requirement is also impacted by the soil type, the soil infiltration capacity (hydraulic conductivity), and soil salinity. Data were collected on hydraulic conductivity and salinity within reach 2B (Figure 5-12). The NRCS soil survey of Merced county has the predominate soil type as sandy loam which corresponds to the soil hydraulic conductivity data collected showing moderate rates of infiltration. A micro-sprinkler system was chosen because of higher infiltration rates. Drip irrigation was ruled out because of the potential for non-uniform wetting in the desired wetting radius. Soil salinity data shows that electrical conductivity and salinity may be within acceptable levels, which indicate that application of irrigation water to flush salts will not be required initially. However, flushing irrigation maybe required in year 2 or 3 if salinity builds up in soil.

The NRCS soil survey data also provides information on the available soil water supply (AWS) or the amount of water that is held within the soil for the plant to use. Since plants in the first year will not have very deep rooting depths, the 0 to 25 centimeter depth was examined and plotted in Figure 5-13. The highest AWS was the Chino loam with 4.25 cm or 1.67 in and the lowest was the Riverwash of

1.25 cm or 0.49 in. An area weighted average was performed and the AWS for the irrigation area was 2.79 cm or 1.1 in.

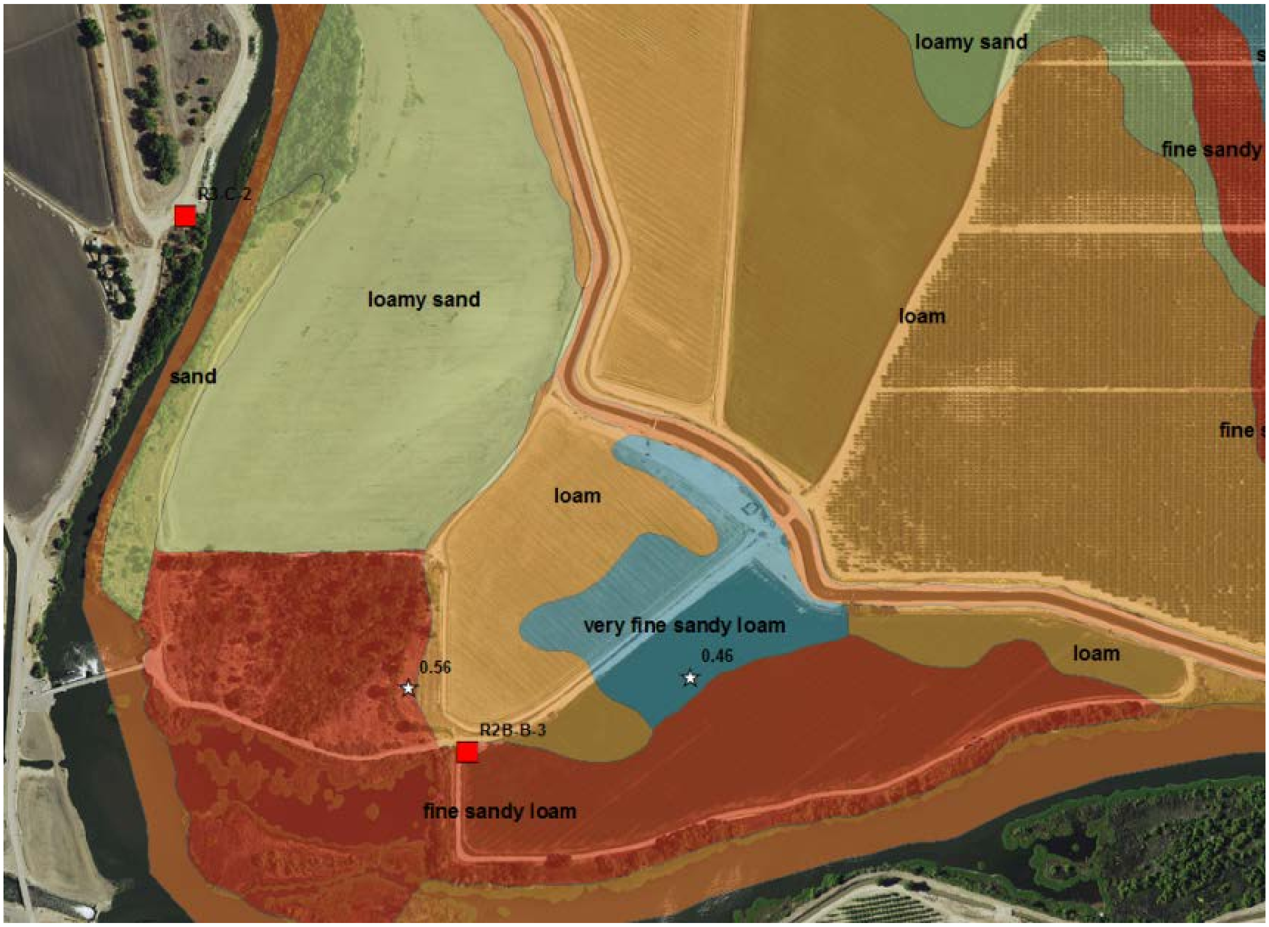


Figure 5-12.— Reach 2B soils texture, salinity, and hydraulic conductivity data. The white stars indicate soil salinity locations and values in dS/mm. The red squares are the locations of soil hydraulic conductivity test locations.

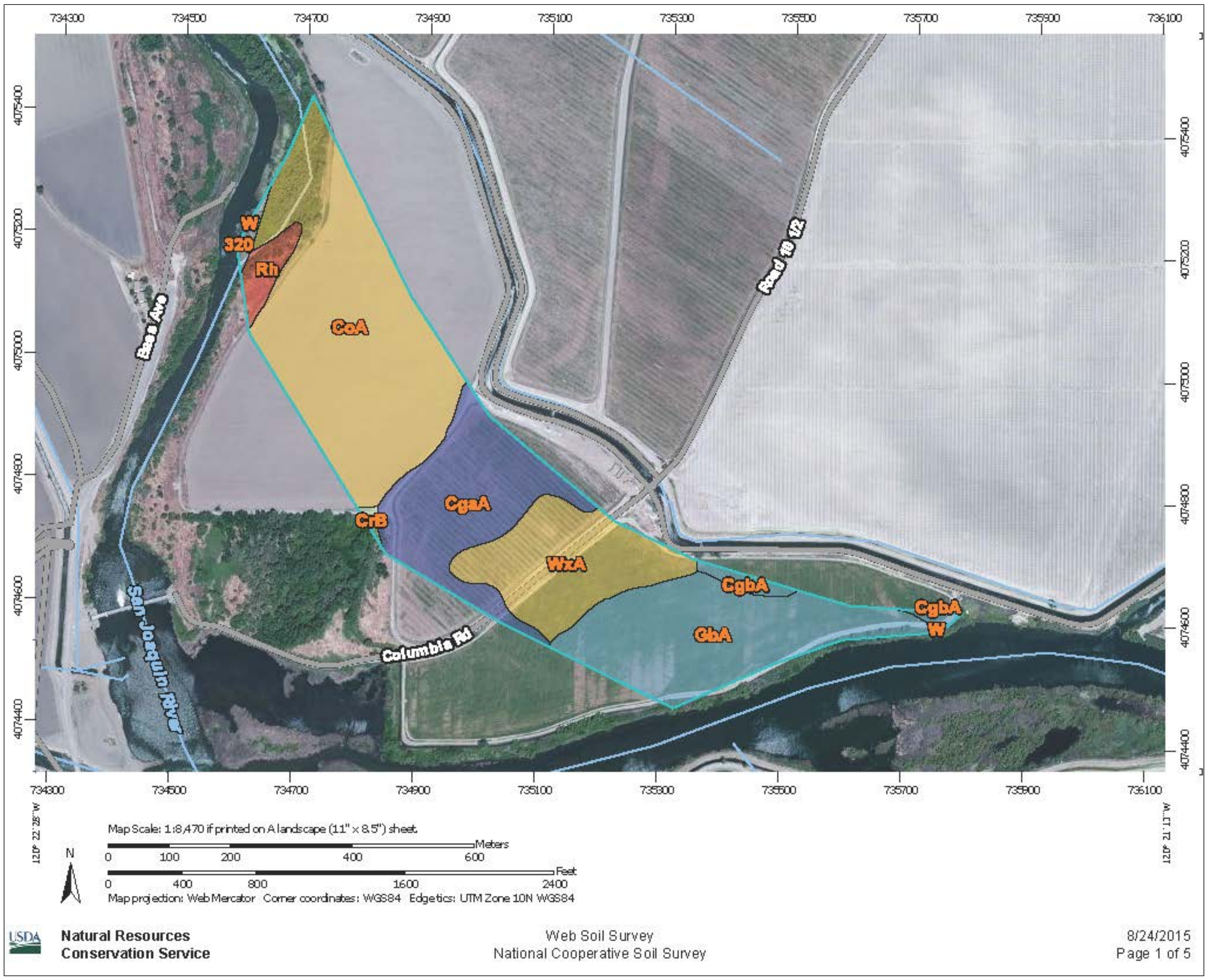


Figure 5-13.—NRCS Soil Survey Available water supply at 0 to 25 centimeters in the soil depth.

Table 5-15.—Area weighted capacity for the available water supply for reach 2B bypass area.

Map Unit	Available Water Supply Rating (cm)	Available Water Supply Rating (in)	Acres	Area Weight (in)
Chino Loam (CgaA)	4.25	1.67	13.7	0.3
Chino Loam (CgbA)	3.15	1.24	1.2	0.02
Columbia loamy sand (CoA)	2.25	0.885	30	0.35
Columbia soils (CrB)	2.5	0.98	0.3	0.00
Grangeville fine sandy loam (GbA)	3.25	1.28	17.1	0.29
Riverwash (Rh)	1.25	0.49	1.8	0.01
Wunjey very fine sandy loam (WxA)	2	0.78	11.8	0.12
Total			75.9	1.1

5.4.3 Irrigation Schedule

The amount of water required for the bypass area is dependent upon the number of plants. The planning density decided upon was 500 plants/acre for a total of 28,481 plants within the bypass revegetation area. The exact make up of plants and their arrangements are currently unknown; therefore, a conservative assumption was made on the irrigation water requirement by assuming all plants require the same amount of water as willows. Table 5-16 provides the total volume of water required by the project.

The irrigation schedule is determined by the volume of water required by the plants, the volume of water that can be stored in the soil, and surface soil hydraulic conductivity. It is assumed that the soil reservoir on average can store up to 1.1 inches before losing water to deep percolation. The irrigation rates were altered so the required amount of water was met but did not exceed the 1.1 inch soil reservoir. This irrigation schedule assumed there were winter rains. Additional irrigation schedules could be developed to account for drought conditions. Table 5-16 provides the number of irrigation days and the number of hours to be operated during those days. It also details the amount of water stored each month within the soil reservoir and how much water is lost to deep percolation. The total amount of water lost to deep percolation per plant in one year is approximately 2.4 inches. This equates to a total deep percolation loss of 1.7 ac-ft for the entire revegetation bypass area and is an application efficiency of 96%.

Due to the desired wetting radius of 16 ft by 5 ft and predominate sandy loam soil type, drip irrigation was ruled out and a micro-sprayer system was chosen. The irrigation design layout will be discussed later. The emitter selected has a flow rate of 4.4 gallons/hour. Table 5-16 shows the numbers of days and hours in which the irrigation system will have to be operated in order to meet the irrigation water requirements for the plants. The table also indicates that 83 ac-ft will be required each year for the bypass revegetation.

The irrigation volume per hour was calculated by:

$$IV\ (GPH) = I_T Q_e \qquad \text{Eq 14}$$

where IV is the irrigation volume (GPH), I_T is the total irrigation time (hours), and Q_e is the emitter flow rate (GPH). The total irrigation volume was calculated by:

$$TIV\ (ac-ft) = \frac{Q_e * N}{SG_W * 43{,}560} \qquad \text{Eq 15}$$

where TIV is the total irrigation volume in acre-feet, N is the number of plants to be watered, and SG_w is the specific gravity of water.

Table 5-16.—Irrigation schedule for the Reach 2B bypass revegetation

Property	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
Plant Water Requirement (in/plant/month)	0.0	0.0	0.90	2.36	3.56	4.26	4.23	3.85	2.80	1.52	1.39	-	25
Plant Water Requirement (in/plant/day)	0.0	0.0	0.03	0.08	0.11	0.14	0.14	0.13	0.09	0.05	0.05		1
Irrigation Days/month	0	0	1	12	12	13	18	15	19	10	1	0	98
Irrigation hrs/day	0.0	0.0	1.00	0.75	1.00	1.0	1.0	1.25	0.75	0.50	0.50	0	4.25
Irrigation hrs/month	0	0	0	9.0	12.0	13.0	18.0	18.8	14.3	5.0	0.0	0.0	81.0
Emitter GPH/plant/month	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
in of irrigation/plant	0.0	0.0	0.0	1.3	1.7	1.8	2.5	2.6	2.0	0.7	0.0	0.0	12.85
Water supplied (in/plant/day)	0.0	0.00	0.00	0.11	0.14	0.18	0.14	0.18	0.11	0.07	0.00	0.00	0.92
Water Stored in the Soil (in/month)	0.95	1.10	0.29	0.85	1.67	1.05	1.10	1.10	1.04	1.10	0.59	0.96	11.79
Irrigation lost to deep percolation (in/month)	0.0	0.59	0.0	0.0	0.0	0.0	0.69	1.45	0.0	1.05	0.0	0.0	3.78
Volume Irrigation supplied (gal/month)	0.0	0.0	0.0	1,127,998	1,503,998	1,629,331	2,255,997	2,349,997	1,785,997	626,666	94,000	0	11,373,984
Volume of Irrigation Supplied (ac-ft/month)	0	0	0.0	3.46	4.62	5.00	6.92	7.21	5.48	1.92	0.29	0	34.9

5.4.4 Irrigation Layout

5.4.4.1 Irrigation zones

The Reach 2b bypass revegetation area was divided into four irrigation zones to increase pressure uniformity, reduce pipe sizes, and to increase flexibility in the irrigation schedule.   The irrigation design capitalized pressure reduction by placement of pipe along the downslope. The plants have been spaced at a distance of 5 ft along the rows. Reach row is spaced at 16 foot intervals. This configuration achieves a planting density of 500 plants/acre. The irrigation zones and layout are delineated in Figure 5-14.

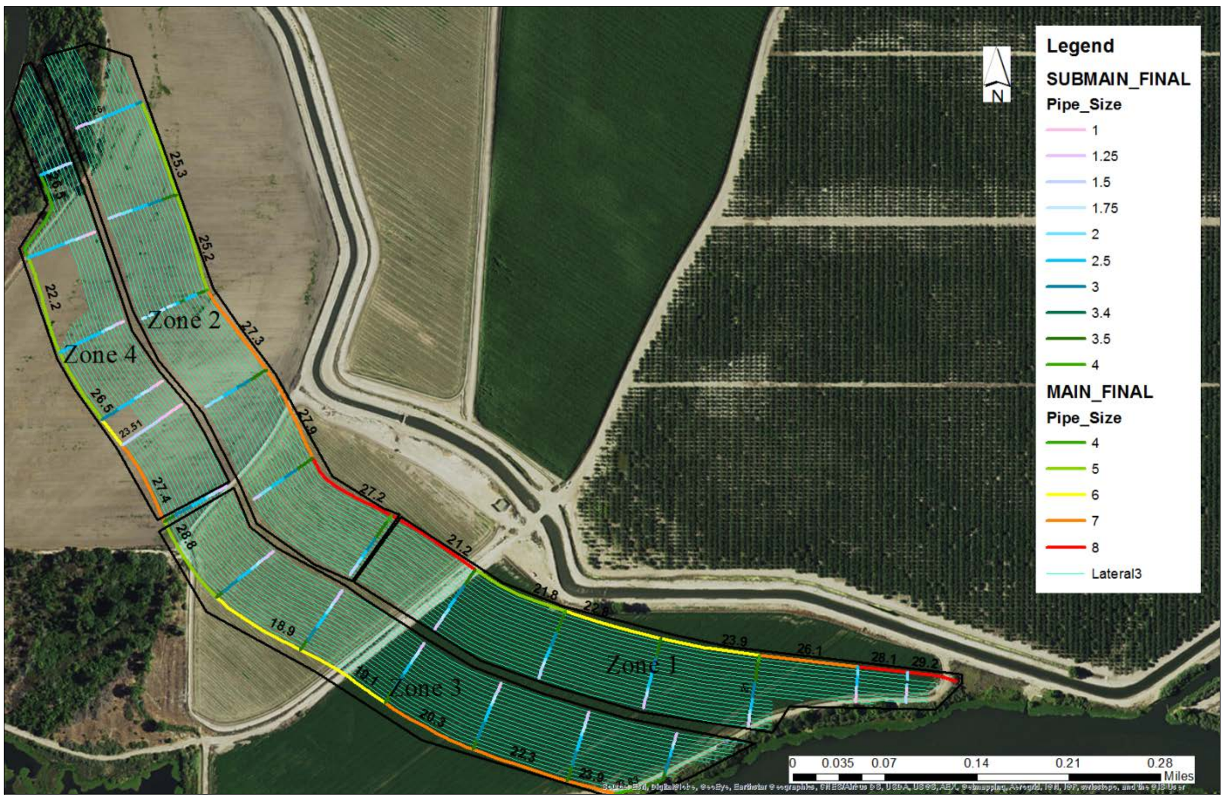


Figure 5-14.—Irrigation layout and irrigation zone delineated.

