State of California

California Natural Resources Agency

Department of Water Resources

Bay-Delta Office

Efficacy Report

2015 Emergency Drought Barrier Project

June 2019

Executive Summary

California’s four-year drought of 2012–2015 was one of the worst in California’s recorded history. As a result of the severe drought conditions, the amount of fresh water flowing through the Sacramento-San Joaquin River Delta (Delta) in the summer of 2015 would have been insufficient to adequately counter tidal pumping of Pacific Ocean saltwater into the Delta had the California Department of Water Resources (DWR) not taken appropriate measures. These measures included: (1) construction of the Emergency Drought Barrier (EDB) and (2) successful petitioning by DWR and the U.S. Bureau of Reclamation (USBR) to the California State Water Resources Control Board (SWRCB) for the establishment of temporary emergency water quality standards through the Temporary Urgency Change Petition (TUCP) process. This report focuses primarily on the EDB — how it was installed, what its effects were, and how it helped see California through the drought, which could well have persisted beyond 2015.

To prevent further salinity intrusion into the Delta, DWR planned, designed, constructed, and monitored the 2015 EDB project in consultation with federal and State water and wildlife agencies. The trapezoidal-shaped barrier, which consisted of 92,500 cubic yards of aggregate rock, spanned the West False River from Jersey Island to Bradford Island in Contra Costa County for a period of approximately five months (May to October 2015). The total project cost was $36 million.

DWR decided to install the EDB salinity barrier, in part, based on the performance of several rock barriers installed throughout the Delta during 1976 and 1977 to help mitigate extreme drought conditions. The EDB was a high-priority project, with decisions to install the barrier made at the Governor and the DWR Director levels. DWR Deputy Directors of the Security and Emergency Management Program and of the State Water Project facilitated communication across divisions and closely monitored progress. Staff from across DWR cooperated to rapidly implement the project in a way that was well-founded technically, appropriately environmentally compliant, and responsive to public needs. This report describes the planning, design, construction, and monitoring of the EDB, and analysis of its effectiveness.

The EDB performed largely as anticipated:

- It shielded the interior (upstream) Delta from salinity intrusion, which, once established, can be difficult to reverse.

- It protected the freshwater corridor through the central Delta, along which fresh water releases from upstream flow toward the export pumps in the southern Delta.
- It limited increased salinity in the interior Delta to not beyond acceptable levels on the mainstem Sacramento and San Joaquin rivers.

The efficacy analysis took several forms:

- Estimating how much worse interior Delta salinity would have been without the EDB, assuming normal project operations — as much as 300 microsiemens per centimeter (µS/cm) specific conductance (EC) more saline.
- Estimating the amount of water conserved through the installation of the EDB, assuming fixed water quality goals — approximately 100,000 acre-feet.

This report also includes broader analysis of the measured and modeled flow, velocity, and water quality patterns associated with the EDB.

Although the circumstances of the 2012–2015 California drought are unlikely to be exactly replicated, California is certain to experience another long-term drought. The EDB was shown to be an effective drought mitigation tool, suggesting that preparation should be made for its more rapid and efficient implementation in the future by using normal rather than emergency permitting processes. This report concludes with lessons learned from the 2015 EDB team experiences, including:

- Importance of early and transparent communications and outreach though the Public Affairs Office so that the public stays informed.
- Closure timing can affect the efficacy of a salinity barrier. Modeling suggested a shift two weeks earlier than actual installation would have enhanced 2015 EDB efficacy by avoiding the surge in salinity that occurred in early June because of wind and offshore barometric forcing.
- Planning ahead for future long-term droughts by preparing a “roadmap” for implementation, including draft environmental documentation and permits, will result in a faster response to installing a drought salinity barrier when needed.

Contents

Executive Summary	i
Contents	iii
Figures	iv
Tables	iv
Acronyms and Abbreviations	vii
1.0 Introduction	1
1.1 Continuing Long-Term Drought	3
1.2 How the Emergency Drought Barrier Works	6
1.3 Purpose and Objectives of Efficacy Report	7
2.0 Siting and Planning	8
2.1 Siting	8
2.1.1 Historical Installations	9
2.1.2 Modeling	9
2014 and 2015 Modeling Processes	10
Evolving Objectives for Studies in 2014 Analysis used to Inform 2015 Modeling and Operations	18
Discussion of Differences in Salinity Results between Different Delta Models	19
Water Cost Analysis	20
2015 Forecasts	21
Stakeholders Coordination	21
2.2 Planning	22
2.2.1 Public Outreach	22
2.2.2 Real Estate	25
2.2.3 Agency Coordination and Permitting	29
Federal Permits	29
State Permits	31
3.0 Design, Construction, and Monitoring and Impacts	34
3.1 Design	34
3.2 Construction	36
3.2.1 Installation	37
3.2.2 Removal	40
3.3 Monitoring and Project Impacts	42
3.3.1 Fish and Wildlife	42
Environmental Compliance during Barrier Installation	42
Environmental Compliance during Barrier Removal	47
3.3.2 Water Quality	50
Water Quality Monitoring during Barrier Construction	51
Selecting Water Quality Monitoring Station Locations	52
Water Quality Station Installation	55
Water Quality Parameters Measured	55

Effects of the Barrier on Water Quality 56
3.3.3 Hydrodynamics 56
Establishing the four EDB-related flow stations (FCT, SOI, SXS, and MIR) 57
Velocity changes within the vicinity of the 2015 EDB 57
3.3.4 Bathymetry 62
Challenges in Describing Eroded Levee Geometry 62
Channel Bed Elevation Change Pre- and Post-Rock Barrier Installation 63
3.3.5 Other Impacts 67
4.0 EDB Efficacy 75
4.1 Water Quality 75
4.1.1 Comparison of Measured (Observed) Salinity Intrusion before, during, and after EDB installation 76
4.1.2 Modeled Comparisons of Barrier versus No Barrier 82
4.2 Hydrodynamics 91
4.2.1 Tidal Water Levels 91
4.2.2 Flow 98
4.2.3 Velocity 99
5.0 Conclusions 103
5.1 Lessons Learned 105
5.1.1 Team Structure and Internal Communication 105
5.1.2 Planning 106
5.1.3 Modeling 108
5.1.5 Real Estate 110
5.1.6 Design and EDB Construction 111
5.1.7 Fish and Wildlife Environmental Monitoring and Compliance 112
5.1.8 Water Quality Monitoring 113
5.2 Future Planning 115
6.0 References 117
7.0 Appendix A 119

Figures

Figure 1-1 Site Location ... 2
Figure 1-2 Inflow and Exports to the Delta (DAYFLOW) From 1970 to 2015 ... 5
Figure 1-3 Salinity Near Franks Tract on Flood and Ebb Tide With and Without EDB ... 7
Figure 2-1 Data and Existing Models Used in Delta Models' Forecast Modeling Process ... 11
Figure 2-2 Barrier Locations Considered in Phase 1 Analysis, 2009 Emergency Barriers Report ... 15
Figure 2-3 Location of Barriers in Phase 2 Analysis, 2009 Emergency Barriers Report ... 16
Figure 3-1 2015 Emergency Drought Barrier General Layout ... 35

Figure 3-2 Typical Cross-Section Through the 2015 Emergency Drought Barrier 35
Figure 3-3 Profile of Drought Barrier and Levee Sheet Piles 36
Figure 3-4 Rock Placement During EDB Installation 39
Figure 3-5 Rock Placement During EDB Installation 40
Figure 3-6 Locations of Water Quality Monitoring Stations 53
Figure 3-7 Mean Channel Velocities at the Fisherman's Cut (FCT) Monitoring Station 59
Figure 3-8 Mean Channel Velocities at the Old River at Franks Tract (OSJ) Monitoring Station 60
Figure 3-9 Mean Channel Velocities at the Dutch Slough at Jersey Island (DSJ) Monitoring Station 61
Figure 3-10 Bathymetry Survey Areas 64
Figure 3-11 Areas of Levee Undercutting 65
Figure 3-12 Typical Levee Undercutting Plan and Profile 66
Figure 3-13 Histograms of Elevation Change at Various Locations 67
Figure 3-14 Location of Navigational Aid Ball Float Anchorage Piles 70
Figure 4-1 Main Salinity Intrusion Pathway and Water Quality Stations Used for Comparison 76
Figure 4-2 Tidally Filtered Salinity at Stations Along the Intrusion Pathway in 2013–2014 77
Figure 4-3 Tidally Filtered Salinity at Stations Along the Intrusion Pathway in 2015 78
Figure 4-4 Pairs of Stations That Equilibrate in Salinity 80
Figure 4-5 EC Stations Spanning the Eastern Side of Franks Tract 81
Figure 4-6 Stations Used to Examine Old-Middle River Mixing 81
Figure 4-7 Stations South of Franks Tract on Old and Middle River 82
Figure 4-8 Conductivity Differences July 5–18 Resulting From the Barrier 84
Figure 4-9 Modeled Conductivity at the Three Most Likely Limiting Compliance Locations Under the TUCP with Barrier: Three Mile Slough at the Sacramento River, Jersey Point, and Bacon Island at Old River 88
Figure 4-10 Modeled Conductivity at the Three Most Likely Limiting Compliance Locations Under the TUCP With no Barrier: Three Mile Slough at the Sacramento River, Jersey Point, and Bacon Island at Old River 89
Figure 4-11 Effect of Advancing the Closure Date by Two Weeks at Jersey Point (Top) and Bacon Island and Hwy 4 (Bottom) 90
Figure 4-12 Low/Vulnerable Sections of Levees Identified by DWR and RD 2059 92
Figure 4-13 Change in Daily Maximum Water Levels (Barrier Minus No Barrier) for June 16, 2015 (Spring Tide) 93
Figure 4-14 Simulated Water Levels for Low Spot #1 With Daily Maximum Values Labeled 94
Figure 4-15 Simulated Water Levels For Low Spot #2 With Daily Maximum Values Labeled 95
Figure 4-16 Simulated Water Levels For Low Spot #3 With Daily Maximum Values Labeled 96
Figure 4-17 Simulated Water Levels For Low Spot #4 With Daily Maximum Values Labeled 97
Figure 4-18 Changes in Tidal Range of Flow, Fisherman's Cut and Mouth of Old River 98
Figure 4-19 Changes in Tidal Range at Holland Cut, Turner Cut, and the San Joaquin River at Prisoners Point 99
Figure 4-20 Changes in Tidal Velocities Around the Time of Breach at Fisherman's Cut and the Mouth of Old River (OSJ) 100
Figure 4-21 Observed (ADCP) Velocities on 4/22/15 Before the Barrier Installation at Peak Flow 101
Figure 4-22 Observed (ADCP) Velocities on 6/3/2015 With Barrier Closed at Peak Flow 102
Figure 5-1 Google Map of Rendezvous Location of May 8, 2015, Media Event 110
Figure A-1 Sediment Change Pre/Post Barrier Around the Confluence of San Joaquin River and False River 119
Figure A-2 Sediment Change Pre/Post Barrier on the West Shore of Bradford Island Along San Joaquin River 120

Figure A-3 Sediment Change Pre/Post Barrier on the Northwest Shore of Bradford Island and Souhwest Shore of Twitchell Island Aong San Joaquin River....121
Figure A-4 Sediment Change Pre/Post Barrier on the North Shore of Bradford Island Along San Joaquin River....122
Figure A-5 Sediment Change Pre/Post Barrier Around the Confluence of San Joaquin River and Fishermans Cut, and the Southeast Shore of Twtichell Island....123
Figure A-6 Sediment Change Pre/Post Barrier Between Bradford Island and Webb Tract Along Fishermans Cut....124
Figure A-7 Sediment Change Pre/Post Barrier Around the Confluence of False River and Fishermans Cut Between Bradford Island and Webb Tract....125
Figure A-8 Sediment Change Pre/Post Barrier Along Old River Near Franks Tract....126
Figure A-9 Sediment Change Pre/Post Barrier Along Dutch Slough Near Big Break....127
Figure A-10 Sediment Change Pre/Post Barrier along Dutch Slough Near Jersey Island Road....128
Figure A-11 Sediment Change Pre/Post Barrier Along Dutch Slough and Taylor Slough....129
Figure A-12 Sediment Change Pre/Post Barrier Along Dutch Slough Near Bethel Island Cove....130

Tables

Table 2-1 Phase 2 Analysis Barrier Locations and EC Reduction at Banks Pumping Plant 17
Table 2-2 Federal Permits for the 2015 Emergency Drought Barrier Project....29
Table 2-3 State Authorizations and Permits for 2015 EDB Project....32
Table 3-1 Installation Dates and Milestones....37
Table 3-2 Removal Dates and Milestones....41
Table 3-3 Water Quality Monitoring Stations....54
Table 3-4 Navigational Aid Ball Float Anchorage Piles at EDB Site....70

Acronyms and Abbreviations

µg/L	microgram per liter
µS	microSiemens
µS/cm	microSiemens per centimeter
BA	biological assessment
BDO	Bay Delta Office
BET	Bethel Island near Piper Slough
BO	biological opinion
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CVFPB	Central Valley Flood Protection Board
CVP	Central Valley Project
CWA	Clean Water Act
D-1641	Water Rights Decision 1641
dB	decibels
DCC	Delta Cross Channel
DCO	Delta Coordinated Operations
DCP	Drought Contingency Plan
DICU	Delta Island Consumptive Use
Delta	Sacramento-San Joaquin Delta
DES	Division of Environmental Services
DFA	Delta Ferry Authority
DSJ	Dutch Slough at Jersey Island
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources

DO	dissolved oxygen
EC	specific conductance
EDB	Emergency Drought Barrier
EO	Executive Order
ESA	Endangered Species Act
FAL	False River
FAQs	frequently asked questions
FCT	Fisherman's Cut
ft/s	feet per second
FRK	Franks Tract, Mid Tract
GZL	Grizzly Bay
HCP	habitat conservation plan
HOL	Holland Cut near Bethel Island
HON	Honker Bay
HWB	Miner Slough at Highway 84
IS	initial study
ITP	Incidental Take Permit
LIB	Liberty Island
mg/L	milligram per liter
MIR	Miner Slough near Sacramento River
MND	mitigated negative declaration
MOU	memorandum of understanding
NCRO	North Central Regional Office
NDOI	Net Delta Outflow Index
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NTU	Nephelometric Turbidity Units