5.4.4.2 Emitters

Emitters will be located at every plant location, and are placed every 5 ft along the lateral row. As stated previously the selected emitters have a rectangular wetting area of 10 ft by 5 ft, a flow rate of 4.4 gallons per hour, and an operating pressure of 10 psi. A pressure regulating emitter was select to ensure irrigation uniformity even in the presence of pressure variation. Each emitter will require a 6-inch riser to meet its wetting radius. The emitter connects to the lateral tubing through a 1-foot feeder tube of polyethylene with a 0.140-inch inner diameter.

5.4.4.3 Pipe Sizes

The lateral lines that supply the emitters are a polyethylene resin 1.38-inch inner diameter pipe. This size was selected to minimize pressure loss, is rated for the operating pressure (a maximum of 42 psi), and the manufacture makes coil lengths that do not require couplers to meet the lateral lengths. Sub-mains and main pipe sizes were determined by examining pressure loss across the pipes from friction and head loss. The friction losses within the pipes were calculated by the Hazen-Williams equation:

$$P_d = \frac{4.52q^{1.85}}{c^{1.85}d_h^{4.8655}} \qquad \text{Eq 16}$$

where P_d is the pressure drop over the length of the pipe (psi/ft), q is the flow rate in (gpm), c is the design coefficient of friction, and d_h is the inside hydraulic diameter. A c value of 145 was selected for polyethylene pipe. The head loss was determined from the terrain developed for the bypass design (Figure 5-15). The system was sized systematically by calculating loss through laterals, then sub-mains that supply the laterals, and finally losses through the main that supply the sub-mains. Appendix D and Appendix E provide the pressure loss calculations, flow through the pipes, the lengths of pipes, the inner diameter of pipes, and the flow through the pipes. Table 5-17 and Table 5-18 provide the total pipe size quantities for the irrigation system.

Table 5-17.—Pipe size and quantities for the sub-mains.

Sub-main Pipe Size (in)	Quantity (ft)
1	200
1.25	100
1.5	700
1.75	100
2	1000
2.5	1200
3	1400
3.5	1500
4	700

Table 5-18.—Pipe sizes and quantities for the main.

Pipe Size (in)	Quantity (ft)
8	1500
7	2000
6	2000
5	2000
4	400

Table 5-19 - Lateral line sizes and quantities.

Brand	Type	Size	Quantity (ft)
BowSmith or equivalent	Premium Plus + tubing	1530P72	143,541

Table 5-20 - Emitter properties and quantities.

Brand	Type	Nozzle/type	Spray Pattern	Quantity
BowSmith or equivalent	Fan-Jet "PC" series	PC-4 with #30 Nozzle (Black)	Rectangular	28,481
BowSmith or equivalent	Feeder Tube	0.245 O.D Polyethylene feeder tubing		28,481
BowSmith or equivalent	Standard Coupling			28,481
BowSmith or equivalent	SK-C Stake	9"		28,481

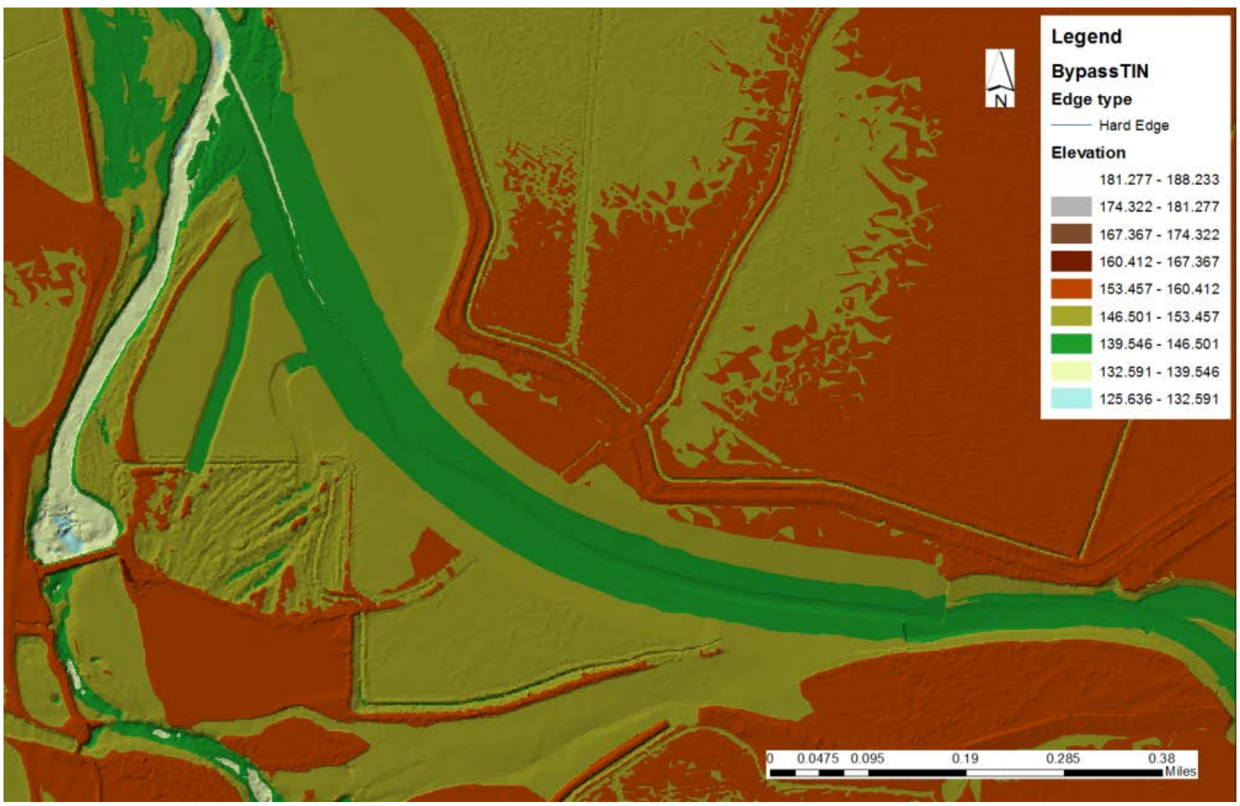


Figure 5-15.—Reach 2B bypass channel terrain

5.4.4.4 Pumps

The source or location of water being supplied to the irrigation system is currently unknown. However, the design requires pumps to supply water to the reach 2b bypass. The irrigation schedule shows that the longest duration or irrigation on any day is 5 hours. One pump could feasibly supply each of the zones. This analysis or design has yet to be completed. Table 5-21 provides the required pumping rates and pressures for each irrigation zone.

Table 5-21 - Pumping pressures and flow rate for each irrigation zone.

Irrigation Zone	Pressure (psi)	Flow rate (gpm)
1	30	725
2	30	822
3	26	816
4	28	459

5.4.4.5 Filters

One of the highest costs of maintaining an irrigation system is unclogging particulates from emitters. Identifying these problematic locations and repairing them can lead to timely and expensive repairs and reduce overall distribution uniformity. To prevent emitter clogging from particulates, manufacturers of the selected emitters recommend a 150-mesh (opening size of 0.0041 inches) size for filtration. The filter shall be placed in series just downstream of the pump. The filter shall have a maximum flow rate of 900 gpm and have a connection size of 8 inches. Note there will be a pressure drop along the filter that is selected; therefore the pump may have to supply a higher pressure than what is prescribed in this report.

5.4.4.6 Air vents

It is highly recommend that air vents be incorporated at the end of each lateral line. Air vents release large volumes of air on startup to prevent air blockage and water hammer. Additionally, the air vent continuously releases pressure after the system has been pressurized to prevent water hammer. The air vents chosen for this study are a 1.5” kinetic air vent and vacuum regulator.

5.4.5 Irrigation System Maintenance

The irrigation system will need to be checked periodically for damage, clogs, and adequate performance. Annual maintenance will likely be necessary to make sure the system is operating correctly, and may require soil moisture monitoring to fully assess timing and duration (adaptive management).

5.5 Schedule

The excavation, revegetation and re-introduction of flow to the Bypass needs to be carefully planned. If the revegetation is not done quickly then invasive species control will be difficult; if high flows are introduced into the Bypass too quickly then much of the revegetation work will be lost and extensive bank erosion is possible.

The following schedule for the components described above is suggested in Table 5-22. The Bypass excavation would begin in Winter of Year 0, where Year 0 indicates the beginning of the project. It is assumed that excavation and installation of an irrigation system could be complete by the following fall, at which time the planting of Zones 1 through 3 would occur. The vegetation would be allowed to grow for 2 years under irrigation and there would be invasive weed control during that period. In Fall of Year 2, the herbaceous understory in Zone 1 and 2 would be planted.

The introduction of flows into the Bypass would occur in stages. The first stage would be the introduction of base flows (less than 200 cfs) in Spring of Year 3, three years after the initial planting. The introduction of base flows would promote continued establishment of the vegetation and would allow monitoring of bank erosion to ensure that the channel is stable at low flow. The base flows would be introduced through the fish ladder and the water surface elevations in Reach 2B would be kept near Mendota pool elevations so that the low flows do not incise into Reach 2B.

The second stage would be introduction of flows up to 1200 cfs. Prior to the introduction of these flows, the irrigation system should be removed. In addition, the pilot channel would be excavated into Reach 2B. These flows would pass through open gates at the head of the Bypass and would allow incision into Reach 2B. Significant geomorphic change is anticipated as a result of these flows and monitoring would be performed in the Bypass and Reach 2B.

If the first two stages of flow reintroduction are successful, the third stage would be introduction of high flows in Spring of Year 5. However, it will not be possible to introduce flows larger than 1200 cfs into the Bypass until all the levees in Reach 2B are rebuilt.

Table 5-22.—Schedule for excavation, revegetation and flow reintroduction, schedule is assumed to start in Winter of Year 0 termed "Winter 0".

Component	Begin	End
Source Plant Materials	Fall -2	Fall 0
Bypass Channel Excavation	Winter 0	Fall 0
Installation of Irrigation system	Summer 0	Fall 0
Initial Planting of Zones 1 – 3	Fall 0	Spring 1
Vegetation Maintenance and Invasive Control	Fall 0	Fall 3
Planting of Understory in Zones 1 and 2	Fall 2	Fall 2
Removal of Irrigation System	Winter 3	Winter 3
Introduction of Base Flows (up to 200 cfs)	Spring 3	-
Construction of Pilot Channel in Reach 2B	Winter 4	Winter 4
Introduction of Bank Full Flows (up to 1200 cfs)	Spring 4	-
Introduction of High Flows (up to 4500 cfs)	Spring 5	-

6 References

Aceituno, M.E. 1990. Habitat preference criteria for chinook salmon of the Stanislaus River, California. USDI Fish & Wildlife Service, Sacramento, California.

Biedenharn, D.S., Watson, C.C., and Thorne, C.R. (2008). "Fundamentals of Fluvial Morphology," Ch 6 of *Sedimentation Engineering*, ASCE Manual and Reports on Engineering Practice No. 110, Edited by M. Garcia.

Bormann, N.E., and Julien, P.Y. (1991). "Scour Downstream of Grade-Control Structures," *Journal of Hydraulic Engineering*, Vol. 117, No. 5, pp. 579 – 594.

Buffington, J.M, and Montgomery, D.R. (1997). "A systematic Analysis of Eight Decades of Incipient Motion Studies, with special Reference to Gravel-Bedded Rivers," *Water Resources Research*, Vol. 33, No. 8, pp. 1993-2029.

Bunte, Kristin; Abt, Steven R. (2001). *Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring*. Gen. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.

Burchsted, D., Daniels, M.,Wohl, E., (2013). "Introduction to the Special Issue on Discontinuity of Fluvial Systems," *Geomorphology*, doi:10.1016/j.geomorph.2013.04.004.

Caamaño, D., Goodwin, P., and Buffington, J.M. (2012). "Flow Structure through Pool-Riffle Sequences and a Conceptual Model for Their Sustainability in Gravel-Bed Rivers," *River Research and Applications*, 28:377-390.

Cain, J.R. (1997). *Hydrologic and geomorphic changes to the San Joaquin River between Friant Dam and Gravelly Ford and implications for restoration of Chinook Salmon (Oncorhynchus tshawytscha)*. M.A. Thesis, University of California, Berkely, 143 p.

Camenen, B. (2012). "Discussion of "Understanding the influence of slope on the threshold of coarse grain motion: Revisiting critical stream power" by C. Parker, N.J. Clifford, and C.R. Thorne", *Geomorphology* 139-140, 34–38, doi:10.1016/j.geomorph.2011.10.033.

Childers, D., 1999, Field Comparisons of Six Pressure-Difference Bedload Samplers in High Energy Flow, U.S. Geological Survey Water Resources Investigations Report 92-4068, 59 p.

Comiti F., V. D'Agostino, V. Ferro, M.A. Lenzi, (2006). Fenomeni di erosione localizzata a valle di opere trasversali: integrazioni tra indagini di campo e di laboratorio, Quaderni di Idronomia Montana, 25, 217-225.

Davis, B.E. (2005). "A Guide to the Proper Selection and Use of Federally Approved Sediment and Water-Quality Samplers," January 2005, Report QQ, Federal Interagency Sedimentation Project, Waterways Experiment Station, Vicksburg, MS.

DeFlitch (2010). *Measurements and Monitoring of Bedload Sediment Transport Along the Upper San Joaquin River from Gravelly Ford to the Chowchilla Bypass Bifurcation Structure, California*, A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology in the College of Science and Mathematics California State University, Fresno, May 2010.

Dust, D. and Wohl, E. (2012). "Conceptual model for complex river responses using an expanded Lane's relation," Geomorphology 139-140 (2012) 109–121.

Edwards, T.K., and Glysson, G.D., 1999. Field Methods for Measurement of Fluvial Sediment. U.S. Geological Survey Techniques of Water Resources Investigation, Book 3 Chapter C2, 89 p.

Engelund, F., and Hansen, E. (1972). *A monograph on sediment transport in alluvial streams*, Teknish Forlag, Technical Press, Copenhagen, Denmark

ESA (2012). Conceptual Riparian Revegetation Approach, San Joaquin River Restoration Program, Reach 4B, prepared for U.S. Bureau of Reclamation, June 2012.

Federal Highways Administration (1989). "Design of Riprap Revetment," Hydraulic Engineering Circular No. 11, Publication No. FHWA-IP-89-016, March 1989.

García (2008). "Sediment Transport and Morphodynamics," Ch 2 of Sedimentation Engineering, ASCE Manual and Reports on Engineering Practice No. 110, Edited by M. Garcia.

Geomorphology, Volume 126, March 2011, Pages 51-65

Graham Matthews & Associates (2004-2011). Annual Flow Release Sediment Transport Monitoring Reports. Reports for Trinity River Restoration Program, Bureau of Reclamation, Weaverville, CA.

Graham Matthews and Associates (2011). *San Joaquin near Ledger Island Water Year 2011 Bedload Sampling*, Technical Memorandum dated June 13,2011. In Appendix D Sediment of 2011 Final Annual Technical Report San Joaquin River Restoration Program.

Gray, D.H. and R.B. Sotir, 1996. *Biotechnical and Soil Bioengineering Slope Stabilization*, John Wiley and Sons, NY

Greimann, B., Lai, L., and Huang, J. (2008). "Two-Dimensional Total Sediment Load Model Equations," *Journal of Hydraulic Engineering*, ASCE, Vol. 134, No. 8: 1142-1146.

Gurnell, A.M., Petts, G.E. (2002). Island-dominated landscapes of large floodplain rivers, a European perspective. Freshw. Biol. 47, 581–600.

Huang, J. and Greimann, B. (2012). *User's Manual for SRH-1D, Sedimentation and River Hydraulics – One Dimension Version 3.0,* Technical Report SRH-2013-11, Technical Service Center, US Bureau of Reclamation, Denver, CO.

Jones and Stokes Associates, Inc. (JSA) and Mussetter Engineering Inc. (MEI) (1998). *Analysis of physical processes and riparian habitat potential of the San Joaquin River – Friant Dam to the Merced River. Sacramento, CA.* With Technical Assistance from Ayers Associates. Prepared for U. S. Bureau of Reclamation, Fresno, CA.

Kottegoda, N., and Rosso, R. (1997). Statistics, Probability, and Reliability for Civil and Environmental Engineers, McGraw-Hill.

Lai, Y. 2008. SRH-2D version 2: Theory and User's Manual, Sedimentation and River Hydraulics – Two-dimensional River Flow Modeling, US Bureau of Reclamation, Technical Service Center, Denver, CO.

Lagasse, P.F., Clopper, P.E, Zevenbergen, L.W., and Ruff, J.F. (2006). "Riprap Design Criteria, Recommended Specifications, and Quality Control," National Cooperative Highway Research Program, Transportation Research Board, Washington, DC.

Lamb, M.P, Dietrich, W.E., and Venditti, J.G. (2008). "Is the critical Shields stress for incipient sediment motion dependent on channel-bed slope?," Journal of Geophysical Research, vol. 113, F02008, doi:10.1029/2007JF000831.

Laursen, E.M.(1958). "The total sediment load of streams," *Journal of Hydraulic Division*, ASCE, Vol. 84(1), 1531-1536.

Luhdorff and Scalmanini, Kenneth D. Schmidt and Associates (2011). *Mendota Pool Group Pumping and Monitoring Program: 2010 Annual Report*. Prepared for San Joaquin River Exchange Contractors Water Authority, Paramount Farming Company, and Mendota Pool Group.

Madden, E.B. (1993) *Modified Laursen Method for Estimating Bed-Material Sediment Load*, U.S. Army Corps of Engineers, U.S. Army Engineer Waterways Experiment Station, Contract report HL-93-3.