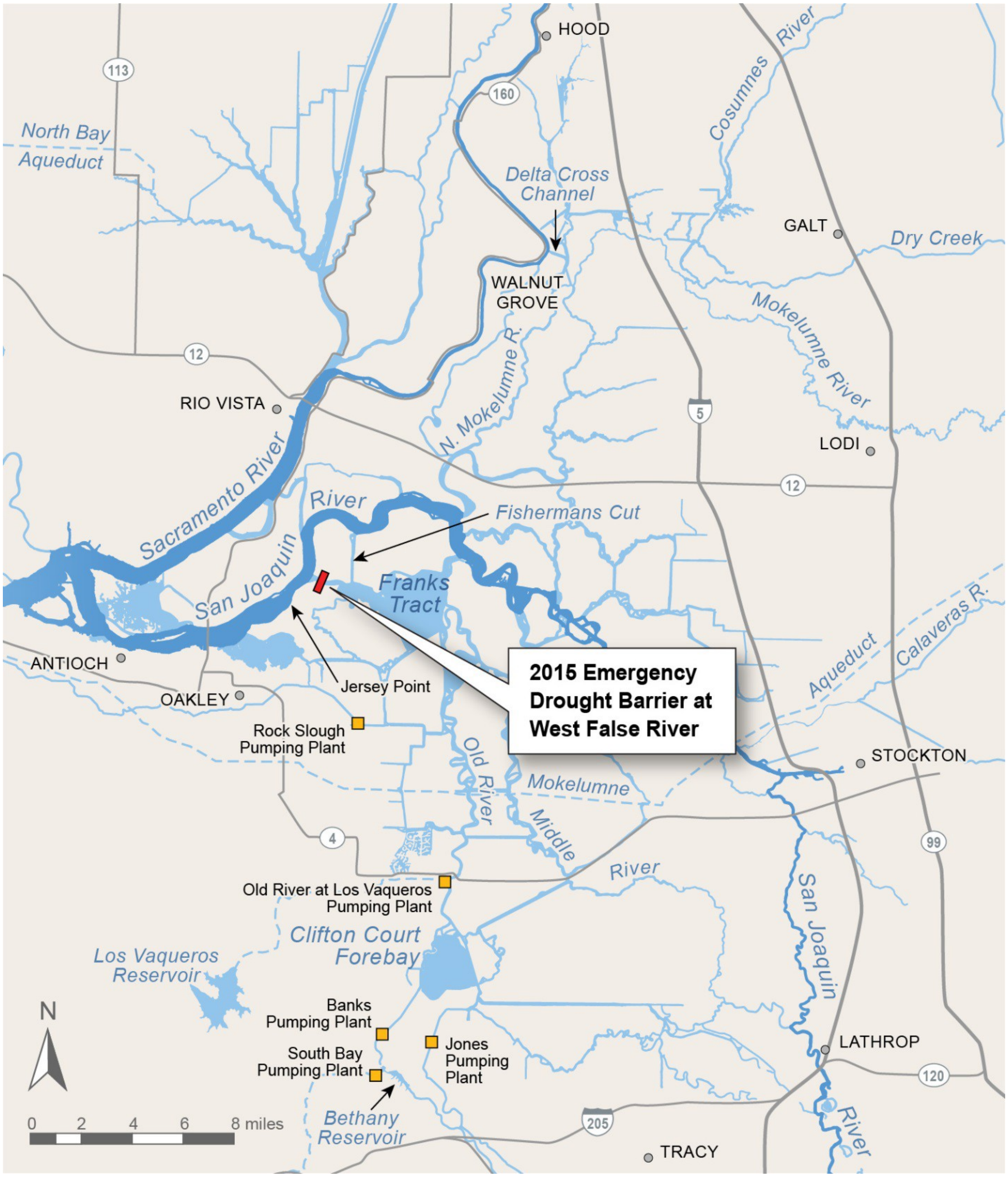
OSJ	Old River at Franks Tract near Terminous
PAO	Public Affairs Office
RD	Reclamation District
Reclamation	United States Bureau of Reclamation
REB	Real Estate Branch
RMA	Resource Management Associates
RTDOT	Real Time Drought Operations Management Team
RWQCB	Regional Water Quality Control Board
RYC	Suisun Bay – Cutoff near Ryer Island
RYI	Cache Slough at Ryer Island
SELFE	Semi-implicit Eulerian Lagrangian Finite Element
SJJ	San Joaquin River at Jersey Point
SLC	California State Lands Commission
SOI	Sacramento River downstream of Isleton
SSI	Sacramento River near Sherman Island
SUS	Steamboat Slough below Sutter Slough
SWE	snow water equivalent
SWP	State Water Project
SWRCB	State Water Resources Control Board
SXS	Steamboat Slough near Sacramento River
TSL	Threemile Island Slough at San Joaquin River
TWI	Sacramento River at Twitchell Island
TUCP	Temporary Urgency Change Petition
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

WEAT	Worker Environmental Awareness Training
WY	water year
X2	A point identified by its distance from the Golden Gate Bridge where salinity at the river's bottom is about 2 parts per thousand.
YSI	Yellow Spring Instruments

1.0 Introduction

Faced with potentially insufficient water supplies necessary to achieve the water quality objectives from Water Rights Decision 1641 (D-1641) and repel salinity in the Sacramento-San Joaquin River Delta (Delta), the California Department of Water Resources (DWR) installed a temporary rock barrier across West False River (Figure 1-1) as part of the 2015 Emergency Drought Barrier (EDB) Project. The EDB was intended to lessen the intrusion of Pacific Ocean saltwater, protect in-Delta water supplies, maintain water quality objectives, and allow exports of water for the State Water Project (SWP) and Central Valley Project (CVP). A large portion of California's freshwater supply is used by people who live in the Delta and in Contra Costa, Alameda, and Santa Clara counties, as well as the 25 million people served by the SWP and CVP. On January 17, 2014, Governor Edmund G. Brown Jr. proclaimed a State of Emergency brought on by the severe drought conditions that began in 2012. Executive Order B-29-15 was issued on April 1, 2015, as a directive to streamline government responsiveness. The executive order included several required responses to the drought conditions, including installation of the EDB, which was part of the 2015 California Drought Contingency Plan (DCP).

Figure 1-1 Site Location



1.1 Continuing Long-Term Drought

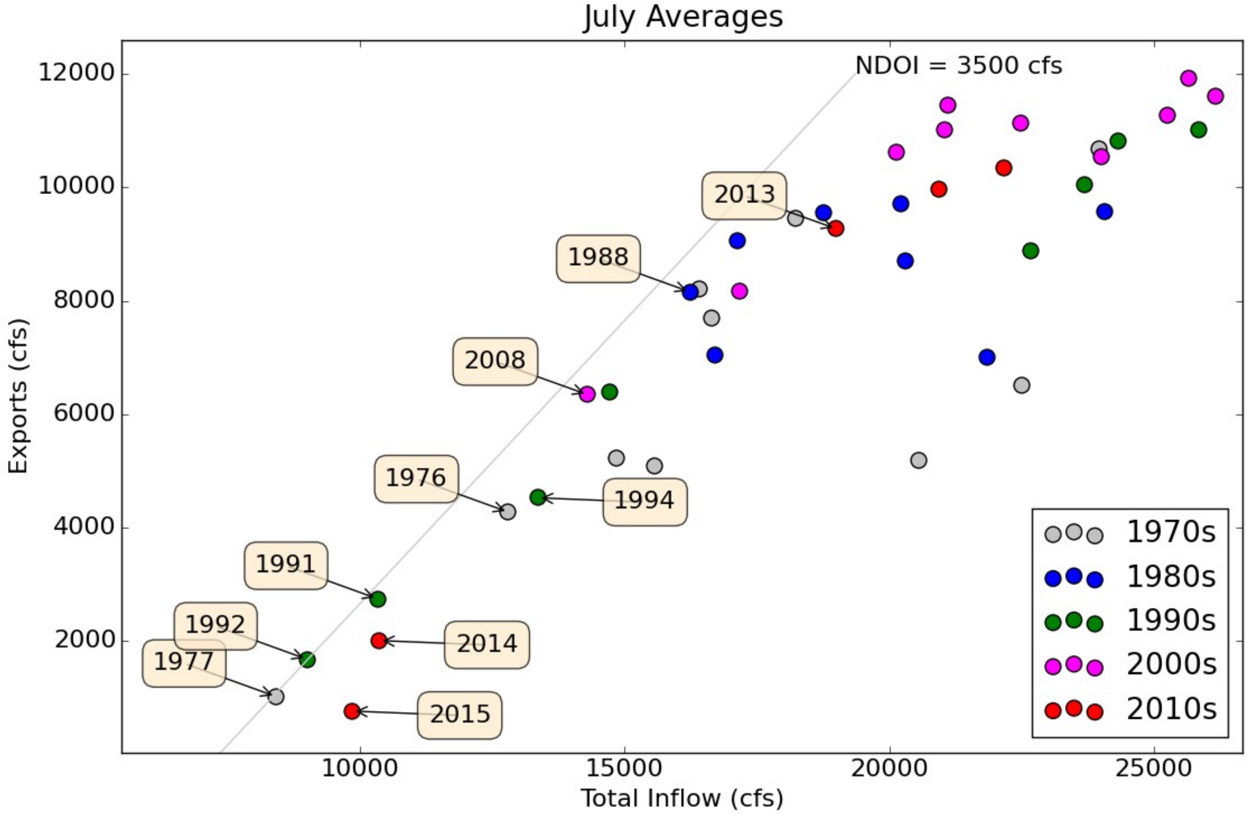
Drought is a recurring feature of California’s climate. Perspective on long-term climate variability can be provided by paleoclimate information such as streamflow or precipitation reconstructions developed from tree-ring data. Reconstructed hydrologic records show that California has experienced droughts of much longer duration than those in our century-plus period of recorded history.

Water Year (WY) 2015 was California’s fourth consecutive year of below-average rainfall and snowpack, and was also the eighth of nine years and seventh of nine years with below-average runoff for the Sacramento and San Joaquin Valley, respectively. This extended drought produced chronic and significant shortages to municipal and industrial, environmental, agricultural, and wildlife refuge water supplies, leading to historically low groundwater levels. This dry hydrology set many new statewide records, including the driest four-year period of statewide precipitation (2012–2015) since records have been kept. In calendar year 2013, many communities recorded their lowest-ever levels of annual precipitation. California tied a record for lowest April 1 statewide Snow Water Equivalent (SWE) in 2014, at 25 percent of average, breaking records dating back to 1950. That record was broken in 2015 when the April 1 SWE was 5 percent of average (California Department of Water Resources 2016). WY 2015 also produced by far the lowest snowpack in the Sierra Nevada since records have been kept, and January 2015 was the driest January on record for precipitation statewide. Some estimates, based on tree-ring analysis, indicate that WY 2015 was the lowest over the past five centuries (University of Arizona 2016).

This drought occurred at a time of record warmth in California. Broadly speaking, the period since 1950 has been warmer across the Southwestern United States (including California and the Colorado River Basin) than in any comparable period in at least 600 years, according to the 2013 Southwest Climate Assessment. Increased warmth in the climate system has many implications — an increasing fraction of precipitation falling as rain instead of snow, diminished mountain snowpack, earlier snowmelt runoff, and increased water demands for crops, urban landscaping, and native vegetation.

Regulatory mandates govern operation of the SWP and CVP system, including the Delta. Typically, with each successive year of drought, water delivery operators reduce the volume of water traversing the system by storing more inflows through upstream storage and exporting less water. These decisions to reduce the volume of flow can be complex and must consider many factors, some of which have competing priorities. For example, Water Right Decision 1641 (D-1641) outlines a set of flow objectives intended to protect water quality in the Delta. A water delivery operator may not have the flexibility to simply reduce delivery volume without also considering the effects downstream and the potential consequences of impacting the ability to meet related obligations, such as the objectives identified in D-1641. Figure 1-2 shows the average inflows and exports from DAYFLOW (computer program to estimate daily Delta outflow) over the past 45 years for the month of July. In July 2015, only a small proportion of river inflows were captured as exports to serve as water supply (approximately a tenth of total inflow). Moreover, WY 2015 is the lowest year shown in terms of exports and nearly so in terms of river inflows. By contrast, there is little to distinguish 2015 or any other low-water year in terms of Net Delta Outflow Index (NDOI), an index of how much water flows through the Delta to the ocean. Almost all dry years lie a short distance to the right of (i.e., higher than) the 3,500 cubic feet per second (cfs) contour of NDOI, which is representative of D-1641 objectives in dry years. The lack of variation on this axis illustrates the high degree of regulation under D-1641 and its predecessors.

Figure 1-2 Inflow and Exports to the Delta (DAYFLOW) From 1970 to 2015



Note: Three outlier years are omitted. The gray line indicates combinations of inflow and outflow that yield NDOI of 3,500 cfs for July.

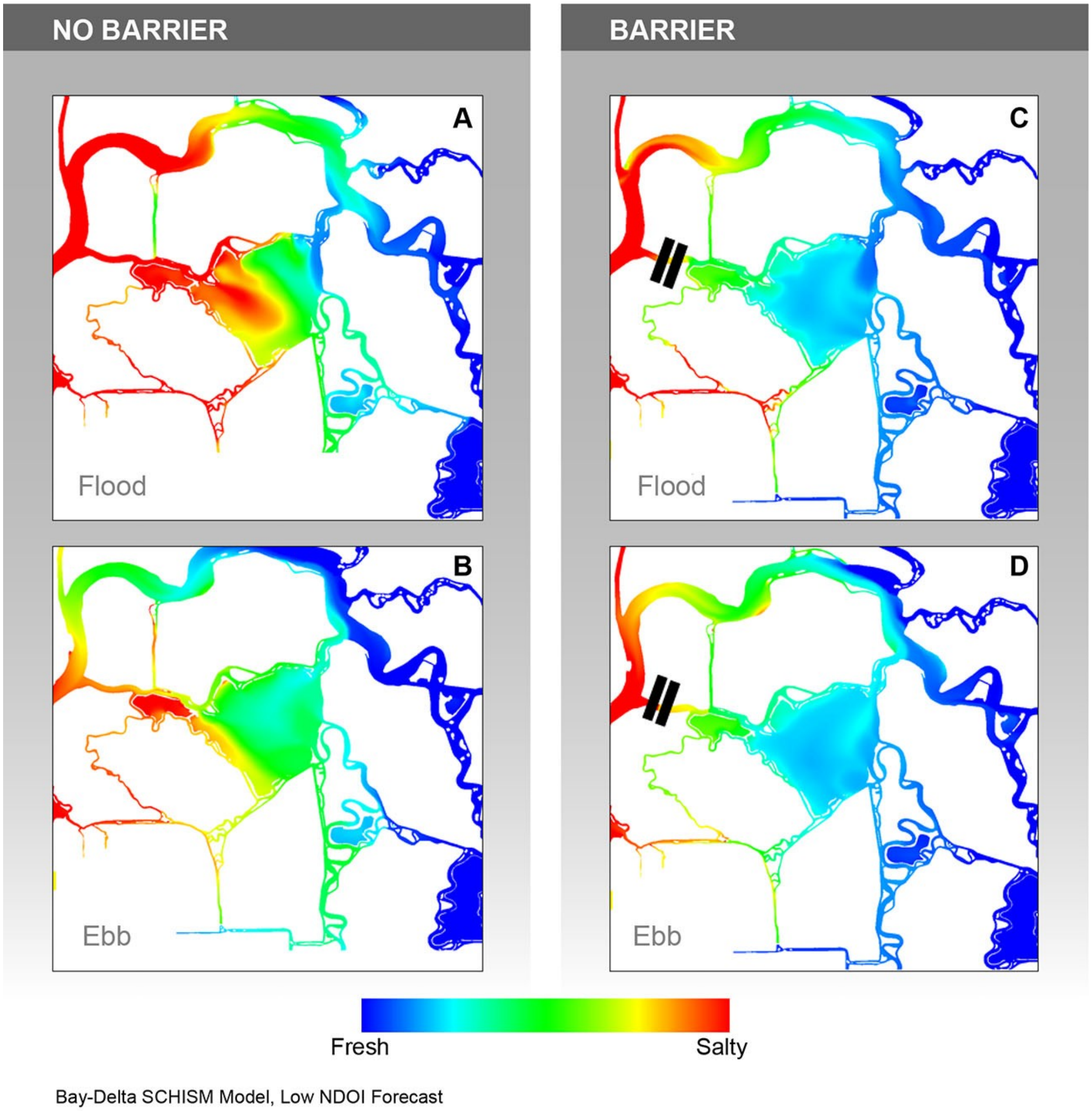
Operational change of the system is a key component of the DCP, which represents the first State drought plan developed following the Governor's executive orders and drought proclamations in 2008 and 2009. It is a planning and implementation document intended to assist agencies in preparing for, responding to, and recovering from drought. The goals of the DCP are to minimize drought impacts through improved agency coordination, enhanced procedures for monitoring drought conditions, and more effective responses to drought emergencies. Improved agency coordination resulted in adjustments to existing regulatory requirements for 2014 and 2015. The State Water Resources Control Board (SWRCB), as jointly requested by DWR and the U.S. Bureau of Reclamation's (Reclamation) Temporary Urgency Change Petition (TUCP), granted adjustments of certain D-1641 water quality objectives since limited water supplies in upstream reservoirs was insufficient to meet all the competing uses of water. The approval of the TUCP allowed for the construction of the EDB to prevent loss of control of the interior Delta salinity.

1.2 How the Emergency Drought Barrier Works

The main purpose of the EDB was to prevent higher-salinity water from reaching the central Delta where water quality is difficult to control. Figure 1-3 is a conceptual illustration of salinity intrusion through Franks Tract and how the EDB disrupted it. The main mechanism transporting salt into Franks Tract is called “tidal pumping,” a characteristic of open waterways fed by small inlets. In Panel A of Figure 1-3 (no barrier during a flood tide), a jet of higher salinity (red) water can be seen entering Franks Tract from False River through an aperture sometimes referred to as “the nozzle.” Water quality in this jet is heavily influenced by the San Joaquin River at Jersey Point. In Panel B of Figure 1-3, the return flow from Franks Tract is fresher (blue) because the salty jet of water will have mixed out somewhat and the ebb flow is drawn radially from a broader area, so it includes more of the ambient water in Franks Tract. Even if the volume of flow is the same in both directions, the asymmetry between a salty flood and a fresher ebb adds up and causes a net transport of salt into the Delta. The transport mechanism is entirely tidal, and the primary role of net flow is in controlling whether salty water reaches Jersey Point.

Panels C and D of Figure 1-3 demonstrate the alternative transport into Franks Tract with the EDB. With the EDB, the importance of False River and “the nozzle” was greatly reduced because the only exchange within False River was leakage through the (finite-height, and somewhat porous) EDB and increased flows through Fisherman’s Cut. With the EDB, the main pathway for tidal flow into the central Delta is through Old River at its mouth on the San Joaquin River just northeast of Franks Tract. Because this location is upstream of False River and more influenced by the Mokelumne River and Delta Cross Channel (DCC), it tends to be lower in salinity than either False River or Franks Tract. Tidal pumping or dispersion may still occur from Old River, but it is smaller and exerts a freshening effect upon the Central Delta. Ultimately with the EDB, Franks Tract remained fresher during both flood and ebb flows.

Figure 1-3 Salinity Near Franks Tract on Flood and Ebb Tide With and Without EDB



1.3 Purpose and Objectives of Efficacy Report

This efficacy report has been prepared to describe the EDB’s observed ability to reduce saltwater intrusion into the central Delta at West False River in the summer of 2015, as well as its effect on local water quality as well as its hydrodynamic and bathymetric effects. Additionally, this report describes mitigation actions and general actions taken to plan, design, construct, and monitor the EDB as well as lessons learned and future planning activities.

2.0 Siting and Planning

2.1 Siting

In 2009, DWR conducted preliminary investigations into the use of rock barriers to help control salinity in the Delta. Candidate sites were drawn from historical drought barrier locations in 1976–1977, previously studied restoration and salinity control proposals, and some new and novel locations and combinations. DWR identified nine waterways (i.e., Sutter Slough, Steamboat Slough, Three Mile Slough, Dutch Slough, West False River, Fisherman's Cut, Old River, Connection Slough, and the San Joaquin River) where barriers might be located, either at single locations or in combinations of multiple barriers (California Department of Water Resources 2009). The investigation considered both rock barriers and barge-mounted operable barriers (i.e., gates). The goal of the investigation was to identify the option that shielded the interior Delta from salinity intrusion, which once established could be difficult to reverse, and maintained the lowest salinity levels at SWP and CVP pumps from July through November. Overall, the investigation concluded that Three Mile Slough and West False River resulted in the most benefit; however, when completing a cost/benefit analysis, Sutter Slough and Steamboat Slough were more favorable.

Based on these screening results, DWR undertook a second-round analysis involving barriers at West False River, Sutter Slough, and Steamboat Slough. DWR did not consider installing a barrier on Three Mile Slough because the investigation assumed a barge-mounted operable barrier, which was infeasible in 2015 because of logistics and cost. A draft initial study/proposed mitigated negative declaration for barriers at West False River, Sutter Slough, and Steamboat Slough was circulated in January 2015. DWR received numerous comments, including those concerned with the potential impairment to agricultural diversion pumps on Sutter Slough and Steamboat Slough. Major concerns over impacts on protected salmon species and Delta smelt raised by U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and California Department of Fish and Wildlife (CDFW) resulted in requests to install the Sutter and Steamboat slough barriers as late as possible and at locations as far upstream as possible to avoid impacts on Delta smelt. Although not analyzed in the initial investigation, DWR also considered installing a barrier at Miner Slough in lieu of a Sutter Slough barrier. In attempts to minimize impacts on protected fish species as well as minimize impacts on agricultural diversions, the

Steamboat Slough Barrier was moved downstream to Ryer Island and the Sutter Slough Barrier was moved to Miner Slough at Prospect Island. After extensive coordination with USFWS and local agricultural diverters, DWR decided to forgo pursuing these northern barriers predominantly because of potential impacts on Delta smelt habitat.

Consequently, DWR selected West False River understanding that a rock barrier there would protect the central and south Delta by blocking flood tides from entering Franks Tract and forcing higher salinity water to travel a longer path that would increase mixing/dilution with freshwater prior to reaching south Delta export facilities.

2.1.1 Historical Installations

Setting a precedent for the 2015 EDB Project, several rock barriers were installed throughout the Delta during 1976 and 1977 to help mitigate drought conditions. In 1976, DWR installed a rock barrier at Sutter Slough to help meet water quality criteria and allow for conserving additional water in upstream reservoirs and Old River (at its divergence from the San Joaquin River, often referred to as the “Head of Old River”) to protect special-status fish by keeping them in the San Joaquin River, thereby reducing entrainment risk at CVP and SWP export facilities in the south Delta. In 1977, as drought conditions continued, rock barriers and control facilities were installed throughout the Delta. DWR installed six rock barriers at Old River east of Clifton Court, San Joaquin River near Mossdale, Rock Slough, Indian Slough, Dutch Slough, and the Head of Old River. The rock barriers served different purposes, such as increasing water circulation and quality, reducing salinity, allowing water users to pump at a constant rate, and protecting special-status fish. DWR also installed control structures in the Suisun Marsh and on Sherman Island. The control structures provided better quality water to produce waterfowl vegetation and farming (California Department of Water Resources 1978).

2.1.2 Modeling

This section describes the modeling methods used to determine the need and best locations for drought barriers. The goal of modeling was to determine if barriers were necessary and estimate the potential effects of various proposed combinations of structural mitigation (barriers) and operational changes (inflows and exports) dealing with salinity, water levels, flows, and velocities. Delta-wide scenario modeling was initially completed in

2014 for the potential drought barriers considered for a 2014 installation, and similar methods were followed in 2015 using updated 2015 operational forecast flows as input. More detailed information on the 2014 modeling methods can be found in the *Annual Report to the State Water Resources Control Board*, 2014, Chapter 6 (Smith 2014).

The processes used to determine the location and effects of the drought barrier included the following:

- Simulating the current-year-forecasted Delta hydrology to estimate the potential of salinity intrusion into the Delta.
- Reviewing the water quality effects of previously installed barriers and modeling studies for drought years.
- Simulating the current year forecasted Delta hydrology with a barrier or barriers was a way to estimate the effects of drought barriers and compare to previous studies.
- Modifying flows and exports timing in the current-year-forecasted Delta hydrology.
- Evaluating water level, flow, and velocity effects from Delta modeling studies for conditions with and without drought barriers.
- Evaluating the water costs associated with the barrier(s) and changes in the SWRCB D-1641 water quality objectives.

2014 and 2015 Modeling Processes

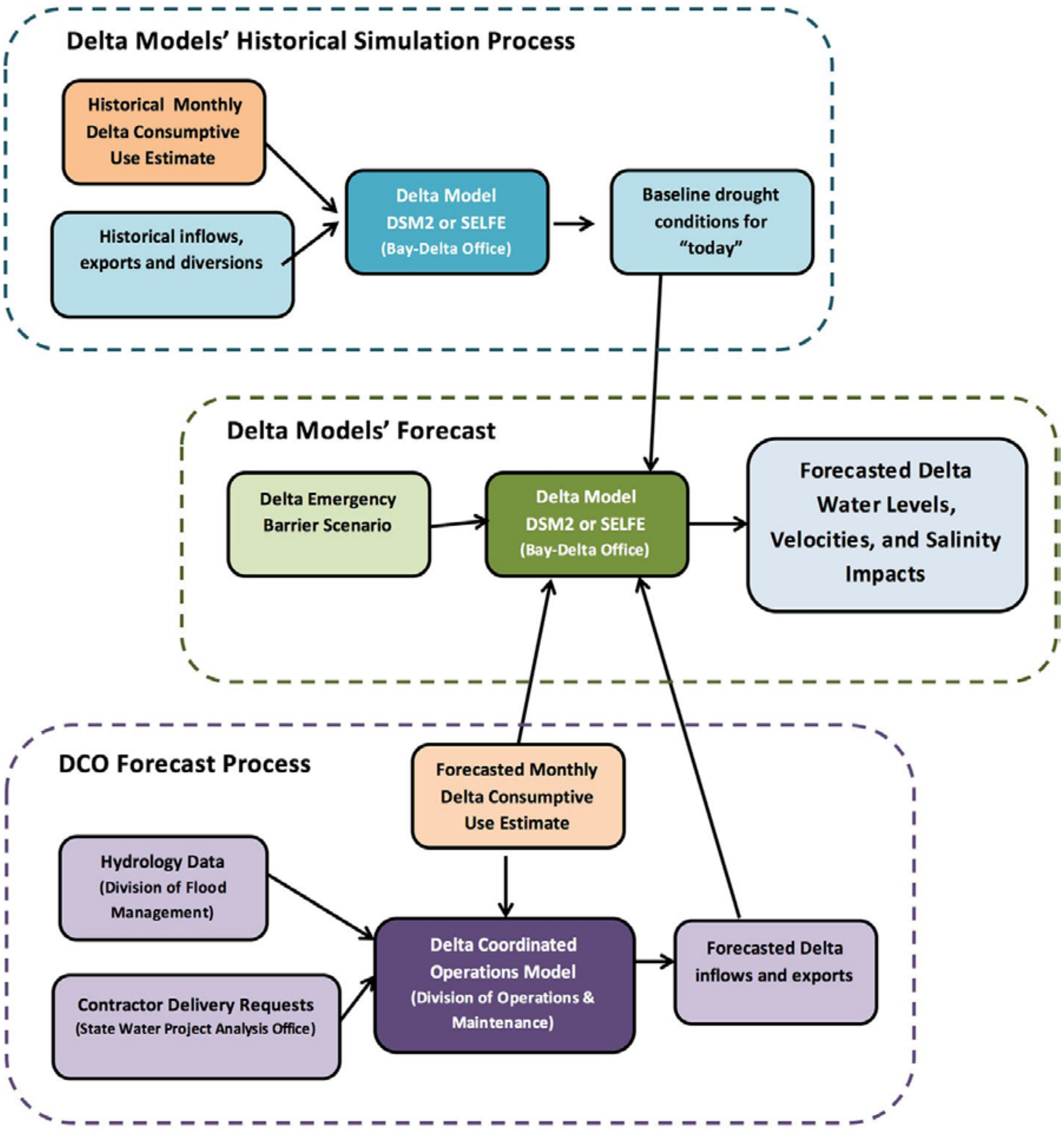
Prior to discussing the historical hydrologic conditions when barriers were installed and the previous studies investigating the effects of barriers, the next section discusses the modeling approach used to determine the need for barriers in 2014 and 2015. The difference between the modeling in 2014 and 2015 was primarily the use of new forecasts for 2015 that provided flow and export values that were then input to the Delta Simulation Model 2 (DSM2). The forecasts take into consideration the current reservoir levels, recent precipitation, water demands, and regulatory requirements. These hydrologic conditions were different between 2014 and 2015. Additionally, any changes in the location of barriers as discussed between DWR and the fishery agencies were also modeled in 2015. The following sections describe the modeling process in more detail. These sections describe all the models and data used in the process. They also include a review of the administrative draft of *Delta Drought Emergency Barriers* (California

Department of Water Resources 2009) and reanalyzes the effectiveness of barriers given the 2014 hydrology and later the 2015 forecasted hydrology.