McBain and Trush, Inc. (eds.). *2002. San Joaquin River Restoration Study Background Report*. Prepared for Friant Water Users Authority, Lindsay, CA, and Natural Resources Defense, Council, San Francisco, CA.

Meadows, T., Tjarks, H., Rentner, J., Sheppard, S., Weaver, S., Salimbene, J., Rayburn, A., (2015) "Multi-benefit weed control: the San Joaquin River invasive species management and jobs," San Joaquin River Restoration Program Science Meeting, June 2015, Los Banos, CA.

Mueller, E.R., Pitlick, J., and Nelson, J. (2005). "Variation in the Reference Shields Stress for Bed Load Transport in Gravel-Bed Streams and Rivers," *Water Resources Research*, vol. 41, W04006, doi:10.1029/2004WR003692.

Parker, C., Clifford, N.J., Thorne, C.R. (2011). Understanding the influence of slope on the threshold of coarse grain motion: Revisiting critical stream power, *Geomorphology*, 126:51-65, doi:10.1016/j.geomorph.2010.10.027.

Parker, G. (1990). "Surface based bedload transport relationship for gravel rivers," *Journal of Hydraulic Research*, Vol. 28(4), 417–436.

Pettsa, G.E., and Gurnell, A.M. (2005). Dams and geomorphology: Research progress and future directions, *Geomorphology*, Volume 71, Issues 1–2, 1 October 2005, Pages 27–47

Pittman, S.A. 2005. WY 2005 Technical Memo #1: Toutle River-2 Bedload Sampler. Prepared for Trinity River Restoration Program, Bureau of Reclamation, Weaverville, CA. September 2005.

Recking, A. (2009). "Theoretical development on the effects of changing flow hydraulics on incipient bed load motion," *Water Resources Research*, vol. 45, W04401, doi:10.1029/2008WR006826.

Reclamation (1984). "Hydraulic Design of Stilling Basins and Energy Dissipators," Engineering Monograph No. 25, Bureau of Reclamation, Denver, CO.

Reclamation (2008). San Joaquin Data Collection Report Sediment Sampling February 4-6, 2008. San Joaquin River Restoration Project, Technical Service Center, Bureau of Reclamation, Denver, CO.

Reclamation (2009). *Geomorphology, Sediment, and Vegetation Impacts of the San Joaquin River Restoration Program*, Bureau of Reclamation, Technical Report No. SRH-2009-27, Technical Service Center, Denver, CO

Reclamation (2012a). *Hydrology, Hydraulic, and Sediment Studies for Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project*, Technical Report No. SRH-2012-16. Prepared for San Joaquin River Restoration Project, Mid-Pacific Region, US Bureau of Reclamation, by the Technical Service Center, Denver, CO.

Reclamation (2012b). *San Joaquin River Restoration Daily Flow Model (SJRRW) Documentation for the Reach 4B Study*, Technical Report No. 86-68210-2012-04, Technical Service Center, Denver, CO.

Reclamation (2012c). Central Valley Subsidence Investigation – Data Update, Memorandum dated Aug 21, 2012 to San Joaquin River Restoration Project from Ani Bhattacharyya.

Reclamation (2012d). *Hydraulic Studies for Fish Habitat Analysis*, San Joaquin River Restoration Project, Mid-Pacific Region, Technical Report No. SRH-2012-15, December, 2012.

Reclamation (2012e). *Mendota Pool Sediment Quality Investigation - Analytical Results, Data Assessment, and Quality Assurance Summary*, In Support of the Mendota Pool Bypass and Reach 2B Improvements Project, San Joaquin River Restoration Program, Bureau of Reclamation, Mid-Pacific Region, Division of Environmental Affairs, February 10, 2012.

Reclamation (2014a). *Large Wood National Manual*, Technical Review Draft, January 2014.

Reclamation (2014b). *Sediment Budget Analysis of the San Joaquin River WY 2010 to 2012*, prepared for the San Joaquin River Restoration Project, Mid-Pacific Region.

Reclamation (2015a). *Bank Stabilization Design Guidelines*, Report No. SRH-2015-25. Bureau of Reclamation, Technical Service Center, Denver, CO.

Reclamation (2015b). *Conceptual Hydraulic Design of the Mendota Bypass*, Technical Report No. SRH-2015-26, Bureau of Reclamation, Technical Service Center, Denver, CO.

S. Anders Brandt (2000). "Classification of geomorphological effects downstream of dams," *Catena* 40, pp. 375–401.

Schumm S.A., Harvey M.D.,Watson, C.C. (1984). Incised Channels: Morphology, Dynamics, and Control. Water Resources Publications: Littleton, CO.

Simon A, Hupp CR. (1986). Geomorphic and vegetative recovery processes along modified Tennessee streams: an interdisciplinary approach to disturbed fluvial systems. Forest Hydrology and Watershed Management. IAHS-AISH Publ.167.

SJRRP (2012a). *Appendix D Sediment*, in *2011 Final Annual Technical Report.*

SJRRP (2012b). Mendota Pool Bypass and Reach 2B Improvements Project, Project Description Technical Memorandum. May 2011, First Administrative Draft.

SJRRP (2012c). Minimum Floodplain Habitat Area for Spring and Fall-Run Chinook Salmon. November 2012.

SJRRP (2014). Fish Passage Design Criteria,

Stillwater Sciences (2003). *Draft Restoration Strategies for the San Joaquin River*, Appendices, February 2003, Prepared for Friant Water Users Authority and Natural Resources Defense Council.

Tetra Tech (2011). *San Joaquin River Reach 1A HEC-RAS Steady-state Hydraulic Model Geometry Updates*, DRAFT dated July 22, 2011.

Tetra Tech (2012a). *2011 San Joaquin River Sand Storage Evaluation*, DRAFT dated January 11, 2012.

Tetra Tech (2012b). *San Joaquin River: Evaluation of Sand Supply Storage and Transport in Reaches 1A and 1B*, DRAFT dated January 26, 2012.

Tetra Tech (2012c), *Reach 2A Sedimentation Evaluation* (2011), dated April 17, 2012.

Tetra Tech (2013), *San Joaquin River and Bypass System 1-D Steady State HEC-RAS Model Documentation*, May 16, 2013.

Wilcock, P.R., and Crowe J.C. (2003). “Surface-Based Transport Model for Mixed-Size Sediment,” *Journal of Hydraulic Engineering*, ASCE, 129(2):120-128.

Wu, W., S.S.Y. Wang, and Y. Jia (2000). "Nonuniform sediment transport in alluvial rivers," *Journal of Hydraulic Research*, Vol. 38(6):427-434.

NRCS (2007a). “Grade Stabilization Techniques,” Technical Supplement 14G to *Stream Restoration Design*, National Engineering Handbook Part 654. August, 2007.

NRCS (2007b). “Flow Changing Techniques,” Technical Supplement 14H to *Stream Restoration Design*, National Engineering Handbook Part 654. August, 2007.

NRCS (2007c). “Use of Large Woody Material for Habitat and Bank Protection,” Technical Supplement 14J to *Stream Restoration Design*, National Engineering Handbook Part 654. August, 2007.

NRCS (2007d). “Streambank Armor Protection with Stone Structures,” Technical Supplement 14K to *Stream Restoration Design*, National Engineering Handbook Part 654. August, 2007.

NRCS (2007e). "Streambank Soil Bioengineering," Technical Supplement 14I to *Stream Restoration Design*, National Engineering Handbook Part 654. August, 2007.

U.S. Army Corps of Engineers, (1994). "Hydraulic Design of Flood Control Channels," EM-1110-2-1601, Department of the Army, U.S. Army Corp of Engineers, Washington, DC.

7 Appendix A Bypass Hydraulic Properties

Table 7-1. Bypass Hydraulic Properties for Range of Flow Conditions, using 2008 to 2010 geometry.

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
4800	50	141.28	143.12	142.17	143.13	0.00044	0.91	55	53	0.16
4800	75	141.28	143.39	142.33	143.41	0.000477	1.07	70	56	0.17
4800	100	141.28	143.62	142.45	143.64	0.000504	1.2	83	58	0.18
4800	200	141.28	144.35	142.82	144.39	0.000558	1.56	128	66	0.2
4800	500	141.28	145.68	143.51	145.74	0.000585	1.82	275	191	0.27
4800	750	141.28	146.38	143.94	146.42	0.000593	1.71	439	274	0.24
4800	1000	141.28	146.91	144.32	146.95	0.000594	1.72	590	295	0.21
4800	1200	141.28	147.28	144.6	147.33	0.000592	1.75	703	310	0.19
4800	1500	141.28	147.81	145.32	147.86	0.000577	1.8	872	331	0.18
4800	2000	141.28	148.69	145.78	148.75	0.000514	1.84	1181	367	0.16
4800	2500	141.28	149.63	146.08	149.68	0.000431	1.84	1540	404	0.15
4800	3000	141.28	150.51	146.31	150.56	0.000372	1.84	1914	439	0.13
4800	3500	141.28	151.38	146.49	151.42	0.000324	1.84	2307	474	0.13
4800	4000	141.28	152.18	146.65	152.23	0.000291	1.84	2700	506	0.12
4800	4500	141.28	152.93	146.81	152.98	0.000266	1.85	3089	523	0.11
4700	50	141.24	143.08	142.13	143.09	0.000446	0.91	55	53	0.16
4700	75	141.24	143.34	142.29	143.36	0.000487	1.08	70	56	0.17
4700	100	141.24	143.57	142.41	143.59	0.000516	1.21	83	58	0.18
4700	200	141.24	144.29	142.78	144.33	0.000573	1.57	127	66	0.2
4700	500	141.24	145.62	143.46	145.68	0.0006	1.84	271	188	0.27
4700	750	141.24	146.32	143.91	146.36	0.000608	1.73	434	273	0.24
4700	1000	141.24	146.85	144.28	146.89	0.000607	1.73	583	294	0.21
4700	1200	141.24	147.22	144.56	147.27	0.000604	1.77	696	309	0.2
4700	1500	141.24	147.75	145.28	147.8	0.000586	1.82	865	330	0.18
4700	2000	141.24	148.64	145.74	148.69	0.000518	1.85	1176	366	0.16
4700	2500	141.24	149.58	146.04	149.63	0.000432	1.84	1539	404	0.15
4700	3000	141.24	150.48	146.28	150.53	0.000371	1.84	1915	439	0.13
4700	3500	141.24	151.34	146.45	151.39	0.000323	1.83	2311	474	0.13
4700	4000	141.24	152.15	146.61	152.2	0.00029	1.84	2706	506	0.12
4700	4500	141.24	152.9	146.77	152.95	0.000264	1.85	3096	523	0.11

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
4600	50	141.21	143.03	142.1	143.04	0.000468	0.93	54	53	0.16
4600	75	141.21	143.29	142.26	143.31	0.000512	1.1	68	56	0.17
4600	100	141.21	143.52	142.38	143.54	0.000543	1.23	81	58	0.18
4600	200	141.21	144.23	142.75	144.27	0.0006	1.6	125	65	0.2
4600	500	141.21	145.56	143.43	145.61	0.000625	1.89	265	183	0.28
4600	750	141.21	146.25	143.88	146.3	0.000633	1.77	424	272	0.25
4600	1000	141.21	146.78	144.25	146.83	0.000629	1.76	574	293	0.21
4600	1200	141.21	147.16	144.53	147.21	0.000623	1.79	686	308	0.2
4600	1500	141.21	147.69	145.25	147.74	0.000602	1.83	855	329	0.19
4600	2000	141.21	148.59	145.71	148.64	0.000527	1.86	1168	365	0.17
4600	2500	141.21	149.54	146.01	149.59	0.000434	1.84	1536	409	0.15
4600	3000	141.21	150.44	146.25	150.49	0.000369	1.83	1919	443	0.13
4600	3500	141.21	151.31	146.42	151.36	0.000319	1.82	2322	486	0.12
4600	4000	141.21	152.12	146.58	152.17	0.000284	1.82	2737	534	0.12
4600	4500	141.21	152.88	146.74	152.93	0.000257	1.82	3149	550	0.11
4500	50	141.18	142.98	142.07	142.99	0.000496	0.94	53	53	0.17
4500	75	141.18	143.24	142.23	143.26	0.000543	1.12	67	56	0.18
4500	100	141.18	143.46	142.35	143.48	0.000576	1.26	80	58	0.19
4500	200	141.18	144.17	142.72	144.21	0.000631	1.63	123	65	0.21
4500	500	141.18	145.49	143.41	145.55	0.000654	1.93	258	178	0.28
4500	750	141.18	146.19	143.84	146.24	0.000661	1.81	414	270	0.26
4500	1000	141.18	146.72	144.22	146.77	0.000653	1.79	563	292	0.22
4500	1200	141.18	147.09	144.5	147.14	0.000644	1.82	676	307	0.2
4500	1500	141.18	147.63	145.22	147.68	0.000618	1.86	845	328	0.19
4500	2000	141.18	148.53	145.68	148.59	0.000536	1.87	1159	364	0.17
4500	2500	141.18	149.5	145.98	149.55	0.000439	1.85	1531	420	0.15
4500	3000	141.18	150.4	146.21	150.45	0.000369	1.83	1945	487	0.13
4500	3500	141.18	151.28	146.39	151.33	0.000315	1.81	2390	528	0.12
4500	4000	141.18	152.09	146.55	152.14	0.000279	1.81	2837	574	0.12
4500	4500	141.18	152.86	146.71	152.9	0.00025	1.8	3284	594	0.11
4400	50	141.14	142.93	142.03	142.94	0.000512	0.95	52	53	0.17
4400	75	141.14	143.18	142.19	143.2	0.000566	1.13	66	55	0.18
4400	100	141.14	143.4	142.31	143.43	0.000601	1.27	78	58	0.19
4400	200	141.14	144.1	142.68	144.14	0.000657	1.65	121	65	0.21
4400	500	141.14	145.42	143.36	145.48	0.000677	1.97	253	174	0.29
4400	750	141.14	146.12	143.81	146.17	0.000683	1.85	406	267	0.26

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
4400	1000	141.14	146.65	144.18	146.7	0.000672	1.82	555	290	0.22
4400	1200	141.14	147.03	144.46	147.08	0.000661	1.84	667	305	0.21
4400	1500	141.14	147.56	145.18	147.62	0.000631	1.87	837	327	0.19
4400	2000	141.14	148.48	145.64	148.53	0.000542	1.88	1154	364	0.17
4400	2500	141.14	149.45	145.94	149.5	0.00044	1.85	1541	453	0.15
4400	3000	141.14	150.37	146.18	150.41	0.000366	1.82	1989	530	0.13
4400	3500	141.14	151.25	146.35	151.3	0.000309	1.79	2482	582	0.12
4400	4000	141.14	152.07	146.51	152.11	0.00027	1.78	2982	647	0.11
4400	4500	141.14	152.83	146.67	152.88	0.000242	1.77	3576	832	0.11
4300	50	141.1	142.88	141.99	142.89	0.000532	0.97	52	53	0.17
4300	75	141.1	143.13	142.15	143.15	0.000593	1.15	65	55	0.19
4300	100	141.1	143.34	142.27	143.36	0.000632	1.3	77	57	0.2
4300	200	141.1	144.03	142.64	144.08	0.000687	1.67	119	64	0.22
4300	500	141.1	145.35	143.33	145.41	0.000705	2.02	248	170	0.29
4300	750	141.1	146.04	143.76	146.1	0.000704	1.89	396	263	0.26
4300	1000	141.1	146.58	144.14	146.63	0.000698	1.88	533	289	0.23
4300	1200	141.1	146.95	144.42	147.01	0.00069	1.91	634	304	0.21
4300	1500	141.1	147.49	145.14	147.55	0.000665	1.96	783	326	0.2
4300	2000	141.1	148.42	145.6	148.48	0.000578	1.99	1051	363	0.18
4300	2500	141.1	149.4	145.9	149.46	0.000478	1.97	1355	416	0.16
4300	3000	141.1	150.32	146.12	150.37	0.000412	1.98	1656	585	0.14
4300	3500	141.1	151.2	146.29	151.26	0.000362	1.99	1964	658	0.14
4300	4000	141.1	152.02	146.46	152.08	0.000329	2.01	2261	747	0.13
4300	4500	141.1	152.81	146.63	152.85	0.000232	1.74	3750	846	0.11
4200	50	141.07	142.82	141.96	142.84	0.000578	0.99	50	53	0.18
4200	75	141.07	143.06	142.12	143.08	0.000647	1.18	63	55	0.19
4200	100	141.07	143.27	142.24	143.3	0.000688	1.33	75	57	0.2
4200	200	141.07	143.96	142.61	144.01	0.000737	1.71	117	64	0.22
4200	500	141.07	145.27	143.3	145.34	0.000747	2.08	240	164	0.3
4200	750	141.07	145.97	143.73	146.03	0.000745	1.94	386	256	0.28
4200	1000	141.07	146.5	144.11	146.56	0.000727	1.89	534	287	0.24
4200	1200	141.07	146.88	144.39	146.94	0.000709	1.89	646	303	0.22
4200	1500	141.07	147.43	145.11	147.48	0.000668	1.91	816	324	0.2
4200	2000	141.07	148.36	145.57	148.42	0.00056	1.91	1137	360	0.17
4200	2500	141.07	149.36	145.87	149.41	0.000447	1.86	1504	380	0.15
4200	3000	141.07	150.28	146.1	150.33	0.000376	1.85	1864	398	0.14
4200	3500	141.07	151.17	146.28	151.22	0.000325	1.84	2228	416	0.13