Data Analysis and Forecast Modeling Processes to Determine Potential Salinity Impacts

Historical data observations and computer modeling of forecasted conditions were utilized in analyzing potential salinity intrusion into the Delta during a drought. The data and existing models used for the forecast modeling process are illustrated in Figure 2-1.

Figure 2-1 Data and Existing Models Used in Delta Models' Forecast Modeling Process



The Delta models that were used in this analysis were DSM2 and the Bay-Delta semi-implicit Eulerian-Lagrangian finite element (SELFE) model (Ateljevich 2014), which was later modified and renamed Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM). DSM2 is a one dimensional, physically based model that assumes flows are moving either upstream or downstream in a channel. In SCHISM, the direction and magnitude of flow can change across the channel or down the water column. DSM2 runs much faster and requires less input data than SELFE/SCHISM; however, SELFE/SCHISM has greater resolution.

DWR decided to use forecasted flow conditions under a dry (90 percent and sometimes 99 percent exceedance) hydrology to get a better understanding of what can be expected under a worst-case scenario. DWR then compared the modeling results to the salinity intrusion that occurred in the extremely dry years between 1921–2012. Historical data was supplemented with DSM2 simulation data for the historical period.

DWR also focused on in-Delta diversions and returns. These values are calculated using the Delta Island Consumptive Use (DICU) Model. There has not been a good way to validate these values Delta-wide, and in a dry year the quantities of water involved are commensurate with total outflow. Consequently, a relatively small difference in these consumptive use estimates in a dry year can have significant impacts on salinity intrusion.

DWR also ran studies to evaluate the operation of the Delta Cross Channel (DCC) and compare impacts on water quality with and without the barrier(s).

Forecasted Inflows, Diversions, Agricultural Net Channel Depletions and Exports

To model the Delta flows, water levels, and salinity, Delta models such as DSM2 and SCHISM need data such as boundary inflows, exports, diversions, agricultural diversions and returns, water levels, and salinity. For inflows-to and exports-from the Delta, the models use forecasted flows extracted from the Delta Coordinated Operations (DCO) studies that DWR's Division of Operation and Maintenance conducts to determine SWP allocations (Figure 2-1). DCO studies incorporate hydrology data (developed by the Flood Management Division), contractor delivery requests (compiled by State Water Project Analysis Office), and regulatory and court restrictions on exports. The primary DCO allocation forecasts that were used for the 2014 and 2015 analyses assumed a 90 percent hydrology. A 90 percent hydrology is one that, based on historical statistics, assumes only one in 10 years would be drier than the 2014 and 2015 forecast (99 percent forecasted hydrologies were also evaluated for some months). The models also use observed historical data up until the forecast period begins.

DCO forecasts are completed monthly, and DSM2 simulations were run each month starting in February. In February of both 2014 and 2015, 90 percent of the forecasts indicated that there would not be enough water supply to meet D-1641 Delta objectives through the summer. In 2014, DSM2 simulations were made until it was decided not to install any drought barriers because of the precipitation that occurred throughout the spring. In 2015, forecasts continued through the summer after the False River barrier was installed. In both years, DWR and Reclamation submitted a TUCP requesting a relaxation of certain D-1641 objectives to the SWRCB. In both years, the SWRCB agreed to the requests in the petition.

In 2014, the first DSM2 forecasts, using the early February DCO forecast, showed that DSM2 was underestimating the historical salinity at D-1641 water quality objective locations in the Delta. One of the potential errors in input was determined to be consumptive use during February, which is typically estimated to be very small, assuming recent precipitation (Mahadevan 1995). But, since the winter of 2013–2014 was very dry, the consumptive use values were adjusted to reflect a higher consumptive use.

Review of Documents on Salinity Impacts of Barriers in Droughts

To investigate potential sites for barriers, historical drought barrier installations were examined and the results from other studies investigating the placement of barriers to improve water quality in the Central Delta were reviewed. The report that provided the most useful information was the *Draft Delta Drought Emergency Barrier Report* (California Department of Water Resources 2009). In that report, several alternatives for barrier installation effects on salinity at the Harvey O. Banks Pumping Plant (Banks Pumping Plant) were investigated. The Banks Pumping Plant is in the southern Delta and provides an indication of how far salinity intrudes from the ocean. Phase I was the identification of alternatives in which a list of barrier salinity impacts was evaluated. These locations are shown by the red rectangles in Figure 2-2. These locations were evaluated individually and in various combinations in the Phase 1 analysis. The effectiveness of the alternatives was measured by looking at the percentage reduction in specific conductance (EC) at SWP and CVP export locations between each barrier alternative and the base condition (no project). The analysis was conducted for the July through November period using 2001 and 2002 hydrology (dry years) and using DSM2 for the modeling analysis. If the reduction in EC was less than 5 percent, it was not included in the Phase 2 analysis. The black Xs indicate the barrier locations that did not provide a 5 percent or better reduction. Details of the Phase 1 analysis can be found in the *Draft Delta Drought Emergency Barrier Report* (California Department of Water Resources 2009).

Figure 2-2 Barrier Locations Considered in Phase 1 Analysis, 2009 Emergency Barriers Report

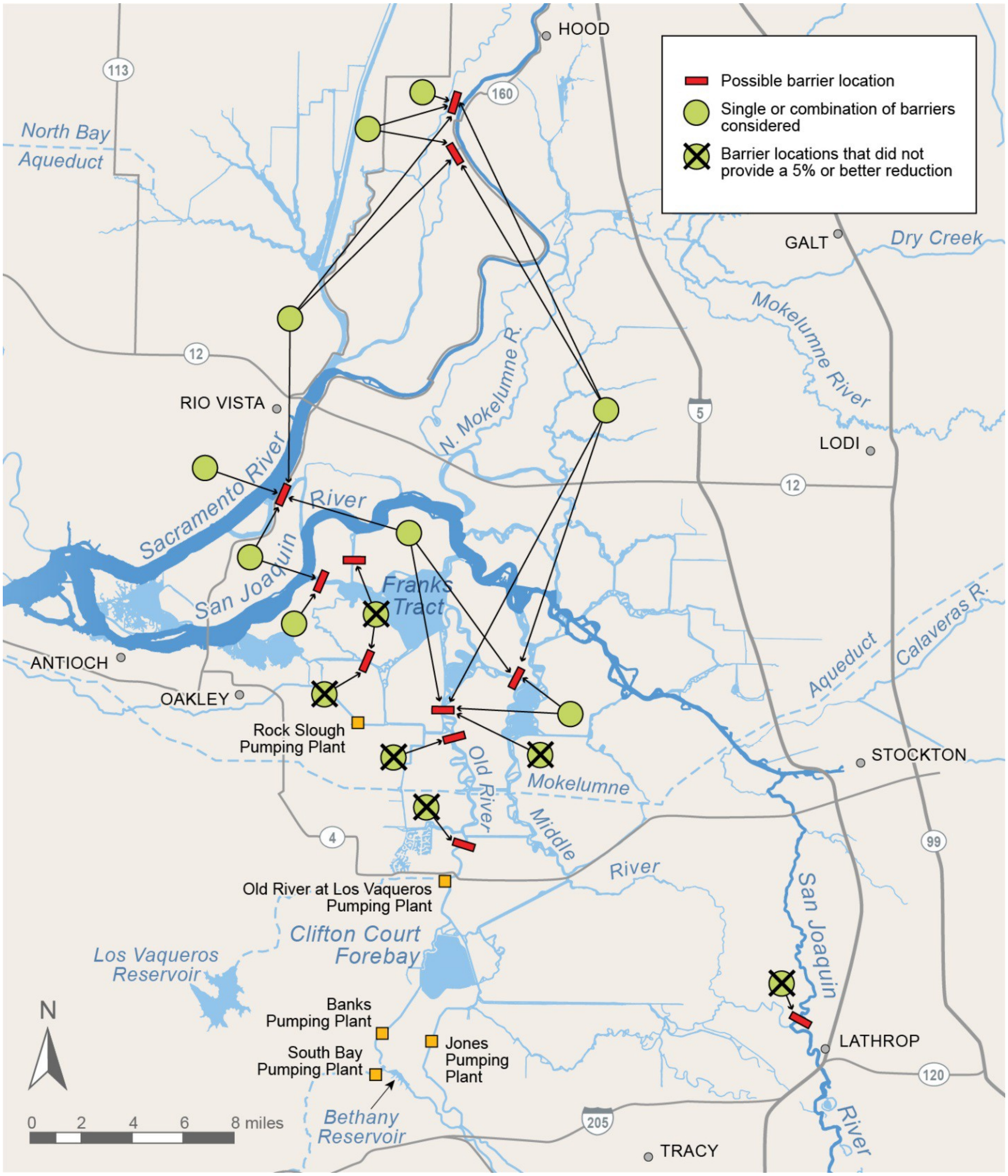


Figure 2-3 Location of Barriers in Phase 2 Analysis, 2009 Emergency Barriers Report

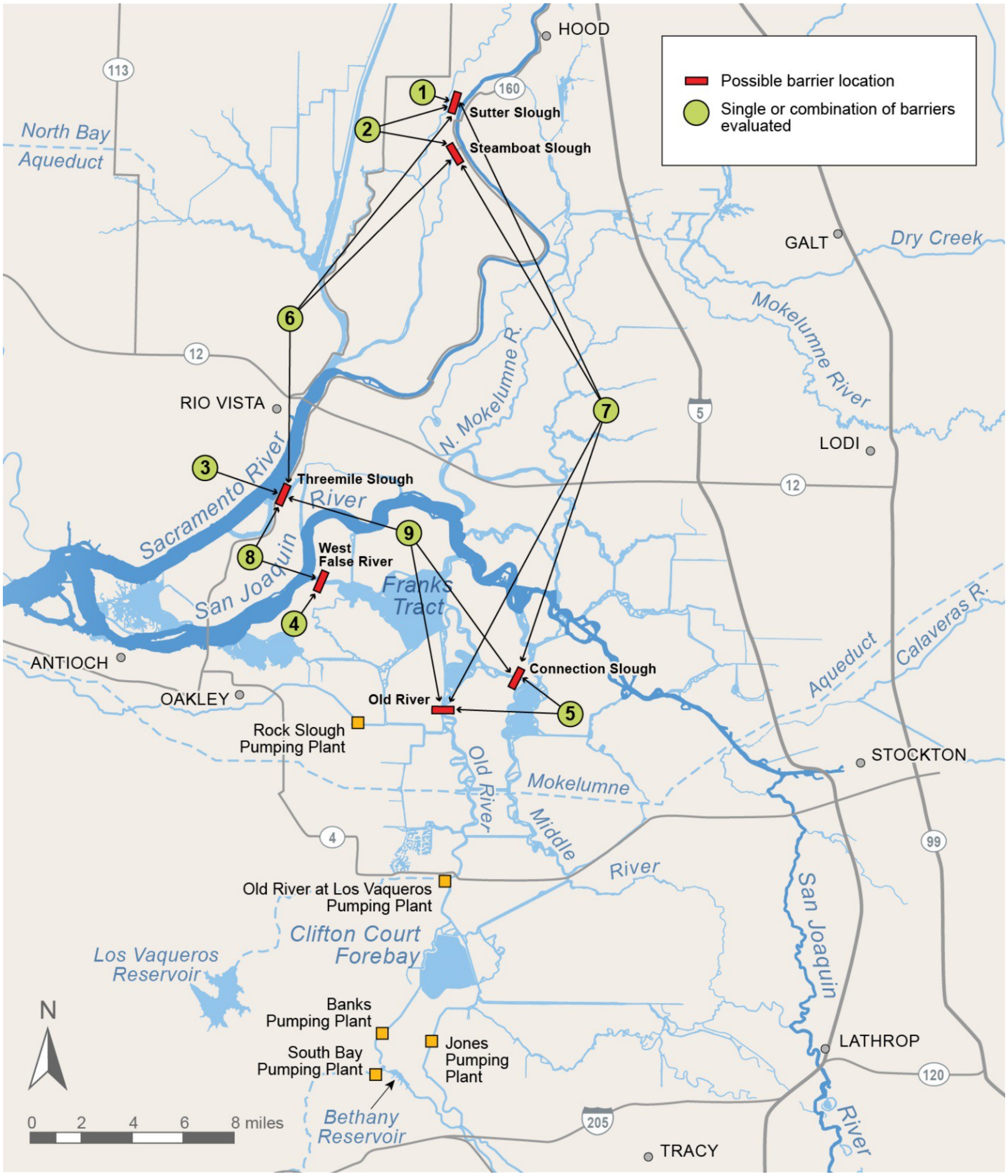


Figure 2-3 shows the barrier locations for the Phase 2 analysis. The Phase 2 alternatives were modeled and analyzed using DSM2 for the July through November historical period of the three years, 2007 through 2009. Table 2-1 summarizes the calculated EC reductions at Banks Pumping Plant from the three modeled periods and summarizes the alternative locations and types of barriers considered in the Phase 2 analysis.