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
4200	4000	141.07	152	146.44	152.05	0.000292	1.85	2577	433	0.12
4200	4500	141.07	152.78	146.6	152.83	0.000267	1.86	2917	441	0.11
4100	50	141.04	142.76	141.93	142.78	0.000641	1.03	49	52	0.19
4100	75	141.04	142.99	142.09	143.02	0.000719	1.23	61	55	0.2
4100	100	141.04	143.2	142.21	143.23	0.000762	1.38	72	57	0.21
4100	200	141.04	143.88	142.58	143.93	0.000798	1.76	114	63	0.23
4100	500	141.04	145.19	143.26	145.26	0.000797	2.16	231	157	0.31
4100	750	141.04	145.89	143.71	145.95	0.000789	2.01	373	250	0.29
4100	1000	141.04	146.43	144.08	146.49	0.000765	1.93	520	285	0.25
4100	1200	141.04	146.81	144.36	146.87	0.000741	1.93	632	301	0.22
4100	1500	141.04	147.36	145.08	147.42	0.000692	1.94	803	323	0.2
4100	2000	141.04	148.31	145.54	148.36	0.000572	1.92	1127	361	0.17
4100	2500	141.04	149.31	145.84	149.36	0.000452	1.87	1510	401	0.15
4100	3000	141.04	150.24	146.08	150.3	0.000377	1.85	1901	438	0.14
4100	3500	141.04	151.14	146.25	151.19	0.000323	1.83	2311	474	0.13
4100	4000	141.04	151.97	146.41	152.02	0.000287	1.83	2715	501	0.12
4100	4500	141.04	152.75	146.57	152.8	0.000258	1.83	3110	509	0.11
4000	50	141	142.69	141.89	142.71	0.000704	1.06	47	52	0.2
4000	75	141	142.92	142.05	142.94	0.000797	1.27	59	54	0.21
4000	100	141	143.11	142.17	143.15	0.000843	1.43	70	56	0.22
4000	200	141	143.79	142.54	143.85	0.000862	1.81	111	63	0.24
4000	500	141	145.1	143.23	145.18	0.000846	2.23	224	151	0.32
4000	750	141	145.8	143.66	145.87	0.00083	2.07	362	244	0.3
4000	1000	141	146.35	144.04	146.41	0.0008	1.98	508	284	0.25
4000	1200	141	146.73	144.32	146.79	0.00077	1.96	621	299	0.23
4000	1500	141	147.29	145.04	147.35	0.000712	1.96	793	321	0.21
4000	2000	141	148.25	145.5	148.31	0.000579	1.93	1121	360	0.18
4000	2500	141	149.27	145.8	149.32	0.000454	1.87	1507	401	0.15
4000	3000	141	150.21	146.03	150.26	0.000377	1.85	1902	438	0.14
4000	3500	141	151.11	146.21	151.16	0.000323	1.83	2317	482	0.13
4000	4000	141	151.94	146.37	151.99	0.000285	1.83	2728	508	0.12
4000	4500	141	152.72	146.53	152.77	0.000258	1.83	3135	531	0.11
3975	50	141	142.67	141.89	142.69	0.000752	1.08	46	52	0.2
3975	75	141	142.89	142.05	142.92	0.000848	1.29	58	54	0.22
3975	100	141	143.09	142.17	143.12	0.000892	1.45	69	56	0.23
3975	200	141	143.77	142.54	143.82	0.000897	1.83	109	63	0.24

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3975	500	141	145.08	143.23	145.16	0.000871	2.28	220	147	0.31
3975	750	141	145.75	143.66	145.85	0.000892	2.42	309	237	0.28
3975	1000	141	146.27	144.04	146.38	0.000949	2.64	378	281	0.28
3975	1200	141	146.64	144.32	146.76	0.000984	2.81	427	296	0.28
3975	1500	141	147.18	145.01	147.32	0.001004	3.01	498	317	0.27
3975	2000	141	148.12	145.34	148.28	0.000936	3.21	624	355	0.26
3975	2500	141	149.12	145.65	149.29	0.000821	3.3	757	395	0.24
3975	3000	141	150.05	145.94	150.23	0.000748	3.41	881	432	0.23
3975	3500	141	150.94	146.21	151.13	0.00069	3.5	999	475	0.23
3975	4000	141	151.76	146.47	151.96	0.000654	3.61	1108	547	0.22
3975	4500	141	152.53	146.71	152.75	0.000627	3.72	1211	607	0.22
3974	Inl Struct									
3900	50	141	142.66	141.89	142.68	0.000776	1.09	46	52	0.2
3900	75	141	142.89	142.05	142.91	0.000868	1.3	58	54	0.22
3900	100	141	143.08	142.17	143.12	0.000909	1.46	68	56	0.23
3900	200	141	143.76	142.54	143.81	0.000912	1.84	109	63	0.25
3900	500	141	145.06	143.23	145.14	0.000896	2.31	217	144	0.32
3900	750	141	145.73	143.66	145.82	0.000913	2.45	306	234	0.28
3900	1000	141	146.24	144.04	146.35	0.000981	2.68	373	279	0.28
3900	1200	141	146.59	144.32	146.72	0.001027	2.85	421	294	0.28
3900	1500	141	147.12	145.01	147.27	0.001044	3.05	491	315	0.28
3900	2000	141	148.05	145.34	148.21	0.000978	3.25	614	352	0.27
3900	2500	141	149.05	145.65	149.23	0.000851	3.34	748	392	0.25
3900	3000	141	149.98	145.94	150.16	0.000773	3.44	871	429	0.24
3900	3500	141	150.86	146.21	151.05	0.000715	3.54	988	470	0.23
3900	4000	141	151.67	146.47	151.88	0.000676	3.65	1096	533	0.22
3900	4500	141	152.44	146.71	152.65	0.000649	3.76	1198	606	0.22
3800	50	140.96	142.58	141.85	142.6	0.000916	1.15	43	51	0.22
3800	75	140.96	142.79	142.01	142.82	0.001028	1.38	54	53	0.24
3800	100	140.96	142.98	142.13	143.02	0.001064	1.54	65	55	0.25
3800	200	140.96	143.66	142.5	143.72	0.001011	1.91	105	62	0.26
3800	500	140.96	144.96	143.18	145.05	0.000969	2.39	209	136	0.34
3800	750	140.96	145.65	143.63	145.73	0.000943	2.24	335	229	0.33
3800	1000	140.96	146.17	144	146.24	0.000932	2.13	470	278	0.29
3800	1200	140.96	146.54	144.28	146.6	0.000903	2.11	574	293	0.26

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3800	1500	140.96	147.08	145	147.15	0.000824	2.09	741	315	0.23
3800	2000	140.96	148.04	145.46	148.1	0.000657	2.02	1061	353	0.19
3800	2500	140.96	149.07	145.76	149.13	0.0005	1.94	1447	395	0.16
3800	3000	140.96	150.02	146	150.07	0.00041	1.9	1837	432	0.14
3800	3500	140.96	150.91	146.17	150.96	0.000348	1.88	2239	468	0.13
3800	4000	140.96	151.74	146.33	151.79	0.000307	1.88	2649	531	0.12
3800	4500	140.96	152.51	146.49	152.56	0.000275	1.87	3093	593	0.12
3700	50	140.93	142.34	141.81	142.4	0.006656	1.95	26	60	0.53
3700	75	140.93	142.59	142.04	142.64	0.003358	1.84	41	63	0.4
3700	100	140.93	142.82	142.36	142.87	0.002282	1.81	55	65	0.35
3700	200	140.93	143.56	142.62	143.61	0.001152	1.83	109	100	0.31
3700	500	140.93	144.92	143.2	144.95	0.000625	1.35	370	274	0.2
3700	750	140.93	145.61	143.74	145.64	0.000539	1.34	569	301	0.16
3700	1000	140.93	146.13	144.04	146.16	0.000531	1.43	728	322	0.16
3700	1200	140.93	146.49	144.21	146.53	0.000527	1.49	849	336	0.15
3700	1500	140.93	147.04	144.43	147.08	0.000498	1.56	1040	359	0.15
3700	2000	140.93	148.01	144.72	148.04	0.00042	1.61	1404	397	0.13
3700	2500	140.93	149.05	144.94	149.08	0.000335	1.6	1838	439	0.12
3700	3000	140.93	149.99	145.12	150.03	0.000284	1.6	2272	477	0.11
3700	3500	140.93	150.89	145.29	150.93	0.000249	1.61	2716	511	0.11
3700	4000	140.93	151.72	145.46	151.76	0.000222	1.62	3151	546	0.1
3700	4500	140.93	152.5	145.61	152.54	0.000209	1.66	3618	632	0.1
3600	50	140.53	142.2	141.42	142.22	0.00075	1.08	46	52	0.2
3600	75	140.53	142.47	141.58	142.5	0.000738	1.24	61	54	0.21
3600	100	140.53	142.71	141.7	142.74	0.000715	1.35	74	57	0.21
3600	200	140.53	143.48	142.07	143.52	0.000673	1.66	120	64	0.21
3600	500	140.53	144.82	142.76	144.88	0.000669	1.96	255	176	0.29
3600	750	140.53	145.53	143.19	145.58	0.000666	1.82	412	270	0.26
3600	1000	140.53	146.05	143.57	146.1	0.000667	1.81	557	291	0.22
3600	1200	140.53	146.41	143.85	146.47	0.000663	1.84	666	305	0.21
3600	1500	140.53	146.97	144.57	147.02	0.000622	1.86	842	328	0.19
3600	2000	140.53	147.94	145.03	148	0.000513	1.84	1181	367	0.16
3600	2500	140.53	149	145.33	149.05	0.000401	1.79	1589	409	0.14
3600	3000	140.53	149.95	145.56	150	0.000335	1.77	1998	450	0.13
3600	3500	140.53	150.86	145.74	150.9	0.00029	1.77	2428	500	0.12
3600	4000	140.53	151.69	145.9	151.73	0.000259	1.77	2865	561	0.11
3600	4500	140.53	152.47	146.06	152.51	0.000241	1.8	3390	748	0.11

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3500	50	140.49	142.07	141.37	142.1	0.002317	1.41	36	62	0.33
3500	75	140.49	142.37	141.6	142.4	0.001313	1.37	55	65	0.26
3500	100	140.49	142.63	141.92	142.66	0.000996	1.39	72	67	0.24
3500	200	140.49	143.42	142.18	143.45	0.000604	1.37	146	141	0.24
3500	500	140.49	144.8	142.76	144.82	0.000391	1.1	459	286	0.15
3500	750	140.49	145.5	143.3	145.52	0.000366	1.16	670	314	0.13
3500	1000	140.49	146.01	143.6	146.04	0.000379	1.26	836	335	0.13
3500	1200	140.49	146.38	143.77	146.41	0.000387	1.34	962	350	0.13
3500	1500	140.49	146.94	143.99	146.97	0.000378	1.42	1162	372	0.13
3500	2000	140.49	147.92	144.28	147.95	0.00033	1.48	1546	411	0.12
3500	2500	140.49	148.98	144.5	149.01	0.00027	1.49	2003	453	0.11
3500	3000	140.49	149.94	144.68	149.97	0.000234	1.5	2457	492	0.1
3500	3500	140.49	150.84	144.85	150.87	0.000207	1.52	2915	514	0.1
3500	4000	140.49	151.67	145.02	151.71	0.000188	1.54	3362	575	0.09
3500	4500	140.49	152.45	145.17	152.49	0.000182	1.59	3902	764	0.09
3400	50	140.1	142	140.99	142.02	0.000365	0.85	59	54	0.14
3400	75	140.1	142.32	141.15	142.33	0.000374	0.99	76	57	0.15
3400	100	140.1	142.58	141.27	142.6	0.000383	1.1	91	60	0.16
3400	200	140.1	143.37	141.64	143.4	0.000416	1.41	142	68	0.17
3400	500	140.1	144.74	142.33	144.78	0.000444	1.54	324	222	0.23
3400	750	140.1	145.45	142.76	145.48	0.00045	1.48	509	284	0.19
3400	1000	140.1	145.96	143.14	146	0.000471	1.55	659	304	0.18
3400	1200	140.1	146.32	143.42	146.36	0.000482	1.61	773	319	0.17
3400	1500	140.1	146.88	144.14	146.92	0.000467	1.66	957	341	0.16
3400	2000	140.1	147.87	144.6	147.91	0.000401	1.68	1314	381	0.14
3400	2500	140.1	148.94	144.9	148.98	0.000322	1.66	1743	423	0.13
3400	3000	140.1	149.9	145.13	149.94	0.000276	1.66	2170	462	0.12
3400	3500	140.1	150.81	145.31	150.85	0.000243	1.66	2606	498	0.11
3400	4000	140.1	151.65	145.47	151.69	0.000219	1.67	3054	575	0.1
3400	4500	140.1	152.43	145.63	152.47	0.000209	1.71	3600	827	0.1
3300	50	140.06	141.97	140.95	141.98	0.000361	0.85	59	54	0.14
3300	75	140.06	142.28	141.11	142.29	0.000371	0.99	76	57	0.15
3300	100	140.06	142.54	141.23	142.56	0.000381	1.1	91	60	0.16
3300	200	140.06	143.33	141.6	143.36	0.000418	1.41	142	68	0.17
3300	500	140.06	144.7	142.29	144.73	0.000446	1.55	323	221	0.23
3300	750	140.06	145.4	142.72	145.44	0.000452	1.49	507	284	0.19

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3300	1000	140.06	145.91	143.1	145.95	0.000475	1.55	657	304	0.18
3300	1200	140.06	146.28	143.38	146.32	0.000486	1.61	770	319	0.17
3300	1500	140.06	146.84	144.1	146.88	0.00047	1.66	955	341	0.16
3300	2000	140.06	147.83	144.56	147.87	0.000401	1.68	1314	381	0.14
3300	2500	140.06	148.9	144.86	148.95	0.000321	1.65	1746	424	0.13
3300	3000	140.06	149.87	145.09	149.91	0.000274	1.65	2176	463	0.12
3300	3500	140.06	150.79	145.27	150.83	0.000241	1.66	2614	499	0.11
3300	4000	140.06	151.63	145.43	151.66	0.000218	1.67	3073	646	0.1
3300	4500	140.06	152.41	145.59	152.45	0.000207	1.71	3667	920	0.1
3200	50	140.02	141.93	140.91	141.94	0.000357	0.85	59	54	0.14
3200	75	140.02	142.24	141.07	142.26	0.000369	0.98	76	57	0.15
3200	100	140.02	142.5	141.19	142.52	0.00038	1.09	91	60	0.16
3200	200	140.02	143.29	141.56	143.32	0.000419	1.41	141	68	0.17
3200	500	140.02	144.65	142.24	144.69	0.000449	1.55	322	221	0.23
3200	750	140.02	145.36	142.69	145.39	0.000455	1.49	505	283	0.19
3200	1000	140.02	145.86	143.06	145.9	0.000479	1.56	654	304	0.18
3200	1200	140.02	146.23	143.34	146.27	0.00049	1.62	767	318	0.17
3200	1500	140.02	146.79	144.06	146.83	0.000473	1.67	952	341	0.16
3200	2000	140.02	147.79	144.52	147.83	0.000401	1.68	1314	381	0.14
3200	2500	140.02	148.87	144.82	148.91	0.000319	1.65	1750	424	0.13
3200	3000	140.02	149.85	145.06	149.89	0.000272	1.65	2182	463	0.12
3200	3500	140.02	150.76	145.23	150.8	0.000239	1.65	2622	505	0.11
3200	4000	140.02	151.6	145.39	151.64	0.000215	1.66	3113	706	0.1
3200	4500	140.02	152.39	145.55	152.43	0.000194	1.66	3803	1034	0.1
3100	50	139.99	141.9	140.88	141.91	0.000363	0.85	59	54	0.14
3100	75	139.99	142.2	141.04	142.22	0.000375	0.99	76	57	0.15
3100	100	139.99	142.46	141.16	142.48	0.000386	1.1	91	60	0.16
3100	200	139.99	143.24	141.53	143.28	0.000426	1.42	141	68	0.17
3100	500	139.99	144.6	142.21	144.64	0.000457	1.57	318	219	0.23
3100	750	139.99	145.31	142.66	145.34	0.000463	1.5	501	283	0.19
3100	1000	139.99	145.81	143.03	145.85	0.000488	1.57	649	303	0.18
3100	1200	139.99	146.18	143.31	146.22	0.000499	1.63	761	317	0.17
3100	1500	139.99	146.74	144.03	146.78	0.00048	1.68	946	340	0.16
3100	2000	139.99	147.75	144.49	147.79	0.000404	1.69	1310	380	0.14
3100	2500	139.99	148.84	144.79	148.88	0.000319	1.65	1749	424	0.13
3100	3000	139.99	149.82	145.03	149.86	0.000272	1.65	2183	463	0.12
3100	3500	139.99	150.74	145.2	150.78	0.000239	1.65	2626	514	0.11