Table 2-1 Phase 2 Analysis Barrier Locations and EC Reduction at Banks Pumping Plant

No.	Location(s)	Phase II EC Reduction in 2007, 2008, and 2009 at Banks Pumping Plant	Barrier Type(s) Considered
1	Sutter Slough	15%, 7%, and 3%	Rock and Barge-Mounted Operable Barriers
2	Sutter and Steamboat Sloughs	28%, 13%, and 7%	Rock and Barge-Mounted Operable Barriers
3	Three Mile Slough	26%, 6%, and 2%	Barge-Mounted Operable Barrier
4	West False River	11%, 12%, and 20%	Rock and Barge-Mounted Operable Barriers
5	2-Gate (Old River and Connection Slough)	10%, 12%, and 20%	Rock and Barge-Mounted Operable Barriers
6	Sutter Slough, Steamboat Slough and West False River	37%, 23%, and 28%	Rock and Barge-Mounted Operable Barriers
7	Sutter Slough, Steamboat Slough and 2-Gate	39%, 25%, and 29%	Rock and Barge-Mounted Operable Barriers
8	Three Mile Slough and West False River	33%, 16%, and 21%	Barge-Mounted Operable Barrier
9	Three Mile Slough and 2-Gate	32%, 16%, and 22%	Barge-Mounted Operable Barrier

Checking if DSM2 2014 and 2015 Forecast Results Matched Conclusions of 2009 Emergency Barriers Report

Using an early 2014 forecast, DSM2 was run for each of the barrier locations shown in Figure 2-3. The Three Mile Slough barrier and any combination of barriers with Three Mile Slough were dropped as an option because that barrier/gate must be operable to be effective, and this was not feasible because of the short time constraints for design and construction. Consequently, the barrier locations evaluated were Sutter Slough, Steamboat Slough, False River, and Two Gate (Connection Slough and Old River).

Reductions in salinity for the combinations of Sutter, Steamboat, and Two Gate versus Sutter, Steamboat, and False River were very similar, with the former combination resulting is slightly better EC. Nevertheless, the Two Gate configuration was dropped in favor of the Sutter, Steamboat, and False River configuration because of logistical and cost considerations. Forecasted simulations were again run in 2015 to verify the salinity improvement of the selected barrier sites at the export locations.

The simulations indicated that there would be degradation in EC along the Sacramento River at Emmaton and Rio Vista, primarily because of the Sutter and Steamboat Slough barriers. For the early February 90 percent hydrology 2014 forecast, including all three barriers in the late summer, salinity was reduced by approximately 40 percent. With only the False River Barrier, salinity was reduced by approximately 20 percent. These percentages will vary slightly and are dependent on the hydrology and when the barrier(s) were installed.

Evolving Objectives for Studies in 2014 Analysis used to Inform 2015 Modeling and Operations

Early on, the goal for the barrier(s) was to reduce the EC in the Delta so that most of the D-1641 water quality objectives could be met, given that a limited amount of water was available for release to help prevent salinity intrusion. Early forecasts, through the late February forecast, indicated that if the reservoirs were operated so that all water quality objectives were met, then by midsummer there would not be enough water to release to prevent salinity from intruding, resulting in large increases in EC throughout most of the Delta. The barrier(s) would reduce the salinity from intruding into the central Delta.

The 2014 simulations also modeled different barrier installation times. The simulated installation of the barrier(s) earlier in the spring minimized salinity intrusion into the Central Delta. Yet, other concerns, such as the barrier(s) impact on salmon runs and Delta smelt spawning areas, were considered along with the salinity benefits.

Forecasts from later in 2014 that included historical precipitation prior to late March indicated enough reservoir storage to meet the interior Delta 1,000 EC or 250 chloride objectives through August. The available storage in Oroville, Shasta, and Folsom reservoirs closely approached power pool levels in the late March forecast (DWR could not release water below the power pool).

After the late March 2014 forecast, the goal for modeling the barrier(s) was to estimate if the reservoirs could release less water and still meet most of the water quality objectives. This saved water could be released later in the year or in the following year if dry conditions persisted. Additional model simulations were performed to determine the water cost or savings.

These 2014 analyses provided additional insight for operations in 2015. The 2014 studies evaluated options for how to operate the system, and those options were considered in 2015.

Discussion of Differences in Salinity Results between Different Delta Models

In 2014, large differences in salinity results occurred between different Delta models, notably the Historic Preservation Act (RMA) Bay-Delta Model, SELFE, and DSM2. The multi-dimensional models that use a salinity boundary condition at or west of the Golden Gate Bridge, the RMA Bay-Delta model and SELFE, showed a much greater salinity intrusion into the Delta. At the time, these differences were a source of frustration and concern but have since resulted in improvements in boundary conditions and a better understanding of the Delta. After investigating the differences, the following conclusions were reached:

- DSM2 uses a modified empirical model of Delta salinity (G-model) to calculate the Martinez EC boundary condition for DSM2. That model had an EC maximum that could not be exceeded even when the NDOI went very negative. The modified G-model was corrected.
- Although DSM2's Martinez boundary condition using the modified G-model did not reflect an extreme negative NDOI, the EC boundary

condition fell within historical EC conditions, including 1931, when inflow into the Delta was zero or close to zero. This indicated that the extreme salinity intrusion that the other two models showed might also be in question.

- One theory developed as part of the historical investigation is that the NDOI — which is a flow balance (inflows minus exports/diversions) — may achieve some negative equilibrium value when the Delta is stressed. Beginning with western Delta farmers, farmers diverting water may not divert as much water, as the salinity levels may be too harmful for the crops to use. By not diverting water, the NDOI becomes less negative, supporting the theory of a maximum negative equilibrium NDOI. Some historical documentation (the 1931 supervisors' report) indicates a reduction in diversions in the Delta, which supports this theory.
- Delta models are calibrated and validated using data from various hydrologic time periods. Since recent years were critically dry, moreso than the last 30 years, all Delta models were stretched beyond their calibrations and validations. Although the models were being stretched to simulate conditions beyond what has been historically modeled in the last thirty years, this investigation had to do more with the input data than the capability of the models themselves.
- As the forecasts continued, the modeling results were interpreted with this information in mind.

Water Cost Analysis

To determine how much water conservation can be attributed to adjusted water quality objectives and the decision to install one or more salinity barriers, DSM2 was run in an iterative process using a modified Minimum-Water-Cost-Compliance-Problem Tool (Ateljevich 2002).

In 2014, the late March forecast demonstrated that there would likely be enough storage water to meet health and safety exports and keep salinity from intruding. Further studies determined that the barrier(s) could help in saving reservoir storage water for carryover storage, additional exports, or for environmental releases. In 2015, water cost analysis studies were performed to know what the water savings would be if the Emmaton objective were relaxed to Three Mile Slough standards (with and without the barrier[s]). Because of the drought situation, water cost analyses were undertaken to look at relaxation of water quality objectives further into the Delta, including only meeting the water quality objectives of 1,000 EC at the project intake locations. This was done to evaluate the balance of upstream water needs against Delta water needs in addition to seeing possible effects of salinity intrusion. In addition to upstream diversions, cold water storage needs for salmon were considered. For the Delta, one of the other considerations was the location of the point identified by its distance from the Golden Gate Bridge where salinity at the river's bottom is about 2 parts per thousand (X2).

The water cost analysis suggested that the adjustment of the objectives provided water savings. The installation of the EDB improved water quality in the central Delta, which also reduces the risk of violating the relaxed standards. More casual retrospective calculations of water cost using SCHISM supported this conclusion.

2015 Forecasts

In 2015, the forecasts were also made monthly. Late 2013 was dry, but precipitation did occur late in January 2014 and continued through the spring, eliminating the need for a 2014 emergency installation. A series of storms from late November through mid-December 2014 brought the season’s first precipitation, and this was followed by a long period with very little precipitation until mid-February when again there was a brief series of storms bringing precipitation to Northern California. The remainder of the 2015 water year through October 1 produced very little precipitation. Although there were differences in the precipitation patterns between years, forecasts in 2015 showed similar salinity effects as those in 2014 because of the Sutter Slough, Steamboat Slough, and False River modeled barriers. Modeling forecasts also included variations such as moving the Sutter Slough and Steamboat Slough barriers downstream closer to Rio Vista to avoid impacts on water levels. The northern Delta barriers were eventually eliminated from consideration because of forecasted model results; the balance of upstream, Delta, and other stakeholder water needs; and concerns for listed and endangered species, among other non-modeling factors.

Stakeholders Coordination

Because of the number of stakeholders affected and the need to quickly analyze and distribute the results, tools were developed or modified to streamline the process. These tools include spatial salinity comparison plots; an interactive excel spreadsheet to graph flows, water levels, and velocities at many locations in the Delta; and spatial velocity plots to show potential velocity hot spots.

2.2 Planning

Planning for the 2015 EDB Project included public outreach, real estate coordination, and State and federal agency coordination. The sections below present a summary for each of these efforts.

2.2.1 Public Outreach

The Media and Public Information Branch of the Public Affairs Office (PAO) within DWR was tasked with disseminating information on the 2015 EDB Project to interested parties, including the news media, the public at large, and individual members of the public with a specific need-to-know.

PAO's involvement began during the planning phase of the 2014 EDB, which was eventually cancelled. PAO representatives attended numerous internal meetings in March and April 2014 to understand the issues that then carried over to the 2015 EDB Project.

A continuing objective of the 2014 and 2015 outreach efforts was to ensure that the public had opportunities to read, hear, and learn about the project and to offer feedback. Meetings were conducted to brief the public during the first quarter of 2014, and PAO representatives were in attendance when senior DWR personnel explained the necessity to install the barrier. As an example, DWR met with the public at the Bethel Island Municipal Improvement District on March 20, 2014, to discuss recreational boating and fishing. Numerous questions were raised and answered, and the meeting ended cordially in apparent appreciation of DWR's briefing.

Another 2014 public meeting involving DWR participation was held on March 18 at the Walnut Grove Community Church, hosted by local agencies of the north Delta and the North Delta Water Agency. In conjunction with this public outreach, PAO developed project Talking Points, Frequently Asked Questions (FAQs), and the Emergency Drought Barrier page.

DWR continued to assess water conditions in the Sierra Nevada Mountains, SWP reservoirs, and the Delta, and determined that rain and snow from

February and March storms made it unnecessary to construct a drought barrier in 2014, as announced in its April 18 press release. The release noted that DWR would continue to closely monitor water quality and storage capacity data in case barriers were needed later in the year to protect vital water supplies. By November, the project's FAQs had been revised with the conclusion that "…water quality in the Delta can be maintained without the barriers this year." Nevertheless, planning and permitting continued for their possible installation.

On January 26, 2015, PAO issued a press release alerting the public to the possible need for "Delta Salinity Control Barriers" considering the meager precipitation being recorded during the crucial winter months of WY 2015. The release noted that "…the three-year period from 2012 through 2014 has been the driest three-year period on record in California."

DWR issued the *Emergency Drought Barriers Planning Update* in February 2015, which described the agency's analysis of the need for the temporary barriers and discussed DWR's application to the U.S. Army Corps of Engineers (USACE) for a programmatic permit "…to allow the installation of temporary rock barriers for no more than eight months in a single year…" in the Delta.

Water conditions continued to degrade well into 2015, and on April 1 the snow water equivalent in the Sierra Nevada was only 5 percent of normal for that date, the lowest April 1 measurement in DWR's records. Two weeks later, on April 15, PAO issued a press release noting that potentially insufficient water supplies to repel salinity in the Delta had convinced State and federal agencies that a single temporary drought barrier (later referred to as the EDB) was required on West False River.

PAO and DWR's Bay Delta Office worked collaboratively during the preparation for the barrier's construction, which was of great interest to the public and news media. PAO began a series of internal planning meetings to assign responsibilities to the appropriate assets. Personnel representing every PAO discipline attended these sessions — media relations, still and video photography, graphics support, and logistics. Twenty or more individuals attended each meeting, thereby ensuring that all aspects of the planned media visits to the construction site had been thoroughly vetted and that all personnel were aware of the plan. DWR contacted Delta marinas to inform them and their boating customers of the plan to build an EDB. Alternate routes for boaters who normally use West False River were posted at DWR's website, along with a map of the barrier's location and the detours.

On May 7, 2015, PAO issued a media advisory that construction of the EDB would begin the next day. The advisory contained detailed instructions and a map showing the route that media should follow when driving to the construction zone on the north end of Jersey Island. The FAQ document on the 2015 EDB Project was also included in the advisory.

On May 8, 2015, PAO's Media and Public Information Branch members were stationed at the media assembly point on Jersey Island and further west along the levee at the construction site, approximately 0.4 miles east of the West False River confluence with the San Joaquin River. Owing to safety concerns, media vehicles were convoyed in a group to a parking area near the construction site, where DWR's Deputy Director for Statewide Emergency Preparedness and Security and the Chief of the Bay Delta Office briefed the media on the emergency drought barrier's construction, which began while the media were still at the scene. Television and radio stations and newspapers provided prominent coverage of the event, and PAO's video unit posted footage of the event on its YouTube channel. PAO issued a construction-related press release.

On May 20, 2015, DWR issued a notice to the public reminding boaters to take detours around the barrier. On May 28, 2015, DWR issued a media advisory inviting "credentialed media representatives only" to an event the next day at the construction site. On May 29, 2015, PAO hosted a second media visit to the West False River site and issued a press release on the conclusion of the barrier's construction.

The barrier's construction in West False River altered water flows through Fisherman's Cut, which in turn caused navigational difficulties for the Victory II, a ferry providing transportation to Jersey Island, Bradford Island, and Webb Tract. The Media and Public Information Branch coordinated with the Bay Delta Office in crafting responses to media inquiries, noting that DWR was working closely with the Delta Ferry Authority (DFA) to ensure that ferry operations would continue successfully for the duration of the barrier's operation. Additionally, the construction contractor was using one of its vessels to assist the ferry during docking when needed. Media inquiries about ferry operations continued during the summer, but the frequency of such queries diminished toward the end of the year.

Work to remove the barrier began in early September, and PAO’s Media and Public Information Branch revised the project’s FAQs in October to include information about the schedule for complete removal by mid-November, as previously announced. The updated FAQs noted that, as DWR’s modeling had predicted, the barrier helped improve water quality in the central and south Delta. Improved water quality enabled continued use of Delta waters for in-Delta agriculture, municipal and industrial uses, and minimal exports by the SWP and CVP.

On September 29, 2015, DWR’s media advisory informed the media that a site visit and orientation on the removal process for the drought barrier would occur on October 1, featuring the two DWR managers who had briefed the media in May. A map with directions and FAQs were included with the advisory. An October 1 press release covered the removal effort, which had already begun, and noted that permits issued to DWR for installation of the barrier required removal in November because of potential impacts to native fish and potential flood concerns. DWR’s press release reported on progress in removing the barrier.

On November 16, 2015, DWR issued a final press release which included an assessment of the 2015 EDB Project’s results by the Chief of the Bay Delta Office. The release stated, “The barrier worked by preventing salinity to reach the central Delta. We were able to save about 90,000 acre-feet in upstream reservoirs for the last quarter of 2015 and for fish releases.”

2.2.2 Real Estate

Early site selection and communication with the property owners and public were critical to the success of the 2015 EDB Project. The DWR Real Estate Branch (REB) knew early on that site selection would be paramount in their attempt to try to build a trusting working relationship with the Delta landowners. DWR REB set its focus in the beginning stages of the project on the West False River location. It was fortunate that preliminary planning had occurred in 2014 for the West False River site (and two proposed barriers farther north in the Delta on Steamboat Slough and Sutter Slough). Without early site identification, many of the key components required in real property acquisition could have been hindered.

Efficiencies were realized on the West False River barrier by choosing a location where permission from both the landowner and the local maintaining agency (usually a reclamation district [RD] with jurisdiction over the levees) could be negotiated simultaneously. The barrier site for West False River was partially chosen because the site landowners and the reclamation district were the same. RD 2059 was both the owner and the local maintaining agency. On the southern, Jersey Island side of West False River, the landowner is Ironhouse Sanitary District (ISD) and the local maintaining agency is Reclamation District 830. Both boards of trustees for ISD and RD 830 include many of the same people, thus making negotiations much more efficient.

Obtaining Temporary Entry Permits (TEPs) for pre-construction surveys and studies was a challenge because of the controversial nature of the project. Nevertheless, one TEP was obtained as DWR REB was successful in locating a willing landowner on Bradford Island who allowed the Division of Engineering's Geodetic Branch surveyors to access property parcels on the northern part of the island to locate monuments necessary to develop the legal description for the easement. This proved to be vitally important because it allowed the acquisition process to move forward and gave the acquisition agent the necessary information (easement deed) required to subsequently make a formal first written offer to Reclamation District 2059 in the months to come. A "first written offer" is the initial step in the DWR process to purchase property rights.

On April 25, 2014, the governor issued a "Proclamation of a Continued State of Emergency," thereby enabling State officials to take all necessary actions to prepare for drought conditions. This proclamation was the impetus that allowed DWR to obtain permits and agreements in a condensed timeframe. This proclamation also created a sense of urgency with the public and in particular, the local ranchers that were impacted by the installation of the barriers.

DWR REB was ultimately able to secure the necessary right of way from the RD as well as the adjoining property owners. To certify right of way, DWR REB had obtained the following permissions prior to the 2015 EDB installation at West False River:

1. Reclamation District 2059 Perpetual Permanent Easement and Agreement.

2. Reclamation District 2059 Encroachment Permit.
    A. In the agreement, permission was granted by RD 2059 to DWR to install barriers up to three times over a 10-year period between February 2015 and December 31, 2024, including the installation of a permanent sheet-pile structure.
3. Iron House Sanitation District Lease.
    B. This lease allows for the construction of a rock barrier and the installation of the king and sheet piles up to once each calendar year from 2015 to 2024, across West False River between the Bradford Island Levee on the north and the Jersey Island Levee to the south.
4. Reclamation District 830 Encroachment Permit.
5. DFA coordination for construction Contractor since construction of the EDB blocked boat passage on West False River.
    C. Boating detour routes around the EDB with approximate travel times had to be identified.

During the installation of the 2015 EDB at West False River, it was discovered that because of the installation of the barrier, water flow velocities near the barrier had decreased while flow velocities increased in other areas of the Delta. Because of the increased velocities, negative impacts on the ferry service that serves Bradford Island and Webb Tract in West False River were observed.

These impacts were not identified in pre-project planning. As a result, DWR began negotiating with the ferry service operator, the DFA, and entered into a “Right of Way Agreement for Damages to Ferry and Reimbursement of Expenses” (Damage Agreement). On June 16, 2015, the Damage Agreement was signed and executed. Upon final execution of the Damage Agreement, the DFA would submit claims, justifications, estimates and invoices to DWR for review and approval. As a result, DWR reimbursed the DFA for impacts and costs associated with the Victory II ferry. Additional DFA mitigation, outside of the real estate scope, is discussed in the Delta Ferry Authority Mitigation sub-section of Section 3.3.5.

Additionally, as the installation progressed, DWR determined that a local landowner, Smith Cunningham on Bradford Island, was being negatively impacted by the 2015 EDB Project, and a separate damage agreement was pursued. On May 5, 2015, this new damage agreement was signed and executed. Smith Cunningham, under his personal damage agreement, could submit claims, justifications, estimates, and invoices to DWR for review and approval. As a result, DWR reimbursed Smith Cunningham for his additional costs associated with the installation of the 2015 EDB project resulting from temporarily closing the most convenient access route off the island during sheet pile installation. Under DWR's Encroachment and Agreement with RD 2059, Paragraph 6 states, "No interference with access. Permittee's activities shall not interfere with access along the levee crown road." The decision to reimburse the landowner was made in part because of the time cost of shutting down construction for several days to allow unimpeded access and the high cost of the resultant delays.

During the monitoring phase of the 2015 EDB Project, DWR REB observed cracking in the levee on Bradford Island after the installation of the West False River rock barrier and sheet pile. This led DWR REB, along with DOE Design and the Bay Delta Office (BDO), to conduct a site visit with the RD Superintendent (also Smith Cunningham) during which it was determined that the cracking was not related to the 2015 EDB Project.

Ground squirrel sightings were also reported by Bradford Island residents, which prior to construction of the rock barrier, were reportedly only seen on Jersey Island. DWR REB conducted a site visit and no squirrels were observed. In June 2015, DWR contracted with the University of California, Davis to investigate ground squirrel sightings. The investigation concluded with a report entitled *California Ground Squirrels on Bradford: Possible Causes and Solutions*, stating that "the likelihood of a California Ground Squirrel colonizing Bradford Island by walking, swimming, or hitchhiking is low; hence the one squirrel observed is probably a solitary squirrel." Nevertheless, as a precaution, DWR installed barrier fencing to deter squirrels from using the EDB to access Bradford Island, including bait stations on the Bradford Island side of the barrier to deter any determined squirrels that made the crossing.

During the planning, permitting, installation, monitoring, and removal of the rock barrier and sheet piles for the 2015 EDB Project, DWR REB followed all applicable laws, regulations, and administrative procedures to effectively and efficiently manage all real estate transaction requirements while developing good working relationships with the landowner and RD stakeholders.

2.2.3 Agency Coordination and Permitting

Beginning in March 2014, DWR hosted agency coordination meetings with State and federal agencies, including USACE, SWRCB, USFWS, NMFS, Central Valley Flood Protection Board (CVFPB), and CDFW. These meetings specifically addressed the installation of drought salinity barrier(s) as well as the use of emergency procedures, the documentation necessary for issuing environmental permits, and compensatory mitigation. Initially held weekly, these meetings were suspended when the installation of a 2014 barrier was cancelled early in the summer of 2014. The meetings were then reestablished in early 2015 when installation of the 2015 barrier became imminent. The meetings were held on an as-needed basis and continued throughout the 2015 EDB installation and removal processes.

Apart from the agency coordination meetings, DWR also helped form the Real-Time Drought Operations Management Team (RTDOT). The RTDOT, consisting of DWR, Reclamation, SWRCB, CDFW, USFWS, and NMFS executive managers, held meetings throughout 2014 and 2015. One primary concern of the RTDOT regarding the installation of a drought salinity barrier was to ensure that enough water could be directed to communities served by the SWP and CVP for essential public health and safety purposes. The RTDOT also collectively worked to ensure that water management decisions did not unreasonably affect threatened and endangered species.

Federal Permits

Federal permits for the 2015 EDB project are summarized in Table 2-2.

Table 2-2 Federal Permits for the 2015 Emergency Drought Barrier Project

Agency	Regulation(s)	Permit No.	Notes
U.S. Army Corps of Engineers (USACE)	Clean Water Act (CWA) Section 404 and Rivers and Harbors Act Section 10	SPK-2014-00187	Although USACE authorized the 2015 Emergency Drought Barrier (EDB) Project under Emergency Procedures, an Individual Permit was not issued.
National Marine Fisheries Service	Endangered Species Act (ESA) Section 7 Formal Consultation	—	NMFS issued conservation recommendations to USACE.

Agency	Regulation(s)	Permit No.	Notes
U.S. Fish and Wildlife Service (USFWS)	ESA Section 7 Formal Consultation	08FBDT00-2015-FE-0038	In addition to the BO, USFWS issued conservation recommendations to USACE.
State Historic Preservation Officer (SHPO)	National Historic Preservation Act (NHPA) Section106	—	USACE reviewed the Section 106 report provided as well as their own information to allow the project to move forward under the emergency authorization without a SHPO “No Effects” Determination.

From early 2014 to early 2015, DWR proposed to install three rock barriers and convened numerous meetings and conference calls with the USFWS, NMFS, CDFW, SWRCB, and the USACE. Numerous iterations of biological assessments (BAs) were provided, and Endangered Species Act (ESA) Section 7 consultation was initiated by the USACE for the 2014 barriers then withdrawn at the request of DWR when the barriers were not needed. After determining that a 2014 installation was not needed, DWR proposed a potential 10-year programmatic permit and consultation for additional installations of drought barriers. An application package with BAs for a 10-year programmatic period was submitted January 18, 2015.

During agency coordination meetings, USFWS and NMFS expressed concern regarding the decision- making process of installing a rock barrier. Letters were exchanged and meetings conducted with USACE regarding the decision criteria. Although USACE was largely supportive of a longer-term permit, a decision tree or matrix acceptable to USACE was not provided. At USFWS and NMFS suggestion, a single-year BA for the 2015 EDB project was prepared and submitted on April 1, 2015. This BA also included a change in two of the proposed barrier locations. On April 2, 2015, the USFWS and NMFS were copied on DWR's application to the USACE, requesting authorization for an individual permit, pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899, for the 2015 EDB Project. In response to agency requests to limit the proposed action to only one barrier, a revised BA dated April 13, 2015, was prepared and used by USACE to initiate consultation with USFWS and NMFS.

As the proposed installation date neared, it was determined that the standard permitting process would not be completed in time. A letter dated April 20, 2015, containing justification for the use of emergency procedures was submitted to USACE, requesting that emergency procedures be used to secure permits for the 2015 EDB Project to begin in-water work in early May 2015. The San Francisco division commander approved the use of emergency procedures but advised the USACE Sacramento District that emergency procedures could not be used to authorize this barrier in the future as it could no longer be deemed unforeseeable. USACE, via email on April 30, 2015, requested emergency ESA Section 7 consultations, specifically requesting that within 48 hours the NMFS and USFWS provide measures to reduce impacts on listed species. On May 1, 2015, NMFS and USFWS provided conservation recommendations, by email, to USACE, including implementation of conservation measures identified in the April 29 BA, as well as removal of the abutments that had been proposed to be left in place. NMFS and USFWS requested that formal consultation be initiated as soon as practicable after the emergency was under control. USACE authorized DWR, under emergency procedures, to construct the 2015 EDB Project on May 4, 2015. Post construction BAs were submitted to USACE for USFWS and NMFS on July 10, 2015. USFWS issued a biological opinion (BO) on March 9, 2016. At the time of this report, DWR has not received a NMFS BO, and further documentation is not expected from USACE.

State Permits

State authorizations and permits for the 2015 EDB Project are summarized in Table 2-3.

Table 2-3 State Authorizations and Permits for 2015 EDB Project

Agency	Regulation(s)	Permit No.	Notes
Governor Brown	Executive Orders B-29-15 and B-26-14	—	The EOs suspended requirements pertaining to the California Environmental Quality Act and Delta Plan (i.e., consistency determination), directed DWR to work directly with USACE on levee encroachments, exempted CVFPB approval, and granted Central Valley Flood Protection Board authority to DWR.
California State Lands Commission	Public Trust Doctrine	October 19, 1979 Memorandum of Understanding (MOU)	MOU was confirmed in letters dated April 9, 2014, and February 17, 2015.
California Department of Fish and Wildlife (CDFW)	Fish and Game Code Section 2081 Incidental Take Permit	2081-2014-026-03	CDFW issued an amendment on December 8, 2015.
CDFW	Fish and Game Code Section 1602 Streambed Alteration Agreement	1600-2014-0111-R3	CDFW issued an amendment on December 8, 2015.
State Water Resources Control Board (SWRCB)	CWA Section 401	Water Quality Certification	SWRCB rather than CVRWCB issued 401 because project in multiple regions.

When it was determined that a spring installation in 2014 was not needed, a draft Initial Study/Mitigated Negative Declaration (IS/MND) was prepared that described three barriers to be installed between 2015 and 2025. During this 10-year perod, the barriers could be installed up to three times, including potentially in consecutive years. The draft IS/MND was released for public review on January 26, 2015. The IS/MND was never adopted because the California Environmental Quality Act (CEQA) was suspended by Governor Brown's Executive Order (EO) B-29-15. Section 27 of EO B-29-15 also suspended the consistency process under the Delta Plan. Finally, Section 28 of EO B-29-15 authorized DWR to exercise any authority vested in the CVFPB necessary to enable urgent actions.

In 2014, a "Notice of Proposed Use of State Lands" pursuant to the 1979 memorandum of understanding (MOU) between the State Lands Commission (SLC) and the DWR was submitted for the original "single installation of three barriers" design. A letter dated April 9, 2014, granted use of the MOU for the 2014 EDB Project. In 2015, the SLC reviewed the draft IS/MND and, in a comment letter to DWR on February 17, 2015, reaffirmed that the 2015 EDB Project qualifies under the 1979 MOU.

CDFW, USACE, and the State Water Resources Control Board (SWRCB) were involved in the initial discussions for the potential 2014 installation, the shift to the programmatic approach, and the final shift to a single barrier in 2015. The final incidental take permit (ITP) and streambed alteration agreement (SAA) were issued by the CDFW on May 1, 2015. The project description in these permits included retention of the steel abutments, so amendments to the permits were sought prior to initiation of barrier removal. The amendments were informally authorized by email on October 30, 2015 (final documents signed December 8, 2015), and incorporated the description of abutment removal and revised calculations of impact acreages. The Clean Water Act Section 401 Water Quality Certification was issued by the State Water Resources Control Board on May 4, 2015.