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3100	4000	139.99	151.58	145.36	151.62	0.000214	1.66	3163	821	0.1
3100	4500	139.99	152.37	145.52	152.41	0.000191	1.65	3939	1129	0.1
3000	50	139.96	141.86	140.85	141.87	0.00037	0.86	58	54	0.15
3000	75	139.96	142.17	141.01	142.18	0.000382	1	75	57	0.15
3000	100	139.96	142.42	141.13	142.44	0.000393	1.11	90	60	0.16
3000	200	139.96	143.2	141.5	143.23	0.000434	1.43	140	67	0.18
3000	500	139.96	144.56	142.18	144.6	0.000466	1.59	315	216	0.23
3000	750	139.96	145.26	142.63	145.3	0.000472	1.52	496	282	0.2
3000	1000	139.96	145.76	143	145.8	0.000497	1.59	643	302	0.18
3000	1200	139.96	146.12	143.28	146.17	0.000508	1.64	754	317	0.18
3000	1500	139.96	146.69	144	146.73	0.000487	1.69	940	339	0.16
3000	2000	139.96	147.71	144.46	147.75	0.000407	1.69	1306	380	0.14
3000	2500	139.96	148.81	144.76	148.85	0.00032	1.65	1748	424	0.13
3000	3000	139.96	149.79	145	149.83	0.000271	1.65	2184	463	0.12
3000	3500	139.96	150.71	145.17	150.75	0.000238	1.65	2635	538	0.11
3000	4000	139.96	151.56	145.33	151.6	0.000213	1.65	3190	791	0.1
3000	4500	139.96	152.35	145.49	152.39	0.00019	1.64	4007	1228	0.1
2900	50	139.92	141.82	140.81	141.83	0.000367	0.86	58	54	0.14
2900	75	139.92	142.13	140.97	142.14	0.00038	0.99	75	57	0.15
2900	100	139.92	142.38	141.09	142.4	0.000393	1.11	90	60	0.16
2900	200	139.92	143.16	141.46	143.19	0.000436	1.43	139	67	0.18
2900	500	139.92	144.51	142.14	144.55	0.00047	1.6	313	215	0.23
2900	750	139.92	145.21	142.59	145.25	0.000476	1.52	494	282	0.2
2900	1000	139.92	145.71	142.96	145.75	0.000502	1.59	639	302	0.18
2900	1200	139.92	146.07	143.24	146.12	0.000514	1.65	751	316	0.18
2900	1500	139.92	146.64	143.96	146.69	0.000491	1.69	937	339	0.17
2900	2000	139.92	147.67	144.42	147.71	0.000407	1.69	1305	380	0.14
2900	2500	139.92	148.78	144.72	148.82	0.000318	1.65	1751	424	0.13
2900	3000	139.92	149.77	144.96	149.81	0.00027	1.64	2190	464	0.11
2900	3500	139.92	150.69	145.13	150.73	0.000236	1.65	2642	542	0.11
2900	4000	139.92	151.54	145.29	151.58	0.00021	1.65	3239	897	0.1
2900	4500	139.92	152.33	145.45	152.37	0.000186	1.63	4125	1323	0.1
2800	50	139.88	141.79	140.77	141.8	0.000363	0.85	59	54	0.14
2800	75	139.88	142.09	140.93	142.11	0.000378	0.99	76	57	0.15
2800	100	139.88	142.35	141.05	142.36	0.000392	1.11	90	60	0.16
2800	200	139.88	143.11	141.42	143.15	0.000439	1.44	139	67	0.18

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
2800	500	139.88	144.46	142.11	144.5	0.000475	1.61	311	214	0.23
2800	750	139.88	145.17	142.54	145.2	0.000481	1.53	491	281	0.2
2800	1000	139.88	145.66	142.92	145.7	0.000508	1.6	636	301	0.19
2800	1200	139.88	146.02	143.2	146.06	0.000519	1.66	747	316	0.18
2800	1500	139.88	146.59	143.92	146.64	0.000495	1.7	933	338	0.17
2800	2000	139.88	147.63	144.38	147.67	0.000407	1.69	1305	380	0.14
2800	2500	139.88	148.75	144.68	148.79	0.000317	1.65	1755	425	0.12
2800	3000	139.88	149.74	144.91	149.78	0.000268	1.64	2196	464	0.11
2800	3500	139.88	150.67	145.09	150.71	0.000234	1.64	2652	560	0.11
2800	4000	139.88	151.52	145.25	151.56	0.000208	1.64	3286	1047	0.1
2800	4500	139.88	152.31	145.41	152.35	0.000182	1.61	4250	1379	0.09
2700	50	139.85	141.75	140.74	141.76	0.00037	0.86	58	54	0.15
2700	75	139.85	142.05	140.9	142.07	0.000385	1	75	57	0.15
2700	100	139.85	142.31	141.02	142.33	0.0004	1.11	90	60	0.16
2700	200	139.85	143.07	141.39	143.1	0.000448	1.45	138	67	0.18
2700	500	139.85	144.41	142.08	144.45	0.000485	1.63	307	212	0.24
2700	750	139.85	145.12	142.51	145.15	0.000491	1.55	486	281	0.2
2700	1000	139.85	145.61	142.89	145.65	0.000519	1.62	629	300	0.19
2700	1200	139.85	145.97	143.17	146.01	0.000531	1.67	739	315	0.18
2700	1500	139.85	146.54	143.89	146.59	0.000503	1.71	926	338	0.17
2700	2000	139.85	147.59	144.35	147.63	0.00041	1.7	1301	379	0.14
2700	2500	139.85	148.71	144.65	148.75	0.000317	1.65	1754	425	0.13
2700	3000	139.85	149.71	144.88	149.75	0.000267	1.64	2198	464	0.11
2700	3500	139.85	150.64	145.06	150.68	0.000234	1.64	2655	578	0.11
2700	4000	139.85	151.5	145.22	151.54	0.000207	1.64	3300	977	0.1
2700	4500	139.85	152.3	145.38	152.33	0.000181	1.61	4182	1150	0.09
2600	50	139.82	141.71	140.71	141.72	0.000378	0.86	58	54	0.15
2600	75	139.82	142.01	140.87	142.03	0.000394	1.01	75	57	0.15
2600	100	139.82	142.27	140.99	142.28	0.000408	1.12	89	59	0.16
2600	200	139.82	143.02	141.36	143.06	0.000458	1.46	137	67	0.18
2600	500	139.82	144.36	142.05	144.4	0.000497	1.65	303	209	0.24
2600	750	139.82	145.07	142.48	145.1	0.000503	1.57	480	280	0.21
2600	1000	139.82	145.56	142.86	145.6	0.000532	1.63	622	299	0.19
2600	1200	139.82	145.91	143.14	145.96	0.000543	1.69	732	314	0.18
2600	1500	139.82	146.49	143.86	146.54	0.000512	1.72	919	337	0.17
2600	2000	139.82	147.54	144.32	147.59	0.000413	1.7	1297	379	0.15
2600	2500	139.82	148.68	144.62	148.72	0.000317	1.65	1753	424	0.13

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
2600	3000	139.82	149.69	144.85	149.72	0.000267	1.64	2199	465	0.11
2600	3500	139.82	150.62	145.03	150.66	0.000233	1.64	2651	502	0.11
2600	4000	139.82	151.48	145.19	151.52	0.000209	1.65	3092	523	0.1
2600	4500	139.82	152.27	145.35	152.31	0.000193	1.66	3515	539	0.1
2500	50	139.78	141.67	140.67	141.69	0.000375	0.86	58	54	0.15
2500	75	139.78	141.97	140.83	141.99	0.000393	1.01	75	57	0.15
2500	100	139.78	142.22	140.95	142.24	0.000409	1.12	89	59	0.16
2500	200	139.78	142.98	141.32	143.01	0.000463	1.46	137	67	0.18
2500	500	139.78	144.31	142.01	144.35	0.000503	1.66	301	208	0.24
2500	750	139.78	145.01	142.44	145.05	0.000509	1.58	477	279	0.21
2500	1000	139.78	145.5	142.82	145.54	0.000539	1.64	618	299	0.19
2500	1200	139.78	145.86	143.1	145.9	0.000551	1.7	727	313	0.19
2500	1500	139.78	146.44	143.82	146.48	0.000517	1.73	915	336	0.17
2500	2000	139.78	147.5	144.28	147.55	0.000414	1.7	1296	379	0.15
2500	2500	139.78	148.65	144.58	148.69	0.000316	1.65	1757	425	0.12
2500	3000	139.78	149.66	144.81	149.7	0.000265	1.63	2206	465	0.11
2500	3500	139.78	150.6	144.99	150.64	0.000231	1.63	2660	503	0.11
2500	4000	139.78	151.46	145.15	151.49	0.000208	1.64	3102	524	0.1
2500	4500	139.78	152.25	145.31	152.29	0.000191	1.65	3526	540	0.1
2400	50	139.74	141.64	140.63	141.65	0.000373	0.86	58	54	0.15
2400	75	139.74	141.94	140.79	141.95	0.000392	1	75	57	0.15
2400	100	139.74	142.18	140.91	142.2	0.00041	1.12	89	59	0.16
2400	200	139.74	142.93	141.28	142.96	0.000467	1.47	136	67	0.18
2400	500	139.74	144.26	141.96	144.3	0.00051	1.68	298	206	0.25
2400	750	139.74	144.96	142.41	145	0.000516	1.59	474	279	0.21
2400	1000	139.74	145.45	142.78	145.49	0.000547	1.65	614	298	0.19
2400	1200	139.74	145.8	143.06	145.85	0.000559	1.71	722	312	0.19
2400	1500	139.74	146.39	143.78	146.43	0.000522	1.73	911	336	0.17
2400	2000	139.74	147.46	144.24	147.51	0.000414	1.7	1295	379	0.15
2400	2500	139.74	148.62	144.54	148.66	0.000314	1.64	1761	425	0.12
2400	3000	139.74	149.63	144.78	149.67	0.000263	1.63	2212	466	0.11
2400	3500	139.74	150.57	144.95	150.61	0.000229	1.63	2669	503	0.11
2400	4000	139.74	151.44	145.11	151.47	0.000206	1.64	3112	524	0.1
2400	4500	139.74	152.24	145.27	152.27	0.00019	1.65	3538	540	0.1
2300	50	139.71	141.6	140.6	141.61	0.000381	0.87	58	54	0.15
2300	75	139.71	141.9	140.76	141.91	0.000401	1.01	74	57	0.16

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
2300	100	139.71	142.14	140.88	142.16	0.00042	1.13	88	59	0.16
2300	200	139.71	142.88	141.25	142.92	0.000479	1.48	135	67	0.18
2300	500	139.71	144.21	141.93	144.25	0.000524	1.7	294	203	0.25
2300	750	139.71	144.91	142.38	144.95	0.000529	1.61	467	278	0.22
2300	1000	139.71	145.39	142.75	145.43	0.000562	1.67	606	297	0.2
2300	1200	139.71	145.74	143.03	145.79	0.000574	1.73	713	311	0.19
2300	1500	139.71	146.33	143.75	146.38	0.000533	1.75	903	335	0.17
2300	2000	139.71	147.42	144.21	147.46	0.000417	1.71	1291	378	0.15
2300	2500	139.71	148.59	144.51	148.63	0.000315	1.64	1760	425	0.12
2300	3000	139.71	149.61	144.75	149.64	0.000263	1.63	2214	466	0.11
2300	3500	139.71	150.55	144.92	150.59	0.000229	1.63	2672	504	0.11
2300	4000	139.71	151.42	145.08	151.45	0.000205	1.63	3117	524	0.1
2300	4500	139.71	152.22	145.24	152.26	0.000189	1.65	3545	555	0.1
2200	50	139.68	141.56	140.57	141.57	0.000391	0.87	57	54	0.15
2200	75	139.68	141.85	140.73	141.87	0.000412	1.02	73	57	0.16
2200	100	139.68	142.1	140.85	142.12	0.000431	1.14	88	59	0.17
2200	200	139.68	142.83	141.22	142.87	0.000493	1.5	134	67	0.19
2200	500	139.68	144.15	141.91	144.2	0.00054	1.73	289	200	0.25
2200	750	139.68	144.85	142.34	144.9	0.000545	1.63	460	277	0.22
2200	1000	139.68	145.33	142.72	145.38	0.000579	1.7	597	296	0.2
2200	1200	139.68	145.69	143	145.73	0.00059	1.75	704	310	0.19
2200	1500	139.68	146.28	143.72	146.33	0.000544	1.76	895	334	0.18
2200	2000	139.68	147.38	144.18	147.42	0.000421	1.71	1286	378	0.15
2200	2500	139.68	148.56	144.48	148.6	0.000315	1.64	1759	425	0.12
2200	3000	139.68	149.58	144.71	149.62	0.000262	1.63	2216	466	0.11
2200	3500	139.68	150.53	144.89	150.57	0.000228	1.63	2676	504	0.11
2200	4000	139.68	151.39	145.05	151.43	0.000205	1.63	3122	524	0.1
2200	4500	139.68	152.2	145.21	152.24	0.000188	1.65	3552	553	0.1
2100	50	139.64	141.52	140.53	141.53	0.00039	0.87	57	54	0.15
2100	75	139.64	141.81	140.69	141.83	0.000413	1.02	73	57	0.16
2100	100	139.64	142.06	140.81	142.08	0.000433	1.14	87	59	0.17
2100	200	139.64	142.78	141.18	142.82	0.0005	1.5	133	66	0.19
2100	500	139.64	144.1	141.86	144.14	0.00055	1.75	285	198	0.26
2100	750	139.64	144.8	142.31	144.84	0.000554	1.65	456	276	0.22
2100	1000	139.64	145.27	142.68	145.32	0.00059	1.71	592	295	0.21
2100	1200	139.64	145.62	142.96	145.67	0.000601	1.76	698	309	0.2
2100	1500	139.64	146.22	143.68	146.27	0.000551	1.77	890	333	0.18

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
2100	2000	139.64	147.34	144.14	147.38	0.000421	1.71	1286	378	0.15
2100	2500	139.64	148.52	144.44	148.56	0.000313	1.64	1763	425	0.12
2100	3000	139.64	149.55	144.68	149.59	0.000261	1.62	2222	467	0.11
2100	3500	139.64	150.51	144.85	150.54	0.000226	1.62	2685	505	0.11
2100	4000	139.64	151.37	145.01	151.41	0.000203	1.63	3132	525	0.1
2100	4500	139.64	152.18	145.17	152.22	0.000186	1.64	3577	587	0.1
2000	50	139.6	141.48	140.49	141.49	0.000388	0.87	57	54	0.15
2000	75	139.6	141.77	140.65	141.79	0.000414	1.02	73	57	0.16
2000	100	139.6	142.01	140.77	142.03	0.000437	1.15	87	59	0.17
2000	200	139.6	142.73	141.14	142.77	0.000508	1.51	132	66	0.19
2000	500	139.6	144.04	141.83	144.09	0.000561	1.77	282	195	0.26
2000	750	139.6	144.74	142.26	144.78	0.000565	1.66	451	276	0.23
2000	1000	139.6	145.21	142.64	145.26	0.000603	1.73	586	295	0.21
2000	1200	139.6	145.56	142.92	145.61	0.000614	1.78	691	309	0.2
2000	1500	139.6	146.17	143.64	146.22	0.000558	1.78	884	333	0.18
2000	2000	139.6	147.29	144.1	147.34	0.000422	1.72	1285	378	0.15
2000	2500	139.6	148.49	144.4	148.53	0.000312	1.64	1767	426	0.12
2000	3000	139.6	149.53	144.63	149.57	0.000259	1.62	2229	467	0.11
2000	3500	139.6	150.48	144.81	150.52	0.000224	1.62	2693	505	0.1
2000	4000	139.6	151.35	144.97	151.39	0.000201	1.62	3145	550	0.1
2000	4500	139.6	152.16	145.13	152.2	0.000184	1.63	3624	635	0.1
1900	50	139.57	141.44	140.46	141.46	0.000399	0.88	57	54	0.15
1900	75	139.57	141.73	140.62	141.75	0.000426	1.03	73	57	0.16
1900	100	139.57	141.97	140.74	141.99	0.00045	1.16	86	59	0.17
1900	200	139.57	142.68	141.11	142.71	0.000525	1.53	131	66	0.19
1900	500	139.57	143.98	141.8	144.03	0.000581	1.81	277	191	0.27
1900	750	139.57	144.68	142.23	144.73	0.000584	1.69	443	274	0.23
1900	1000	139.57	145.15	142.61	145.2	0.000624	1.76	576	293	0.21
1900	1200	139.57	145.5	142.89	145.55	0.000634	1.8	681	307	0.2
1900	1500	139.57	146.11	143.61	146.16	0.000572	1.8	875	332	0.18
1900	2000	139.57	147.25	144.07	147.3	0.000426	1.72	1280	377	0.15
1900	2500	139.57	148.46	144.37	148.5	0.000312	1.64	1766	426	0.12
1900	3000	139.57	149.5	144.6	149.54	0.000254	1.61	2354	712	0.11
1900	3500	139.57	150.46	144.78	150.5	0.000209	1.56	3062	754	0.1
1900	4000	139.57	151.34	144.94	151.37	0.000178	1.53	3728	769	0.09
1900	4500	139.57	152.15	145.1	152.18	0.000157	1.51	4356	784	0.09

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1800	50	139.54	141.4	140.43	141.42	0.000412	0.89	56	54	0.15
1800	75	139.54	141.69	140.59	141.7	0.00044	1.04	72	56	0.16
1800	100	139.54	141.92	140.71	141.94	0.000465	1.17	85	59	0.17
1800	200	139.54	142.62	141.08	142.66	0.000545	1.55	129	66	0.19
1800	500	139.54	143.92	141.76	143.97	0.000604	1.85	271	187	0.27
1800	750	139.54	144.62	142.21	144.67	0.000606	1.73	434	273	0.24
1800	1000	139.54	145.08	142.58	145.13	0.000647	1.79	565	292	0.22
1800	1200	139.54	145.43	142.86	145.48	0.000657	1.83	669	306	0.21
1800	1500	139.54	146.05	143.58	146.1	0.000586	1.82	866	330	0.18
1800	2000	139.54	147.21	144.04	147.25	0.00043	1.73	1275	377	0.15
1800	2500	139.54	148.43	144.34	148.47	0.000315	1.64	1768	457	0.12
1800	3000	139.54	149.48	144.58	149.51	0.000262	1.63	2366	827	0.11
1800	3500	139.54	150.44	144.75	150.48	0.000212	1.57	3312	1051	0.1
1800	4000	139.54	151.32	144.91	151.35	0.000174	1.51	4269	1121	0.09
1800	4500	139.54	152.14	145.07	152.16	0.000149	1.47	5196	1164	0.09
1700	50	139.5	141.36	140.39	141.37	0.000414	0.89	56	54	0.15
1700	75	139.5	141.64	140.55	141.66	0.000445	1.05	72	56	0.16
1700	100	139.5	141.87	140.67	141.9	0.000472	1.18	85	59	0.17
1700	200	139.5	142.57	141.04	142.61	0.000558	1.56	128	66	0.2
1700	500	139.5	143.86	141.73	143.91	0.000621	1.88	266	184	0.28
1700	750	139.5	144.56	142.16	144.61	0.000622	1.75	428	272	0.25
1700	1000	139.5	145.02	142.54	145.07	0.000666	1.81	558	291	0.22
1700	1200	139.5	145.36	142.82	145.42	0.000675	1.85	661	305	0.21
1700	1500	139.5	145.99	143.54	146.04	0.000596	1.83	859	330	0.19
1700	2000	139.5	147.16	144	147.21	0.000431	1.73	1274	377	0.15
1700	2500	139.5	148.4	144.3	148.44	0.000311	1.64	1770	434	0.12
1700	3000	139.5	149.45	144.53	149.49	0.000258	1.62	2413	761	0.11
1700	3500	139.5	150.42	144.71	150.46	0.000209	1.56	3471	1313	0.1
1700	4000	139.5	151.31	144.87	151.34	0.000167	1.48	4679	1406	0.09
1700	4500	139.5	152.12	145.03	152.15	0.000137	1.41	5839	1431	0.08
1600	50	139.46	141.32	140.35	141.33	0.000415	0.89	56	54	0.15
1600	75	139.46	141.6	140.51	141.61	0.00045	1.05	71	56	0.16
1600	100	139.46	141.83	140.63	141.85	0.00048	1.18	85	59	0.17
1600	200	139.46	142.51	141	142.55	0.000573	1.57	127	66	0.2
1600	500	139.46	143.79	141.68	143.85	0.00064	1.91	262	181	0.28
1600	750	139.46	144.49	142.13	144.54	0.00064	1.78	421	271	0.25
1600	1000	139.46	144.95	142.5	145	0.000687	1.84	549	290	0.23

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1600	1200	139.46	145.29	142.78	145.35	0.000695	1.88	652	303	0.22
1600	1500	139.46	145.93	143.5	145.98	0.000607	1.84	852	329	0.19
1600	2000	139.46	147.12	143.96	147.17	0.000432	1.73	1272	376	0.15
1600	2500	139.46	148.37	144.26	148.41	0.000309	1.63	1773	428	0.12
1600	3000	139.46	149.42	144.5	149.46	0.000253	1.61	2485	791	0.11
1600	3500	139.46	150.4	144.67	150.44	0.000204	1.55	3577	1494	0.1
1600	4000	139.46	151.29	144.83	151.32	0.000159	1.45	5068	1725	0.09
1600	4500	139.46	152.11	144.99	152.13	0.000127	1.36	6499	1754	0.08
1500	50	139.43	141.28	140.32	141.29	0.000431	0.9	55	53	0.16
1500	75	139.43	141.55	140.48	141.57	0.000468	1.07	70	56	0.17
1500	100	139.43	141.78	140.6	141.8	0.0005	1.2	83	58	0.18
1500	200	139.43	142.45	140.97	142.49	0.000599	1.6	125	65	0.2
1500	500	139.43	143.72	141.66	143.78	0.000671	1.96	255	176	0.29
1500	750	139.43	144.42	142.09	144.48	0.000669	1.82	411	269	0.26
1500	1000	139.43	144.88	142.47	144.93	0.000719	1.88	537	288	0.24
1500	1200	139.43	145.22	142.75	145.28	0.000725	1.91	639	302	0.22
1500	1500	139.43	145.87	143.47	145.92	0.000624	1.86	841	327	0.19
1500	2000	139.43	147.08	143.93	147.12	0.000436	1.74	1267	376	0.15
1500	2500	139.43	148.34	144.23	148.38	0.000309	1.63	1773	426	0.12
1500	3000	139.43	149.4	144.46	149.44	0.000249	1.59	2539	828	0.11
1500	3500	139.43	150.38	144.64	150.41	0.000201	1.54	3653	1418	0.1
1500	4000	139.43	151.28	144.8	151.3	0.000157	1.44	5163	1788	0.09
1500	4500	139.43	152.1	144.96	152.12	0.000124	1.35	6643	1803	0.08
1400	50	139.4	141.23	140.29	141.25	0.00045	0.91	55	53	0.16
1400	75	139.4	141.5	140.45	141.52	0.00049	1.08	69	56	0.17
1400	100	139.4	141.72	140.57	141.75	0.000524	1.22	82	58	0.18
1400	200	139.4	142.39	140.94	142.43	0.00063	1.63	123	65	0.21
1400	500	139.4	143.65	141.63	143.71	0.000707	2.02	247	170	0.3
1400	750	139.4	144.35	142.06	144.41	0.000701	1.88	400	264	0.27
1400	1000	139.4	144.8	142.44	144.86	0.000756	1.92	523	286	0.24
1400	1200	139.4	145.14	142.72	145.2	0.00076	1.95	625	300	0.23
1400	1500	139.4	145.8	143.44	145.86	0.000643	1.88	830	326	0.19
1400	2000	139.4	147.03	143.9	147.08	0.00044	1.74	1262	375	0.15
1400	2500	139.4	148.31	144.2	148.35	0.000309	1.63	1782	511	0.12
1400	3000	139.4	149.38	144.43	149.41	0.000245	1.58	2629	926	0.11
1400	3500	139.4	150.36	144.61	150.39	0.000196	1.52	3777	1459	0.1
1400	4000	139.4	151.26	144.77	151.29	0.000151	1.42	5354	1844	0.09

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1400	4500	139.4	152.09	144.93	152.11	0.000119	1.32	6887	1861	0.08
1300	50	139.36	141.19	140.25	141.2	0.000458	0.92	54	223	0.16
1300	75	139.36	141.45	140.41	141.47	0.000502	1.09	69	227	0.17
1300	100	139.36	141.67	140.53	141.69	0.000539	1.23	81	231	0.18
1300	200	139.36	142.32	140.9	142.36	0.000656	1.65	121	242	0.21
1300	500	139.36	143.57	141.58	143.64	0.000739	2.07	241	354	0.3
1300	750	139.36	144.28	142.03	144.34	0.000728	1.92	391	455	0.28
1300	1000	139.36	144.72	142.4	144.78	0.000789	1.96	512	485	0.25
1300	1200	139.36	145.06	142.68	145.13	0.000791	1.99	613	502	0.23
1300	1500	139.36	145.73	143.4	145.79	0.000658	1.9	822	536	0.2
1300	2000	139.36	146.99	143.86	147.04	0.000441	1.74	1261	603	0.15
1300	2500	139.36	148.28	144.16	148.32	0.000307	1.63	1799	847	0.12
1300	3000	139.36	149.35	144.4	149.39	0.000242	1.57	2708	1320	0.11
1300	3500	139.36	150.34	144.57	150.38	0.00019	1.5	3896	1769	0.1
1300	4000	139.36	151.25	144.73	151.27	0.000146	1.4	5460	2224	0.08
1300	4500	139.36	152.08	144.89	152.1	0.000115	1.3	6980	2247	0.08
1200	50	139.32	141.14	140.21	141.15	0.000467	0.93	54	242	0.16
1200	75	139.32	141.4	140.37	141.42	0.000516	1.1	68	246	0.18
1200	100	139.32	141.62	140.49	141.64	0.000558	1.24	80	250	0.19
1200	200	139.32	142.25	140.86	142.3	0.000686	1.67	119	260	0.22
1200	500	139.32	143.49	141.55	143.56	0.000777	2.13	235	364	0.31
1200	750	139.32	144.2	141.98	144.26	0.000759	1.97	381	462	0.28
1200	1000	139.32	144.63	142.36	144.7	0.000828	2.01	499	493	0.26
1200	1200	139.32	144.98	142.64	145.04	0.000827	2.03	600	509	0.24
1200	1500	139.32	145.67	143.36	145.72	0.000674	1.92	812	541	0.2
1200	2000	139.32	146.94	143.82	146.99	0.000443	1.75	1259	601	0.15
1200	2500	139.32	148.25	144.12	148.28	0.000306	1.63	1805	833	0.12
1200	3000	139.32	149.33	144.35	149.36	0.000237	1.56	2787	1371	0.11
1200	3500	139.32	150.33	144.53	150.36	0.000178	1.45	3985	1860	0.09
1200	4000	139.32	151.23	144.69	151.26	0.000137	1.35	5493	2147	0.08
1200	4500	139.32	152.07	144.85	152.09	0.000108	1.27	6955	2171	0.07
1100	50	139.29	141.09	140.18	141.11	0.000494	0.94	53	246	0.17
1100	75	139.29	141.35	140.34	141.37	0.000548	1.12	67	250	0.18
1100	100	139.29	141.56	140.46	141.58	0.000594	1.27	79	254	0.19
1100	200	139.29	142.18	140.83	142.23	0.000735	1.71	117	264	0.22
1100	500	139.29	143.41	141.51	143.48	0.000833	2.21	226	361	0.32

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1100	750	139.29	144.12	141.96	144.18	0.000806	2.04	368	463	0.29
1100	1000	139.29	144.54	142.33	144.61	0.000885	2.08	482	501	0.27
1100	1200	139.29	144.89	142.61	144.96	0.000879	2.09	582	518	0.25
1100	1500	139.29	145.6	143.33	145.66	0.000699	1.95	799	557	0.2
1100	2000	139.29	146.9	143.79	146.95	0.000447	1.75	1253	632	0.15
1100	2500	139.29	148.21	144.09	148.25	0.000306	1.63	1811	946	0.12
1100	3000	139.29	149.31	144.33	149.34	0.000229	1.53	2807	1404	0.11
1100	3500	139.29	150.31	144.5	150.34	0.00017	1.42	3973	1800	0.09
1100	4000	139.29	151.22	144.66	151.24	0.000129	1.32	5417	2000	0.08
1100	4500	139.29	152.06	144.82	152.07	0.000103	1.24	6776	2030	0.07
1000	50	139.26	141.04	140.15	141.05	0.000528	0.96	52	264	0.17
1000	75	139.26	141.29	140.31	141.31	0.000588	1.15	65	269	0.19
1000	100	139.26	141.49	140.43	141.52	0.000639	1.3	77	273	0.2
1000	200	139.26	142.1	140.8	142.15	0.000797	1.76	114	286	0.23
1000	500	139.26	143.31	141.48	143.39	0.000904	2.31	216	377	0.33
1000	750	139.26	144.03	141.93	144.1	0.000862	2.12	354	477	0.31
1000	1000	139.26	144.45	142.3	144.52	0.000955	2.16	463	518	0.29
1000	1200	139.26	144.8	142.58	144.87	0.000941	2.15	563	535	0.26
1000	1500	139.26	145.52	143.3	145.58	0.000727	1.98	785	568	0.21
1000	2000	139.26	146.85	143.76	146.9	0.000452	1.76	1248	634	0.15
1000	2500	139.26	148.18	144.06	148.22	0.000306	1.63	1794	809	0.12
1000	3000	139.26	149.28	144.3	149.32	0.000231	1.54	2755	1375	0.11
1000	3500	139.26	150.29	144.47	150.32	0.000172	1.43	3909	1800	0.09
1000	4000	139.26	151.21	144.63	151.23	0.000132	1.33	5267	1892	0.08
1000	4500	139.26	152.05	144.79	152.06	0.000106	1.25	6530	1920	0.07
900	50	139.22	140.99	140.11	141	0.000553	0.98	51	212	0.17
900	75	139.22	141.23	140.27	141.25	0.000621	1.17	64	217	0.19
900	100	139.22	141.43	140.39	141.45	0.000679	1.33	75	220	0.2
900	200	139.22	142.02	140.76	142.07	0.000859	1.81	111	230	0.24
900	500	139.22	143.21	141.45	143.3	0.000978	2.41	208	311	0.34
900	750	139.22	143.93	141.88	144.01	0.000917	2.2	341	412	0.32
900	1000	139.22	144.34	142.26	144.42	0.001029	2.25	445	458	0.31
900	1200	139.22	144.69	142.54	144.77	0.001004	2.22	545	474	0.28
900	1500	139.22	145.45	143.26	145.51	0.00075	2.01	774	509	0.21
900	2000	139.22	146.81	143.72	146.86	0.000454	1.76	1245	574	0.15
900	2500	139.22	148.15	144.02	148.19	0.000305	1.62	1785	732	0.12
900	3000	139.22	149.26	144.25	149.29	0.000234	1.55	2668	1379	0.11

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
900	3500	139.22	150.28	144.43	150.3	0.000174	1.44	3827	1669	0.09
900	4000	139.22	151.19	144.59	151.22	0.000136	1.35	5023	1732	0.08
900	4500	139.22	152.03	144.75	152.05	0.000111	1.29	6134	1782	0.07
800	50	139.18	140.93	140.07	140.94	0.000585	1	50	154	0.18
800	75	139.18	141.16	140.23	141.18	0.000664	1.19	63	158	0.2
800	100	139.18	141.35	140.35	141.38	0.000731	1.36	74	161	0.21
800	200	139.18	141.92	140.72	141.98	0.000942	1.86	107	170	0.25
800	500	139.18	143.1	141.41	143.2	0.001074	2.52	198	242	0.35
800	750	139.18	143.83	141.84	143.91	0.000986	2.3	326	346	0.34
800	1000	139.18	144.22	142.22	144.31	0.001124	2.36	424	404	0.33
800	1200	139.18	144.58	142.5	144.67	0.001083	2.3	525	426	0.29
800	1500	139.18	145.37	143.22	145.43	0.000777	2.04	762	471	0.22
800	2000	139.18	146.76	143.68	146.81	0.000456	1.76	1243	580	0.15
800	2500	139.18	148.12	143.98	148.16	0.000303	1.62	1802	803	0.12
800	3000	139.18	149.24	144.21	149.27	0.000233	1.55	2671	1492	0.11
800	3500	139.18	150.26	144.39	150.29	0.000174	1.44	3796	1589	0.09
800	4000	139.18	151.18	144.55	151.2	0.000138	1.36	4834	1625	0.08
800	4500	139.18	152.02	144.71	152.04	0.000115	1.31	5799	1659	0.08
700	50	139.15	140.87	140.04	140.88	0.000651	1.03	49	192	0.19
700	75	139.15	141.09	140.2	141.11	0.000743	1.24	61	196	0.21
700	100	139.15	141.27	140.32	141.31	0.000823	1.41	71	199	0.22
700	200	139.15	141.82	140.69	141.88	0.001076	1.95	103	207	0.27
700	500	139.15	142.97	141.38	143.08	0.001224	2.68	187	264	0.37
700	750	139.15	143.72	141.81	143.81	0.001087	2.44	308	368	0.36
700	1000	139.15	144.09	142.19	144.19	0.001262	2.52	397	420	0.36
700	1200	139.15	144.46	142.47	144.55	0.001199	2.42	498	443	0.31
700	1500	139.15	145.29	143.19	145.35	0.000815	2.08	745	491	0.22
700	2000	139.15	146.72	143.65	146.76	0.000461	1.77	1237	575	0.15
700	2500	139.15	148.09	143.95	148.13	0.000305	1.63	1798	824	0.12
700	3000	139.15	149.21	144.18	149.25	0.000231	1.55	2735	1449	0.11
700	3500	139.15	150.24	144.36	150.27	0.000178	1.46	3994	1644	0.09
700	4000	139.15	151.18	144.52	151.19	0.000065	0.94	8000	1669	0.06
700	4500	139.15	152.02	144.68	152.03	0.000055	0.91	9409	1680	0.05
600	50	139.12	140.79	140.01	140.81	0.00075	1.08	46	191	0.2
600	75	139.12	141.01	140.17	141.03	0.000862	1.3	58	194	0.22
600	100	139.12	141.18	140.29	141.22	0.00096	1.49	67	198	0.24