3.0 Design, Construction, and Monitoring and Impacts

Once the final decision was made to proceed with the installation of the 2015 EDB Project, there was a relatively short schedule for design and construction. To provide the most benefit, the barrier had to be in place as early as possible. Detailed design for the 2015 EDB Project had been mostly completed in early 2014, when it was thought that it might be needed that year. The barrier was installed between April 2015 and June 2015 and removal began in September 2015, with completion in November 2015. Monitoring occurred throughout the installation and construction periods. The total project cost was $36 million, of which 10 percent of the cost was spent on internal labor including planning, design, and monitoring, and 90 percent of the cost was for operating expenses, equipment, and the construction contract for the EDB installation and removal.

3.1 Design

The major design considerations for the 2015 EDB Project included the hydraulic flow conditions in the Delta, the geotechnical stability of rock material and spongy weak compressible soils, the impact to native plants and wildlife, time restrictions, and the safety and welfare of everyone involved. Descriptions of how each of these considerations were addressed and other design details are provided in the *2015 Delta Emergency Rock Barrier Design and Construction Report* prepared in July 2016 (California Department of Water Resources 2016b).

The 2015 EDB was in Contra Costa County near the west end of False River, just east of the confluence with the San Joaquin River. This location was chosen by DWR to have the largest positive impact to the environment, water quality, and pumping facilities when compared to the cost of constructing the barrier. The final design positioned the barrier across West False River stretching north-northeast from Jersey Island to Bradford Island. The river at the barrier location is approximately 800-feet wide from bank-to-bank and approximately 30-feet deep from thalweg (lowest elevation of the river) to the high tide line (for more details of the barrier layout, see Figure 3-1). The base of the barrier was roughly 150-feet wide along the bottom of the channel and 12-feet wide along its crest. The barrier sloped down to the riverbed from its crest at the rate of 2 horizontal units to 1 vertical unit (2H:1V). A typical cross section through the 2015 EDB is shown in Figure 3-2.

Figure 3-1 2015 Emergency Drought Barrier General Layout

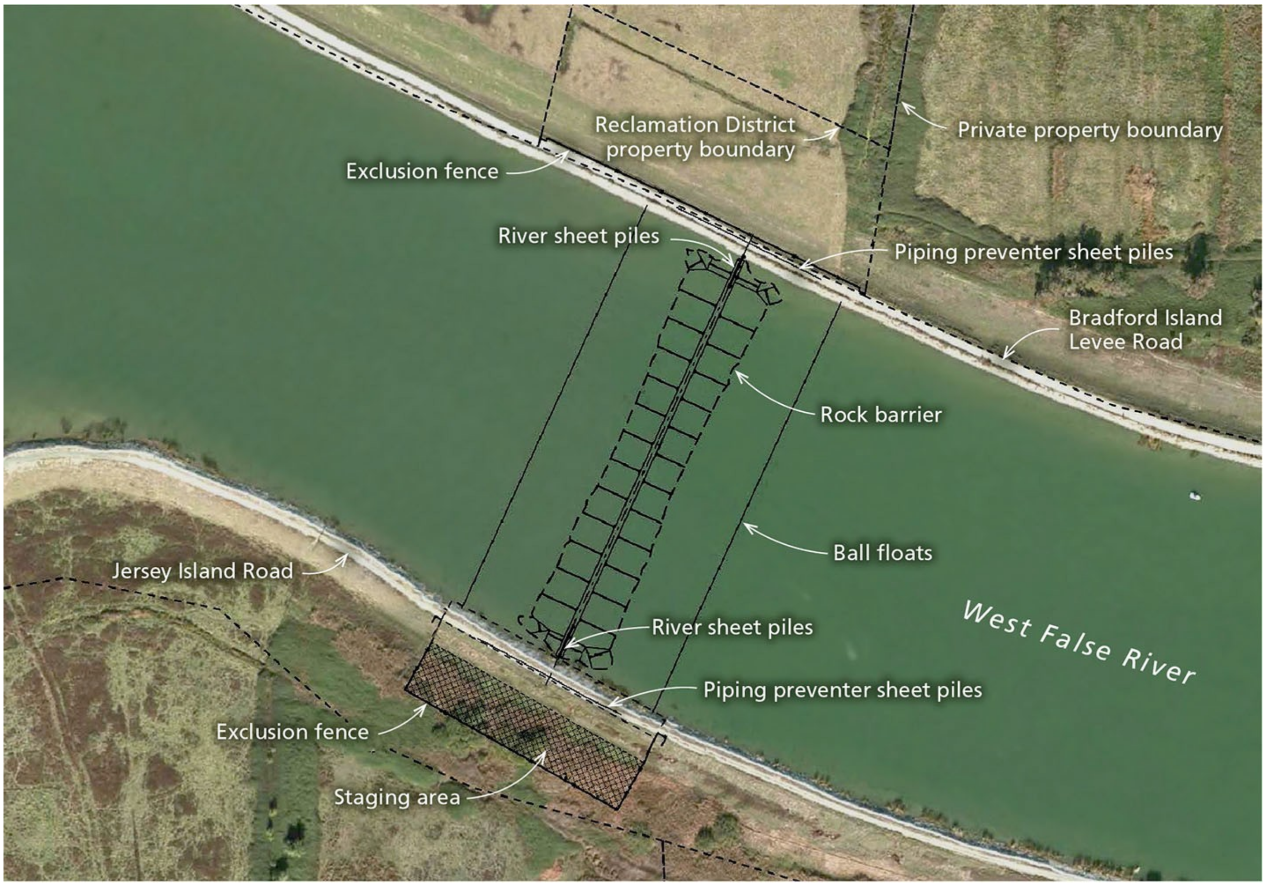
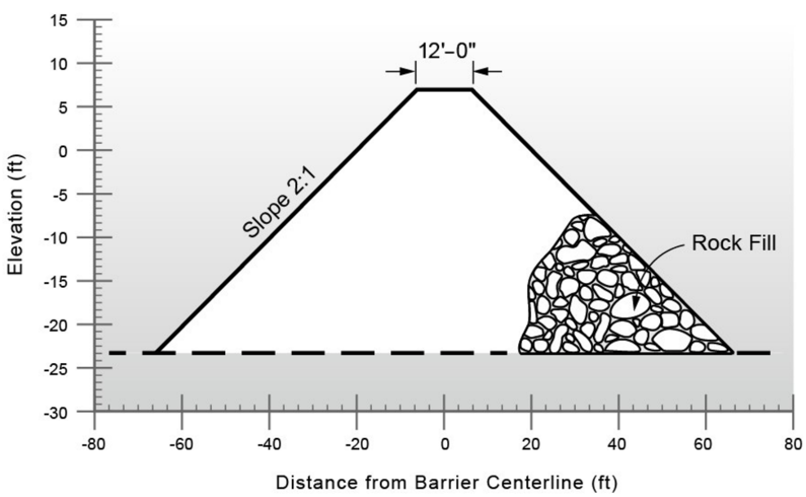


Figure 3-2 Typical Cross-Section Through the 2015 Emergency Drought Barrier



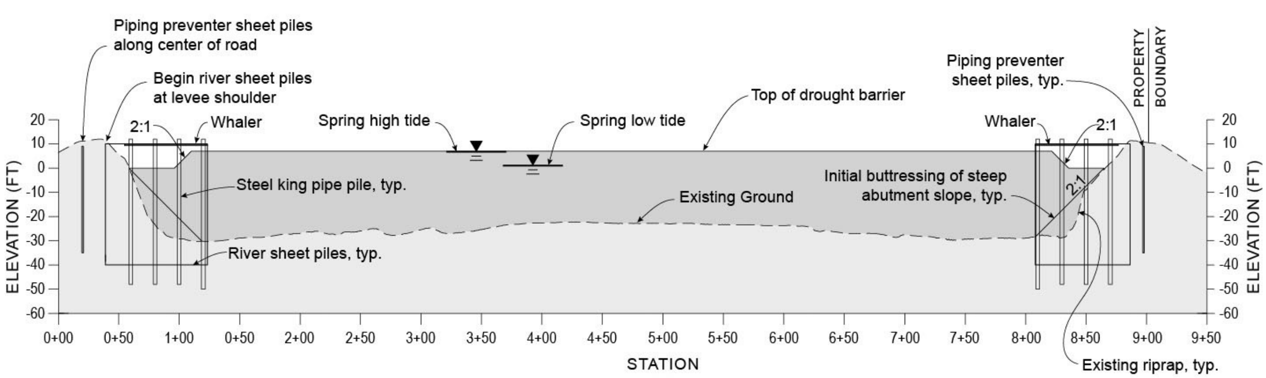
In survey of initial site conditions, including underwater, DWR found significant underwater erosion at the water-side of the levees on each side of the river at the barrier location. The base of the levee was very steep to vertical, and undercut in some locations. The barrier design included rock placement to fill the voids and create a proper levee base before the barrier rock placement could begin (see Figure 3-3 profile).

This was designed to strengthen the levee, preparing it for the barrier installation.

Structural support through a system of sheet piles and king piles was designed to aid in the hydraulic closure of the barrier at each of the salinity barrier's abutments while also reducing the amount of rock placed against the levee sides. These sets of sheet piles were driven perpendicular to the levee from both the Jersey Island and Bradford Island levee waterside shoulders out into the river (see Figure 3-3). These sheet piles are approximately 50-feet tall and extend roughly 85-feet out into the river.

Rows of sheet piles were also designed and placed along the center of each levee crest, extending 150-feet on each side from the centerline of the barrier (see Figure 3-3). These sheet piles were installed approximately 45-feet deep and were included in the design to provide protection against cracking or piping through the levee embankment. The sheet piles also provided additional stability to the undercut levees during construction.

Figure 3-3 Profile of Drought Barrier and Levee Sheet Piles



3.2 Construction

Construction included both installation and removal of the barrier. Installation began on May 5, 2015, and was completed in 54 calendar days.

Removal began on September 1, 2015, and was completed in 80 days. Removal took an extra 26 calendar days because the hours worked per day were reduced and it was generally more labor-intensive (e.g., removing the rock with two barge-mounted excavators). The installation and removal activities are summarized below. For additional details pertaining to barrier installation and removal, refer to the *2015 Delta Emergency Rock Barrier Design and Construction Report* (California Department of Water Resources 2016b).

3.2.1 Installation

Construction for the installation of the 2015 EDB began on schedule with preparation of the staging area and extraction of rock for the barrier from a local quarry. Once in-water work was permitted, buttress rock was placed along each of the undercut waterside levee bases. The levee piping prevention sheet piles were then installed and rock began to be placed in the river using split hopper barges and cranes with clamshell buckets and draglines. The king piles were driven into the river once the levee sheet piles were completed. The whaler attachment system was then connected to the king piles to help guide the river sheet piles into place. Once all the sheet piles were in place, rock continued to be placed into the river. As the work began to constrict the river at its center, a rock gradation with fewer “fines” included was used to finish closing off the river. The installation of the barrier was completed and accepted by the deadlines specified in the contract. Key dates and milestones for the 2015 EDB installation are provided in Table 3-1. Figures 3-4 and 3-5 provide pictures of rock placement during the installation for the EDB.

Table 3-1 Installation Dates and Milestones

Date	Milestone
4/23/2015	DWR issued Notice to Proceed to the Construction Contractor.
5/5/2015	Mobilization and start of on-site, land-based work.
5/6/2015	Began placement of buttress (levee) rock.
5/7/2015	Began placement of embankment (barrier) rock.
5/8/2015	Began placement of levee sheet piles.
5/14/2015	Began placement of barrier pile system.
5/28/2015	Barrier construction effectively closes river.
6/3/2015	Levee road repair completed.
6/12/2015	Barrier construction completed.
6/15/2015	Installed monitoring station piles.
6/27/2015	Demobilization completed.

The EDB construction contract objective was to procure and install the materials and components of the barrier during the brief time allowed. Specific activities included:

- Procure the volume of rock required to construct the barrier. Transport it to the barrier site by barge, and place it in the river in a controlled manner.
- Procure and place additional rock at the base of the levees on each side of the river to fill in the steep or undercut areas of the levee.
- Transport and install the required sheet piles and king piles to construct the levee sheetpile walls, as well as the barrier abutment walls. Installation of the Bradford Levee sheetpile wall was to be performed entirely from barge-mounted equipment. *Note: The sheet and king piles were procured under a separate contract as there would not have been adequate time for the construction contractor to procure the steel piles after the Notice to Proceed.*
- Procure or fabricate warning signs, markers, and buoys, and place them on each side of the barrier and in adjacent rivers, for public safety.
- Procure, transport, and install piles in various rivers and waterbodies in the Delta for ten new flow-rate and water-quality monitoring stations. More information on the installation of the new monitoring stations is included in Section 3.3.2.
- Begin daily survey monitoring of adjacent levees during construction.
- Establish, maintain, and remove staging area on Jersey Island.

Figure 3-4 Rock Placement During EDB Installation

Figure 3-5 Rock Placement During EDB Installation

3.2.2 Removal

Removal of the 2015 EDB began on September 8, 2015. Starting in the center of the channel, rock was removed outward toward the levees. The buttress rock that was placed during the installation of the barrier was left in place to provide stability to the levees. Once all the rock was removed using excavators aboard barges, the river sheet piles and king piles were cut at 1-foot below grade to the extent possible. After all the work in the river was completed, the warning buoys and signs for the barrier were removed. Finally, the levees were hydroseeded and the construction site was returned to its original condition. Key dates and milestones for the 2015 EDB removal are provided in Table 3-2. The deadline for completing in-water work corresponded to the deadline listed in environmental permits and to the start of the flood season.

Table 3-2 Removal Dates and Milestones

Date	Milestone
7/30/2015	DWR issued Notice to Proceed to the Construction Contractor.
9/1/2015	Mobilization and start of initial on-site work.
9/8/2015	Began removal of embankment rock and moving to Rio Vista storage site.
10/1/2015	Contractor began breaching the barrier.
11/7/2015	Sheet pile removal at both ends was completed.
11/15/2015	In-water work completed.
11/19/2015	Demobilization completed.