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
600	200	139.12	141.69	140.66	141.76	0.00128	2.07	97	207	0.29
600	500	139.12	142.82	141.34	142.95	0.001444	2.88	174	249	0.38
600	750	139.12	143.59	141.78	143.69	0.001224	2.61	287	356	0.38
600	1000	139.12	143.94	142.16	144.05	0.001452	2.74	365	418	0.4
600	1200	139.12	144.32	142.44	144.42	0.001356	2.57	467	468	0.35
600	1500	139.12	145.2	143.15	145.27	0.000857	2.12	727	546	0.23
600	2000	139.12	146.67	143.61	146.72	0.000463	1.77	1234	755	0.15
600	2500	139.12	148.1	143.92	148.11	0.000059	0.72	4095	1002	0.05
600	3000	139.12	149.22	144.16	149.23	0.000046	0.69	5493	1511	0.05
600	3500	139.12	150.25	144.33	150.25	0.000037	0.67	7127	1618	0.04
600	4000	139.12	151.18	144.5	151.18	0.000031	0.65	8639	1634	0.04
600	4500	139.12	152.02	144.65	152.03	0.000027	0.64	10020	1647	0.04
500	50	139.08	140.71	139.97	140.73	0.000872	1.13	44	210	0.22
500	75	139.08	140.91	140.13	140.94	0.001017	1.37	55	223	0.24
500	100	139.08	141.07	140.25	141.11	0.001147	1.58	63	226	0.26
500	200	139.08	141.54	140.62	141.61	0.001592	2.22	90	235	0.32
500	500	139.08	142.64	141.3	142.78	0.001766	3.09	162	265	0.38
500	750	139.08	143.44	141.75	143.56	0.001393	2.81	270	408	0.41
500	1000	139.08	143.75	142.13	143.89	0.001691	3.03	338	440	0.43
500	1200	139.08	144.15	142.4	144.27	0.001541	2.86	442	517	0.37
500	1500	139.08	145.11	143.12	145.18	0.000855	2.24	787	635	0.24
500	2000	139.08	146.69	143.56	146.69	0.000069	0.73	3134	743	0.06
500	2500	139.08	148.1	143.83	148.11	0.000048	0.69	4328	1082	0.05
500	3000	139.08	149.22	144.1	149.23	0.000039	0.68	5913	1684	0.05
500	3500	139.08	150.25	144.3	150.25	0.000032	0.66	7672	1724	0.04
500	4000	139.08	151.18	144.49	151.18	0.000027	0.64	9285	1744	0.04
500	4500	139.08	152.02	144.67	152.02	0.000024	0.64	10762	1761	0.04
400	50	139.04	140.61	139.93	140.63	0.001089	1.22	41	255	0.24
400	75	139.04	140.79	140.08	140.83	0.001303	1.49	50	277	0.27
400	100	139.04	140.94	140.21	140.98	0.0015	1.72	58	279	0.29
400	200	139.04	141.33	140.58	141.42	0.002265	2.5	80	286	0.37
400	500	139.04	142.4	141.27	142.58	0.002287	3.38	148	305	0.4
400	750	139.04	143.26	141.71	143.41	0.001651	3.08	243	423	0.47
400	1000	139.04	143.52	142.09	143.7	0.002122	3.39	295	453	0.5
400	1200	139.04	143.96	142.36	144.11	0.001835	3.03	396	511	0.43
400	1500	139.04	145.02	143.09	145.09	0.000955	2.2	700	591	0.24
400	2000	139.04	146.67	143.53	146.68	0.000132	0.93	3517	997	0.08

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
400	2500	139.04	148.09	143.82	148.1	0.000095	0.89	5016	1217	0.07
400	3000	139.04	149.21	144.06	149.22	0.000071	0.84	6658	1696	0.06
400	3500	139.04	150.24	144.24	150.25	0.000056	0.8	8424	1726	0.05
400	4000	139.04	151.17	144.39	151.18	0.000047	0.77	10037	1738	0.05
400	4500	139.04	152.02	144.56	152.02	0.000041	0.76	11507	1751	0.04
300	50	139.01	140.47	139.9	140.5	0.00168	1.41	35	311	0.29
300	75	139.01	140.61	140.06	140.66	0.002175	1.76	43	315	0.34
300	100	139.01	140.72	140.19	140.79	0.002672	2.08	48	317	0.38
300	200	139.01	140.71	140.56	140.98	0.011006	4.2	48	316	0.77
300	500	139.01	142.05	141.23	142.29	0.003648	3.96	126	371	0.5
300	750	139.01	143.02	141.68	143.22	0.002104	3.53	225	496	0.5
300	1000	139.01	143.15	142.05	143.44	0.003181	4.32	249	519	0.63
300	1200	139.01	144.05	142.34	144.05	0.000037	0.45	2471	600	0.06
300	1500	139.01	145.06	143.08	145.06	0.000032	0.45	3091	638	0.05
300	2000	139.01	146.67	143.48	146.68	0.000025	0.46	4336	930	0.04
300	2500	139.01	148.09	143.72	148.09	0.000021	0.48	5781	1216	0.03
300	3000	139.01	149.21	143.72	149.22	0.000019	0.5	7384	1672	0.03
300	3500	139.01	150.24	143.72	150.24	0.000017	0.51	9121	1700	0.03
300	4000	139.01	151.17	143.72	151.17	0.000016	0.51	10711	1715	0.03
300	4500	139.01	152.01	143.72	152.02	0.000015	0.52	12161	1727	0.03
200	50	138.98	139.98	139.94	140.09	0.020685	2.66	19	217	0.87
200	75	138.98	140.15	140.05	140.23	0.012144	2.32	32	247	0.69
200	100	138.98	140.3	140.12	140.37	0.007147	2.08	48	265	0.55
200	200	138.98	140.88	140.33	140.89	0.000036	0.24	867	316	0.04
200	500	138.98	142.2	140.76	142.2	0.000059	0.54	1292	331	0.06
200	750	138.98	143.14	140.76	143.14	0.000063	0.69	1630	409	0.08
200	1000	138.98	143.31	140.76	143.32	0.000099	0.88	1704	431	0.1
200	1200	138.98	144.04	140.76	144.05	0.000086	0.88	2052	520	0.09
200	1500	138.98	145.05	140.76	145.06	0.000072	0.88	2610	584	0.08
200	2000	138.98	146.66	140.76	146.67	0.000069	1	3843	991	0.08
200	2500	138.98	148.08	140.76	148.09	0.000046	0.91	5329	1162	0.06
200	3000	138.98	149.21	140.77	149.21	0.000037	0.89	6885	1550	0.06
200	3500	138.98	150.23	140.77	150.24	0.000031	0.87	8496	1583	0.05
200	4000	138.98	151.17	140.77	151.17	0.000027	0.86	9985	1613	0.05
200	4500	138.98	152.01	140.77	152.01	0.000025	0.86	11357	1642	0.05
100	50	132.87	140.06	133.55	140.06	0.000001	0.08	664	175	0.01

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
100	75	132.87	140.21	133.69	140.21	0.000001	0.11	690	187	0.01
100	100	132.87	140.35	133.78	140.35	0.000002	0.14	719	210	0.01
100	200	132.87	140.88	134.08	140.88	0.000006	0.24	841	235	0.02
100	500	132.87	142.2	134.65	142.2	0.000013	0.43	1159	249	0.04
100	750	132.87	143.13	135.02	143.14	0.000017	0.54	1410	317	0.04
100	1000	132.87	143.31	135.34	143.32	0.000027	0.69	1469	358	0.05
100	1200	132.87	144.03	135.58	144.04	0.000026	0.73	1783	509	0.05
100	1500	132.87	145.04	135.89	145.05	0.000024	0.78	2330	580	0.05
100	2000	132.87	146.66	136.37	146.67	0.00002	0.81	3582	945	0.05
100	2500	132.87	148.08	136.78	148.09	0.000017	0.83	5004	1160	0.05
100	3000	132.87	149.2	137.17	149.21	0.000016	0.86	6499	1475	0.04
100	3500	132.87	150.23	137.53	150.24	0.000015	0.87	8033	1513	0.04
100	4000	132.87	151.16	137.87	151.17	0.000014	0.89	9462	1547	0.04
100	4500	132.87	152	138.2	152.01	0.000013	0.91	10776	1572	0.04

8 Appendix B Reach 2B Hydraulic Properties under Delivery Conditions

Table 8-1. Hydraulic Properties under Delivery Conditions for a flow of 4500 cfs in Reach 2B.

River Sta	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
515424	159.32	170.69	163.56	170.78	0.000102	2.54	2129	515	0.16
515130	157.35	170.5	165.05	170.71	0.000685	3.71	1220	218	0.26
515091	158.18	170.49	163.71	170.68	0.000386	3.5	1286	144	0.21
515089	160	170.09	164.45	170.52	0.000942	5.27	853	85	0.29
515088	160	170.03	164.61	170.51	0.002035	5.61	803	80	0.31
515029	160	169.89	164.61	170.39	0.002111	5.68	792	80	0.32
515028	160.09	169.44	166.7	170.35	0.014107	7.65	588	80	0.5
515026	160.09	169.4	166.7	170.32	0.014342	7.69	585	80	0.5
515025	160	169.67	164.61	170.19	0.002243	5.81	774	80	0.33
515012	160.09	169.68	164.54	170.16	0.001101	5.55	811	85	0.32
515010	162.09	169.26	166.54	170.12	0.00272	7.42	607	85	0.49
515009	160.09	169.51	164.54	170.01	0.001163	5.65	797	85	0.32
514971	154.22	169.8	158.86	169.87	0.000091	2.24	2321	241	0.11
514775	160.45	169.74	164.15	169.84	0.000255	2.6	1757	247	0.17
513785	157.67	169.52	163.06	169.6	0.000222	2.28	1988	993	0.15
512857	157.45	169.22	163.68	169.34	0.000366	2.77	1626	1833	0.19
512308	160.28	169.09	163.79	169.16	0.000245	2.12	2135	2515	0.16
511505	159.83	168.92	164.15	168.97	0.000205	1.85	2447	3651	0.14
510595	158.58	168.79	163.37	168.83	0.000126	1.61	2791	4197	0.11
509963	156.03	168.56	162.85	168.69	0.000339	2.97	1526	3991	0.19
509161	159.04	168.32	163.45	168.43	0.000307	2.64	1736	3643	0.18
508794	158.78	168.16	163.23	168.3	0.000384	3.02	1509	3447	0.2
508239	158.13	168	162.78	168.1	0.000287	2.57	1769	3511	0.17
507644	158	167.85	163.24	167.94	0.000257	2.32	1978	3183	0.16
507030	158.18	167.7	162.72	167.78	0.000251	2.33	1944	2735	0.16
506265	158.31	167.45	162.58	167.55	0.000364	2.56	1822	2461	0.19
505349	156.15	167.03	161.18	167.19	0.000396	3.25	1470	2093	0.21
504369	157.67	166.76	161.29	166.86	0.000263	2.58	1765	2127	0.17

503762	155.59	166.57	161.74	166.68	0.000329	2.68	1685	2444	0.18
503176	157.37	166.44	161.49	166.51	0.000225	2.16	2090	2781	0.15
502614	157.35	166.23	161.37	166.35	0.000388	2.69	1680	2391	0.19
502026	157.15	166.08	160.41	166.17	0.000224	2.34	1957	2777	0.15
501471	151.5	166.08	158.79	166.1	0.00005	1.19	3832	3381	0.07
500616	155.29	165.89	160.05	166.01	0.000265	2.72	1656	2791	0.17
499745	153.83	165.69	159.46	165.78	0.000244	2.33	1939	2709	0.16
498994	154.57	165.49	159.1	165.59	0.000238	2.59	1743	3456	0.16
498396	154.63	165.38	159.79	165.45	0.000206	2.17	2074	3325	0.15
497737	146.99	165.4	151.79	165.41	0.000015	0.81	5574	2846	0.04
497178	153.12	165.3	158.86	165.38	0.000199	2.3	1957	2301	0.15
496461	153.06	165.04	159.45	165.18	0.000395	3	1499	1900	0.2
495752	155.65	164.83	160.04	164.93	0.00029	2.56	1760	1579	0.17
495157	155.53	164.68	159.93	164.76	0.000251	2.27	1979	1579	0.16
494541	155.68	164.53	159.46	164.61	0.000233	2.23	2063	1931	0.16
493824	155.09	164.49	159.25	164.51	0.000072	1.18	3880	2449	0.09
493160	154.49	164.4	158.66	164.45	0.000121	1.66	2777	2642	0.11
492937	154.91	164.37	158.18	164.42	0.000119	1.73	2701	2651	0.11
492900									
492888	154.83	164.28	157.93	164.33	0.000132	1.82	2696	2658	0.12
492641	152.18	164.24	158.33	164.29	0.000137	1.87	2535	2556	0.12
492368	152.67	164.16	158.81	164.24	0.000228	2.34	1947	2825	0.16
491812	150.62	163.99	157.82	164.1	0.000261	2.74	1812	3695	0.17
490882	151.88	163.77	158.48	163.85	0.00026	2.35	1916	2899	0.16
489900	151.74	163.56	157.71	163.63	0.000187	2.18	2074	2777	0.14
489024	151.12	163.42	157.22	163.48	0.000157	2.02	2249	2943	0.13
488185	145.01	163.32	153.02	163.36	0.000119	1.59	2836	2794	0.11
487560	150.8	163.21	157.38	163.27	0.000166	1.99	2285	2977	0.13
487057	149.49	163.09	156.58	163.18	0.000192	2.33	1936	3270	0.14
486414	146.98	162.91	156.91	163.02	0.000331	2.66	1691	3764	0.18
485851	150.84	162.73	157.46	162.84	0.000295	2.6	1733	3350	0.17
485228	150.11	162.6	156.65	162.67	0.000219	2.11	2239	3483	0.15
484767	149.49	162.47	156.77	162.56	0.000259	2.45	2101	3426	0.16
484067	148.6	162.32	154.07	162.4	0.0002	2.33	2339	3073	0.15
483437	146.46	162.2	155.41	162.28	0.000179	2.17	2075	2770	0.14
482911	147.1	162.14	154.27	162.19	0.000121	1.85	2488	2654	0.11
482399	149.19	162.02	154.43	162.11	0.000234	2.39	1912	2666	0.16
481666	148.39	161.87	154.97	161.94	0.000203	2.26	1998	2268	0.15
480974	148.48	161.75	155.13	161.79	0.000202	1.7	2659	2245	0.14
480369	149.25	161.58	154.92	161.66	0.000244	2.2	2045	2121	0.16
479440	150.63	161.31	155.74	161.4	0.000307	2.5	1907	2770	0.18

478427	150.22	161.08	154.95	161.16	0.000184	2.18	2077	2889	0.14
476969	149.81	160.76	154.49	160.85	0.000243	2.46	1866	3158	0.16
475615	151.36	160.3	154.91	160.45	0.000362	3.08	1464	2886	0.2
474411	151.73	159.99	154.62	160.08	0.000238	2.5	1815	3149	0.16
472882	151.58	159.39	154.85	159.57	0.000496	3.41	1642	4842	0.23
471714	147.04	158.92	153.67	159.05	0.000372	3.12	2595	6252	0.2
470917	150.14	158.73	153.91	158.8	0.000227	2.3	4979	6049	0.15
470366	148.46	158.58	153.41	158.67	0.000274	2.54	5338	5925	0.17
469289	148.6	158.34	153.14	158.4	0.000221	2.16	6594	5627	0.15
468184	148.45	158.13	153.4	158.17	0.000177	1.76	5977	4390	0.13
467430	148.99	157.88	153.22	157.99	0.000331	2.7	2164	4127	0.18
466051	149.48	157.47	153.25	157.55	0.000296	2.35	2055	4318	0.17
465182	146.65	157.15	152.32	157.27	0.00035	2.79	1918	3392	0.19
464197	145.19	156.88	150.77	156.97	0.000262	2.41	2081	2576	0.16
463075	148.78	156.62	151.97	156.68	0.000231	2.12	2248	1903	0.15
462074	147.63	156.31	151.44	156.41	0.000313	2.56	2128	1139	0.18
460762	148.75	155.79		155.88	0.000542	2.46	2042	966	0.22
459705	148.9	155.79	152.3	155.95	0.000223	3.22	1497	1080	0.24
459605	148.9	155.49	152.63	155.89	0.000535	5.09	884	1078	0.37
459604									
459555	148.9	155.35	152.63	155.77	0.000579	5.22	863	1078	0.38
459455	148.9	155.48	152.3	155.66	0.000267	3.4	1431	1078	0.26
458383	151.05	155.02	153.73	155.19	0.000845	3.28	1374	636	0.39
457659	146.72	154.75	153.02	154.82	0.000292	2.2	2170	1269	0.24
457157	137.64	154.63	145.4	154.75	0.000084	2.86	1744	828	0.16
456741	138.82	154.58	145.85	154.7	0.000143	2.84	1678	920	0.19
456233	137.62	154.5	145.71	154.61	0.000248	2.71	1741	644	0.23
455801	140.78	154.5	146.74	154.54	0.00004	1.55	2896	413	0.1
455740	138.6	154.51	140.38	154.52	0.000002	0.84	5330	335	0.04
455739	142.8	154.49	144.68	154.52	0.000019	1.24	3619	310	0.06
455738	138.6	154.5	140.38	154.51	0.000002	0.84	5327	335	0.04
455718	138.6	152.2	140.38	152.22	0.000003	0.99	4557	335	0.05
455717	137.6	152.2	139.37	152.22	0.000003	0.92	4892	335	0.04
455714	137.6	152.2	139.37	152.22	0.000003	0.92	4892	335	0.04
455701	131.95	152.21	135.86	152.21	0.000001	0.67	6726	414	0.03
455534	130.62	152.21	135.64	152.21	0.000009	0.61	7366	498	0.03
455295	137.47	152.14	141.57	152.2	0.000119	2.08	2609	1981	0.11
454513	137.07	152.03	141.39	152.1	0.000137	2.1	2292	1711	0.11
453719	136.34	152.01	141.16	152.02	0.00005	1.12	4885	1913	0.06

9 Appendix C Reach 2B Hydraulic Properties under Delivery Conditions with Subsidence

Table 9-1. Hydraulic Properties under Delivery Conditions for a flow of 4500 cfs in Reach 2B with the effects of subsidence included.

River Sta	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
515424	159.32	170.69	163.56	170.79	0.000101	2.53	2131.79	517.03	0.16
515130	157.35	170.5	165.05	170.72	0.000683	3.7	1221.21	218.25	0.26
515091	158.18	170.5	163.71	170.69	0.000385	3.5	1286.63	144.48	0.21
515089	160	170.1	164.45	170.53	0.00094	5.27	853.75	84.55	0.29
515088	160	170.03	164.61	170.52	0.002031	5.6	803.28	80.05	0.31
515029	160	169.9	164.61	170.4	0.002107	5.68	792.31	80.05	0.32
515028	160.09	169.45	166.7	170.35	0.014048	7.64	589.06	80.05	0.5
515026	160.09	169.41	166.7	170.32	0.01428	7.68	585.94	80.05	0.5
515025	160	169.68	164.61	170.2	0.002237	5.81	774.71	80.05	0.33
515012	160.09	169.69	164.54	170.17	0.001098	5.54	811.75	84.55	0.32
515010	162.09	169.28	166.54	170.13	0.002707	7.41	607.5	84.55	0.49
515009	160.09	169.52	164.54	170.02	0.001159	5.64	797.62	84.55	0.32
514971	154.22	169.81	158.86	169.88	0.000091	2.23	2322.95	240.67	0.11
514775	160.45	169.75	164.15	169.85	0.000254	2.6	1759.21	246.72	0.17
513785	157.67	169.53	163.06	169.61	0.000221	2.28	1990.75	992.95	0.15
512857	157.45	169.23	163.68	169.35	0.000364	2.76	1628.79	1833	0.19
512308	160.28	169.1	163.79	169.17	0.000243	2.11	2140.37	2517.5	0.16
511505	159.83	168.94	164.15	168.99	0.000203	1.84	2453.53	3652.22	0.14
510595	158.58	168.8	163.37	168.84	0.000125	1.61	2798.12	4198.25	0.11
509963	156.03	168.57	162.85	168.71	0.000337	2.97	1529.88	4005.95	0.19
509161	159.04	168.34	163.45	168.45	0.000304	2.63	1741.15	3670.16	0.18
508794	158.78	168.18	163.23	168.32	0.00038	3.01	1514.12	3474.65	0.2
508239	158.13	168.02	162.78	168.12	0.000284	2.56	1775.6	3521.67	0.17
507644	158	167.88	163.24	167.96	0.000253	2.31	1986.32	3194.87	0.16
507030	158.18	167.72	162.72	167.81	0.000247	2.32	1952.28	2759.27	0.16
506265	158.31	167.48	162.58	167.58	0.000358	2.54	1832.99	2491.36	0.19
505349	156.15	167.07	161.18	167.23	0.00039	3.24	1479.34	2115.89	0.21
504369	157.67	166.8	161.29	166.9	0.000258	2.56	1775.42	2128.6	0.17

503762	155.59	166.62	161.74	166.73	0.000321	2.66	1697.18	2453.84	0.18
503176	157.37	166.49	161.49	166.56	0.000219	2.14	2107.04	2806.07	0.15
502614	157.35	166.29	161.37	166.4	0.000377	2.67	1695.92	2465.27	0.19
502026	157.15	166.14	160.41	166.23	0.000218	2.32	1975.91	2898.25	0.15
501471	151.5	166.14	158.79	166.16	0.000049	1.18	3865.85	3498.3	0.07
500616	155.29	165.96	160.05	166.07	0.000258	2.7	1670.02	2945.07	0.17
499745	153.83	165.76	159.46	165.84	0.000235	2.3	1960.87	2856.6	0.16
498994	154.57	165.57	159.1	165.67	0.000231	2.56	1760.32	3574.07	0.16
498396	154.63	165.46	159.79	165.53	0.000198	2.15	2099.6	3342.81	0.14
497737	146.99	165.48	151.79	165.49	0.000015	0.8	5615.69	2847.7	0.04
497178	153.12	165.38	158.86	165.46	0.000192	2.28	1977.86	2302.02	0.14
496461	153.06	165.13	159.45	165.27	0.000379	2.96	1519.21	1907.23	0.2
495752	155.65	164.93	160.04	165.03	0.000276	2.52	1786.8	1631.33	0.17
495157	155.53	164.79	159.93	164.87	0.000237	2.23	2014.49	1601.96	0.16
494541	155.68	164.65	159.46	164.73	0.000219	2.19	2104.64	1930.57	0.15
493824	155.09	164.61	159.25	164.63	0.000067	1.16	3965.07	2449.37	0.08
493160	154.49	164.53	158.66	164.57	0.000114	1.63	2834.53	2641.71	0.11
492937	154.91	164.5	158.18	164.55	0.000112	1.7	2754.6	2651.47	0.11
492900									
492888	154.83	164.43	157.93	164.47	0.000123	1.79	2767.11	2658.38	0.12
492641	152.18	164.39	158.33	164.44	0.000128	1.83	2592.1	2555.64	0.12
492368	152.67	164.31	158.81	164.4	0.000212	2.29	1992.12	2824.69	0.15
491812	150.62	164.16	157.82	164.27	0.000243	2.68	1867.36	3694.79	0.16
490882	151.88	163.95	158.48	164.03	0.000239	2.29	1972.14	2903.43	0.16
489900	151.74	163.76	157.71	163.83	0.000171	2.12	2132.93	2779.98	0.14
489024	151.12	163.63	157.22	163.69	0.000143	1.96	2316.32	2945.46	0.12
488185	145.01	163.55	153.02	163.58	0.000107	1.54	2933.72	2797.91	0.1
487560	150.8	163.44	157.38	163.5	0.000149	1.93	2368.05	2981.95	0.13
487057	149.49	163.34	156.58	163.42	0.000174	2.26	1996.95	3274.57	0.14
486414	146.98	163.17	156.91	163.27	0.000293	2.56	1757.76	3771.19	0.17
485851	150.84	163.02	157.46	163.12	0.000258	2.49	1806.05	3356.41	0.16
485228	150.11	162.91	156.65	162.97	0.000186	2.01	2384.03	3506.95	0.14
484767	149.49	162.79	156.77	162.88	0.000221	2.33	2240.7	3439.81	0.15
484067	148.6	162.67	154.07	162.74	0.000172	2.23	2520.1	3096.17	0.14
483437	146.46	162.57	155.41	162.64	0.000154	2.08	2174.43	2778.32	0.13
482911	147.1	162.52	154.27	162.56	0.000104	1.77	2612.93	2660.08	0.11
482399	149.19	162.41	154.43	162.49	0.000197	2.27	2019.89	2671.92	0.14
481666	148.39	162.28	154.97	162.35	0.000169	2.14	2115.59	2294.61	0.13
480974	148.48	162.19	155.13	162.23	0.000155	1.56	2930.26	2265.74	0.12
480369	149.25	162.06	154.92	162.13	0.000194	2.04	2203.72	2128.44	0.14
479440	150.63	161.85	155.74	161.93	0.000224	2.26	2693.5	2776.37	0.15

478427	150.22	161.69	154.95	161.75	0.000136	1.98	3341.23	2910.27	0.12
476969	149.81	161.44	154.49	161.52	0.00018	2.25	2076.05	3186.64	0.14
475615	151.36	161.11	154.91	161.23	0.000259	2.79	1624.52	2901.86	0.17
474411	151.73	160.9	154.62	160.97	0.000162	2.23	2044.51	3180.33	0.14
472882	151.58	160.59	154.85	160.68	0.00023	2.57	5318.39	4874.37	0.16
471714	147.04	160.41	153.67	160.46	0.000132	2.1	9360.59	6307.48	0.12
470917	150.14	160.36	153.91	160.38	0.000066	1.43	13117.57	6111.07	0.09
470366	148.46	160.33	153.41	160.35	0.000071	1.5	13870.94	5980.79	0.09
469289	148.6	160.27	153.14	160.28	0.000054	1.27	15516.57	5701.44	0.08
468184	148.45	160.21	153.4	160.23	0.000048	1.13	12695.49	4466.42	0.07
467430	148.99	160.14	153.22	160.18	0.000089	1.71	7844.36	4238.77	0.1
466051	149.48	160.03	153.25	160.06	0.000078	1.53	6356.87	4444.5	0.09
465182	146.65	159.94	152.32	159.98	0.000096	1.83	5599.6	3513.94	0.11
464197	145.19	159.86	150.77	159.9	0.000074	1.64	4206.76	2647.89	0.09
463075	148.78	159.8	151.97	159.83	0.000051	1.33	5566.35	1972	0.08
462074	147.63	159.73	151.44	159.77	0.000071	1.6	4602.97	1188.33	0.09
460762	148.75	159.66		159.68	0.00005	1.17	5560.58	1042.78	0.07
459705	148.9	159.66	152.3	159.67	0.000002	0.44	23704.22	3497.63	0.02
459605	148.9	159.51	152.63	159.65	0.000094	3.03	1486.84	3497.63	0.17
459604									
459555	148.9	159.45	152.63	159.6	0.000096	3.04	1478.38	3497.63	0.17
459455	148.9	159.53	152.3	159.56	0.000023	1.44	7238.51	3497.63	0.08
458383	151.05	159.53	153.73	159.54	0.00001	0.77	11389.44	4263.12	0.05
457659	146.72	159.53	153.02	159.53	0.000005	0.59	13776.65	4752.3	0.04
457157	137.64	159.52	145.4	159.53	0.000004	0.82	16695.97	4372.91	0.04
456741	138.82	159.52	145.85	159.52	0.000007	0.89	14542.52	4084.29	0.05
456233	137.62	159.51	145.71	159.52	0.000008	0.8	13359.92	3707.05	0.05
455801	140.78	159.5	146.74	159.52	0.000007	0.89	5112.59	709.21	0.05
455740	138.6	159.51	140.38	159.51	0.000003	0.72	6248.43		0.03
455739	142.8	159.5	144.68	159.51	0.000017	0.99	4540.54		0.04
455738	138.6	159.5	140.38	159.51	0.000003	0.72	6248.43		0.03
455718	138.6	152.2	140.38	152.22	0.000003	0.99	4556.73	335	0.05
455717	137.6	152.2	139.37	152.22	0.000003	0.92	4892.06	335	0.04
455714	137.6	152.2	139.37	152.22	0.000003	0.92	4892.06	335	0.04
455701	131.95	152.21	135.86	152.21	0.000001	0.67	6725.66	414.4	0.03
455534	130.62	152.21	135.64	152.21	0.000009	0.61	7366.34	497.83	0.03
455295	137.47	152.14	141.57	152.2	0.000119	2.08	2608.75	1981.32	0.11
454513	137.07	152.03	141.39	152.1	0.000137	2.1	2291.6	1711.27	0.11
453719	136.34	152.01	141.16	152.02	0.00005	1.12	4885.3	1912.5	0.06

10 Appendix D San Joaquin River Seepage Management Program Soils Data within Compact Bypass

San Joaquin River Seepage Management Program

Well or Boring# 04-10 Sampler: Brummer Date: 3/2/10

Location(UTM/NAD83) 10S 0735406 4074621 Landform Floodplain NRCS Map Unit Gba Grangeville fsl

Location Notes About 300 ft South of big cottonwood tree slightly saline - alkali

Topography Nearly Level Vegetation & Conditon Grain; Fair condition

Irrigation System Type: Gravity check Irrigation Quadrant 3/5

Avg EM Measurements; (T, Cor) EM_V 20.0(25.6) EM_H 18.4(22.5) EM Calibration Site: EM_V 20.3 EM_H 18.3

Soil Temperature, ^{0}C (2") 16 °C (16") 14 °C

PROFILE DESCRIPTION AND LABORATORY DATA

Sample No.	Depth (inches)	USDA Texture	% Clay	% Sand	Color	Reaction to HCL[1]	Moisture Content[2]	Mottles	pH Paste	ECe dS/m	Sat. %	Notes:
SJRBS	0-18	SiL	16	25	Dk.Gry	+	VM-M	None				Friable
	18-52	SiL	17	25	Lt.BrnGry	0	SM	None				Soft
	52-30	FSL	8	60	Lt.BrnGry	0	ND	Com				Distinct Mottles
28	0-12	30x					18.4		7.87	1.8	45.2	
31	0-12						21.3		7.76	1.45	46.1	
32	12-30						15.4		7.96	3.21	56	
33	30-60						7.6		7.46	2.16	47.6	

[1] Lime content; HCL reaction 0 none; + slight; ++ moderate +++ strong NE=Not Evaluated

[2] Soil moist: nearly dry=nd; slightly moist = sm; moist = m; very moist= vm; wet = w; saturated=S;

Field capacity will be considered very moist. Wet will be considered capillary fringe conditions.

Site Remarks:

About 300 ft from Mendota Pool

Excellent Profile

No sign of water table or capillary fringe

Too dry for good EM readings; 18-60"

EM38 Measurements:

EM_V	EM_H	EM_V	EM_H	EM_V	EM_H	EM_V	EM_H
20.5	18	19.8	16.7	13.3	11.8	17.9	16.7
21.7	20.7	16.2	14.3	16.4	13.7	24.3	26.2
18.2	15.6	13.9	13.3	32	33.8	20.3	18.3 *
25.1	23.4	13	10.7	18.8	16		
30.6	28.3	13.9	12.9	21.9	19.2		
22.6	21.1	12.6	13.1	26.1	21.7		

San Joaquin River Seepage Management Program

Well or Boring# 05-10 Sampler: Brummer Date: 3/2/10

Location(UTM/NAD83) 10S 0735693 4074638 Landform Floodplain NRCS Map Unit CgbA; Chino Loam

Location Notes About 250 ft west of Pump Moderately saline/alkaline

Topography Nearly Level Vegetation & Conditon Grain

Irrigation System Type: Gravity check Irrigation Quadrant 3/5

Avg EM Measurements; (T, Cor) EM_V 44.8(57.4) EM_H 44.1(53.9) EM Calibration Site: EM_V 56.8 EM_H 50.5

Soil Temperature, ^{0}C (2") 16 °C (16") 14 °C

PROFILE DESCRIPTION AND LABORATORY DATA

Sample No.	Depth (inches)	USDA Texture	% Clay	% Sand	Color	Reaction to HCL[1]	Moisture Content[2]	Mottles	pH Paste	ECe dS/m	Sat. %	Notes:
SJRBS	0-18	L	20	38	V.DkGry	0	VM	None				Friable
	18-30	SiL	21	25	Pale BrnGry	0	M	None				Friable
	30-49	L	15	48	Pale BrnGry	0	M	Few				Few Faint Mottles
	49-60	FSL	15	55	BrnGry	0	M	Com				Common Mottles
35	0-12	30x					22.9		7.23	4.36	56	SAR = 5.1
36	0-12						27.6		6.78	4.23	53.7	SAR = 4.3
37	12-30						24.5		7.23	5.41	49.7	SAR = 7.2
38	30-60						24.7		7.52	1.77	43.8	

[1] **Lime content; HCL reaction 0 none; + slight; ++ moderate +++ strong NE=Not Evaluated**

[2] **Soil moist: nearly dry=nd; slightly moist = sm; moist = m; very moist= vm; wet = w; saturated=S;**

Field capacity will be considered very moist. Wet will be considered capillary fringe conditions.

Site Remarks:

About 250 ft West of Pump; 150 ft from Mendota Pool

No sign of water table or capillary fringe

EM38 Measurements:

EM_V	EM_H	EM_V	EM_H	EM_V	EM_H	EM_V	EM_H
46.9	46.2	47.8	46.8	45.3	48.3	50.9	51
59.7	53	49.9	58.7	46.9	46.7	56.8	50.5 *
49.1	52.4	47.9	51.4	39.1	39.1		
37.1	36.9	46.6	45.7	28.8	34.6		
17.2	15.7	42.8	35.9	60.1	51.8		
34.1	31.9	40.9	42.3	48.4	42.8		

San Joaquin River Seepage Management Program

Well or Boring# sjrrp 6-10 Sampler: brummer Date: 3/2/2010

Location(UTM/NAD83 0734938 4074468 Landform floodplain NRCS Map Unit chino loam

Location Notes 250 feet se of well 2b-2 slt saline /alk

Topography nearly level Vegetation & Conditon grain fair

Irrigation System Type: gravity check Irrigation Quadrant 2//5

Avg EM Measurements; (tcor) EM_V 7.7 (9.9) EM_H 7.9 (9.9) EM Calibration Site: EM_V 8.7 Emh 8

Soil Temperature, ^{0}C (2") 15c (16") 14c

PROFILE DESCRIPTION AND LABORATORY DATA

Sample No.	Depth (Inches)	USDA Texture	% Clay	% Sand	Color	Reaction to HCL[1]	Moisture Content[2]	Mottles	pH Paste	ECe dS/m	Sat. %	Notes:
	0-14	loam	18	35	vdk gray	ne	vm	none				friable
	14-28	loam	16	40	palebrn		sm	none				firm -slightly hard
	28-46	fsl	10	65	palebrn		dry	few				slt hard
	46-60	ls	4	86	palebrn		dry	common				soft
41	0-12 30x						21		7.12	1.49	48.7	
42	0-12						24		6.78	1.08	49.8	
43	12to30						9.4		7.08	1.42	47.4	
44	30-60						2.5		7	1.26	20.1	too dry for em

[1] **Lime content; HCL reaction 0 none; + slight; ++ moderate +++ strong**

[2] **Soil moist: nearly dry=nd; slightly moist = sm; moist = m; very moist= vm; wet = w; saturated=S;**

Field capacity will be considered very moist. Wet will be considered capillary fringe conditions.

Site Remarks:

dryness at depth may have affected Emv readings.

EM38 Measurements:

EM_V	EM_H	EM_V	EM_H
7	6.9	9.1	9.8
6.4	6	8.2	8.8
6.3	6	9	8.5
6.5	7	7.1	8.1
5.7	6.2	7.7	7.8
8.8	10.6	9.7	9.6