The State of California owns and operates a property parcel in Rio Vista used to store emergency flood equipment and materials. This storage site is located just north of the town of Rio Vista, California, on the west side of the Sacramento River where Airport Road intersects St. Francis Way. This site is where the rock removed from the 2015 EDB was stored for future use. The site was prepared to receive the incoming rock and equipment and then set up to deploy the materials during an emergency. The design and site preparation for the rock storage site was completed under a separate project, the Rio Vista Facility Improvement Project. The purpose, design, construction, and costs of the improvements to the rock storage site within the facility are discussed in the *2015 Delta Emergency Rock Barrier Design and Construction Report* (California Department of Water Resources 2016b).

The objective of the barrier removal construction contract was to remove all components of the barrier to a pre-construction condition and restore the areas disturbed on land. Specific activities included:

- Improvements to the site at Rio Vista where the removed rock would be stored.
- Removing embankment rock and transporting it to the Rio Vista storage site. The rock was transported via barge, offloaded as close as possible to the storage site, trucked the remaining distance, and then weighed prior to placement in the storage area.
- Bathymetry survey to confirm the barrier material was removed within prescribed limits.
- Removing warning signs, warning buoys, ball floats, and lights.

- Removing the river sheet piles and appurtenances. This required cutting steel components at or near the ground surface using divers. Sheet piles that were placed in the levee on both Jersey and Bradford islands to prevent piping were left in place.
- Hydroseeding and implementing erosion control measures.
- Piles installed to secure float lines were capped and retained in place for future use.

3.3 Monitoring and Project Impacts

DWR conducted monitoring to minimize impacts to biological resources and water quality during both installation and removal of the 2015 EDB project. Additionally, steps were taken to monitor and minimize the impacts of the 2015 EDB project on hydrodynamics, bathymetry, air quality, and boating.

3.3.1 Fish and Wildlife

Construction impacts on fish and wildlife were minimized because of measures that were implemented and mitigation that was purchased. Implementing these measures was greatly supported by good communication, not only onsite between environmental monitors (biologists), water quality monitors, construction inspectors, and the contractor, but also in the office between the Division of Environmental Services (DES), BDO, and the regulatory agencies.

State and Central Valley Water Project operational impacts of the barrier were covered under the TUCP. These operational effects are covered in the biological reviews in which Reclamation was the federal lead agency consulting with USFWS and NMFS. Operational effects and the biological assessments were coordinated for consistency.

Environmental Compliance during Barrier Installation

Environmental compliance efforts during the 2015 EDB installation are summarized below. For additional details pertaining the environmental compliance efforts, refer to the environmental compliance report entitled *Emergency Drought Barrier Project Environmental Permit Compliance Report: Installation 2015* (California Department of Water Resources 2015b).

All environmental permit commitments were tracked in a spreadsheet throughout the implementation of the project. DWR's DES and BDO sent out all the necessary notifications. On May 5, 2015, CDFW sent an email clarifying that the emergency response plan should be submitted prior to geotechnical activities and not upon initiation of project construction. DES was responsible for pre-construction surveys and environmental monitoring. DWR's North Central Regional Office (NCRO), in coordination with DES, conducted water quality sampling and monitoring. Discussion of the water quality monitoring can be found in Section 3.3.2.

Biological surveys for special status plants, elderberry shrubs, nesting birds, western pond turtles, and giant garter snakes were performed by qualified biologists on April 21, 2015, within and adjacent to the project site. For the in-water footprint, biologists conducted surveys by boat at low tide to maximize visibility of intertidal plants and to maximize visibility of potential nesting habitat on both levees. For the terrestrial footprint, biologists conducted surveys on foot. On Bradford Island, biologists identified a red-tailed hawk nest approximately 500 feet east of the project site and a great horned owl nest approximately 0.25 mile east of the project site. On Jersey Island, biologists identified a giant garter snake on the levee road approximately 0.15 mile west of the project site; a hawk nest approximately 450-feet south of the project site; Delta tule pea on the waterside slope of the levee, approximately 175-feet east of the project site; and Mason's lilaeopsis and Suisun Marsh aster along the waterside slope of the levee, approximately 0.20 mile east of the project site.

On April 23, 2015, biologists re-conducted raptor surveys and confirmed that both hawk nests observed near the project site during the April survey were inhabited by red-tailed hawks. Biologists observed a territorial Swainson's hawk in an area approximately 0.25 mile east of the project site on Jersey Island; however, biologists did not observe a mate or nest. On April 27 and 29, 2015, biologists re-conducted raptor surveys with no new sightings.

On April 30, 2015, biologists, who were visiting the barrier site to flag special status plants, observed a dead giant garter snake nearly a mile southeast of the project site on the ferry road. This snake appeared to have been killed by a vehicle strike. Biologists contacted Laura Patterson at CDFW and Dave Kelly at USFWS and were given authorization to collect the dead snake and take it to the U.S. Geological Survey (USGS) Dixon Field Station.

On May 4, 2015, pre-construction surveys for western pond turtles and giant garter snakes were conducted. No special status reptiles were observed at the project site; however, a western pond turtle was observed walking on the ferry road, approximately 0.75 mile south of the ferry terminal, on Jersey Island.

Prior to installation of the water quality monitoring station piles, biologists conducted pre-construction surveys of those locations. Since piles were placed in open water and all work was conducted by barge, biologists only surveyed for nesting birds (i.e., no botanical surveys or surveys for other terrestrial wildlife). As the pile locations were spread throughout the Delta, the surveys occurred across several days, from May 9–20, 2015. Of the twelve locations surveyed, only the Miner Slough location had a Swainson's hawk nest within a 0.50-mile radius; however, this nest was over 0.25 mile away (approximately 0.3 mile) and was visually obstructed from the proposed monitoring station location.

On May 4, 2015, an approved DWR biologist held a Worker Environmental Awareness Training (WEAT) for DWR staff and most of the contractor's personnel at the contractor's yard in Rio Vista. The WEAT covered the biology, listing status, and project-specific protection measures for giant garter snakes, burrowing owls, Swainson's hawks, general migratory birds, western pond turtles, valley elderberry longhorn beetles, special status plants, Delta smelt, Chinook salmon, Central Valley steelhead, and green sturgeon. The WEAT was subsequently repeated for all new personnel throughout the project.

Onsite environmental monitoring for all construction activities was performed daily by approved biologists. During 24-hour work, monitors were onsite from sunrise to sunset. In general, there was a morning and afternoon monitoring shift, and monitoring logs were completed for each shift. Upon arrival, the monitor would typically clear the Jersey Island side then board an onsite boat and clear the Bradford Island side (when work was taking place on Bradford Island). The monitor then would go back and forth between the islands, as necessary.

In addition to the confirmed giant garter snake observations during pre-construction, there were several observations of possible giant garter snakes during construction. Incidents that were close to the project site and were identifiable were reported to USFWS and CDFW immediately. Incidents that were far from the project site and/or when identification was uncertain were recorded on an internal Giant Garter Snake Observation Form for documentation. Pre-construction observations were submitted to the California Natural Diversity Database immediately, while construction observations were compiled to be submitted upon completion of the project. An individual giant garter snake was observed in riprap on the waterside slope (between the upland exclusion fencing and in-water construction area) on Jersey Island for three consecutive days (May 18–20, 2015). On May 20, 2015, USFWS and CDFW granted approval for approved personnel to relocate the giant garter snake. On May 21, 2015, biologists captured and relocated (west of the barrier site) two giant garter snakes — the previously observed snake and another individual.

Several other snake species were observed on or near the project site, including gopher snakes, king snakes, and yellow-bellied racers. Several bird species were observed on or near the project site, and several sea lions were observed in the area. On May 11, 2015, a smashed killdeer egg was observed approximately 300-feet east of the Jersey Island staging area exclusion fence and 10-feet north of the wetland area at the base of the levee; the cause of damage was unknown (activities prior to the project, predation, or other circumstances). On May 26, 2015, a dead gopher snake was observed on a road just west of the ferry (on Jersey Island); the snake did not appear to be a vehicular mortality, and cause of death was unknown. On June 6, 2015, a dead gopher snake was observed east of the Jersey Island exclusion fence along the waterside levee hinge; this snake may have been crushed by rocks shifting because of people walking on the riprap. No fish mortalities were observed during in-water pile driving. No other impacts on biological resources were reported.

An environmental monitor was also present for the water-quality monitoring station pile driving. No environmental concerns were reported during these activities.

Because all pile driving for this project was conducted using a vibratory driver, there were no applicable sound thresholds for the project. Nevertheless, sound monitoring was conducted to facilitate a quantitative analysis of potential impacts. On May 15, 2015, pile driving was paused when sound levels neared impact hammer thresholds, and driving recommenced only after DWR received confirmation from the regulatory agencies (verbally and through email May 15, 2015, with continued discussion through May 19, 2015) that these thresholds did not apply to vibratory driving, and DWR should just continue to monitor underwater sound. Sound monitoring was conducted on all days that in-water pile driving was scheduled. On days when pile driving occurred at both abutments simultaneously it was not possible to monitor both locations at once. Sound monitoring was also conducted for all the water quality monitoring station piles. Various precautionary measures were taken because of the uncertainty of potential effects related to the lack of accepted sound criteria for vibratory pile driving. On May 15, 2015, a bubble curtain was placed around the vibratory driver to attenuate the sound, although effectiveness was likely reduced when tidal currents dispersed the bubbles. When sound measurements neared impact hammer thresholds, visual monitoring for dead or injured fish near the pile driving was undertaken, with the intent of halting work should any such fish have been observed. Because biologists did not observe any dead or injured fish, pile driving proceeded without being paused further.

In-water pile driving at the barrier site was undertaken on eight days (May 14–16 and May 18–22, 2015). The number of monitored pile-driving sessions ranged from three to eight per day, with the total time spent pile driving ranging from just under an hour on May 14 (king piles, south side) to about 4.5 hours on May 20 (sheet piles, north side). The mean cumulative sound exposure level (SEL) per session monitored for sound was 193.8 decibels (dB) (range 178.7 to 205.1 dB). Pile driving for the water quality monitoring stations was undertaken on six days from June 4–9, 2015. The number of piles driven per day was two to three, with a mean total duration of around seven minutes (range two to 13 minutes) spent pile driving at each site. The mean cumulative SEL per session was 171.8 dB (range 149.0 to 202.5 dB), although it should be noted that one relatively high value (202.5 dB at Miner Slough near Cache Slough on June 6) skewed the mean upwards. The pile in Grizzly Bay was not actually driven, but simply pushed into the soft muddy bottom.

Upon completion of barrier installation, materials installed for staging and exclusion fencing were removed and the levee roads and staging area were restored to pre-project conditions. Soil stabilizer was used for temporary erosion control on the land side of the levee.

The terms and conditions of the environmental permits were met during installation of the drought barrier and onsite environmental disturbance of the surroundings were minimized. In addition to the avoidance and minimization measures implemented, giant garter snake and shallow water disturbances were compensated for through the purchase of mitigation credits at approved mitigation banks, in accordance with the CDFW Incidental Take Permit (2081-2014-026-03). On June 12, 2015, one acre of giant garter snake credit was purchased. On June 22, 2015, 4.9 acres of smelt/salmonid credit were purchased.

Environmental Compliance during Barrier Removal

Environmental compliance efforts during the 2015 EDB removal are summarized below. For additional details pertaining to the environmental compliance efforts, refer to the environmental compliance report entitled *2015 Emergency Drought Barrier Project (Removal) and West False River Salinity Barrier Geologic Exploration Project, Environmental Permit Compliance Report, Annual Status Report, and Final Mitigation Report* (California Department of Water Resources 2015c).

On August 25, 2015, DES discussed the Bradford Island exclusion fence with USFWS. It was determined that an exclusion fence would not need to be installed on the island during removal if the work to remove the security fence began before October 1 and an environmental monitor thoroughly surveyed the riprap for snakes immediately prior to abutment removal.

On August 28, 2015, biologists conducted pre-construction surveys specifically for special status plants, western pond turtles, and giant garter snakes. Surveys for nesting birds were not conducted because removal work occurred outside of nesting season. The survey was conducted by foot on both Jersey and Bradford islands. No special status species were observed aside from the special-status plants documented prior to installation. The immediate project area was resurveyed daily for western pond turtles and giant garter snakes by the environmental monitor during removal activities.

On August 28, 2015, DWR biologists also visited the Rio Vista stockpile site and no special status species were observed. That area was in the process of undergoing improvements as part of the Rio Vista Facilities Improvement Project, so site surveys were conducted in conjunction with their environmental documentation review. A survey was conducted on June 19, 2015, prior to initiation of any work, documenting that “No active nests were observed. Two old stick nests located in the north-east end of the site were observed and recorded for future surveys. No burrows or burrowing owls were located at the project site. No elderberry shrubs were present on or adjacent to the project site. The project site lacks the hydraulic connectivity suitable for giant garter snake habitat.”

On September 1, 2015, biologists conducted WEAT for personnel on the Rio Vista stockpile site prior to mobilization and installation of the staging area exclusion fence. WEAT included the biology, listing status, and project-specific protection measures for the giant garter snake, burrowing owl, Swainson’s hawk, general migratory birds, western pond turtle, valley elderberry longhorn beetle, special status plants, Delta smelt, Chinook salmon, Central Valley steelhead, and green sturgeon. WEAT was subsequently repeated by the environmental monitors for all new personnel throughout the duration of the project.

Since geologic explorations were conducted concurrently with barrier removal in an active construction area, separate pre-construction surveys were not required. Nevertheless, there was a dedicated biologist for the geologic explorations that surveyed distinct project areas immediately prior to setting up exploration equipment. This biologist conducted onsite WEAT for these personnel and monitored all geologic exploration activities.

Onsite environmental monitoring was performed daily, by approved biologists, for all construction activities. Removal activities from September 1–30, 2015, were typically conducted Monday through Saturday, from 6:30 a.m. to 5:30 p.m. Removal activities conducted from October 1 through November 15 were typically seven days a week for the same daily hours. 24-hour work days were not utilized at the West False River site during removal activities. Upon arrival, the monitor would typically clear the Jersey Island side within the staging area surrounded by exclusion fencing, and then board a boat and clear the Bradford Island side (when work was taking place on Bradford Island). Work in open water was typically monitored from Jersey Island; monitors did thorough surveys of the riprap for snakes prior to work occurring on the abutments or levee slope, and directly oversaw that work on the levee when it was occurring.

On September 10, 2015, the biologist observed a single Suisun Marsh aster, a California Native Plant Society (CNPS) 1B.2 plant, within 3 feet of the barrier abutment on Jersey Island. This plant was flagged and avoided while CDFW was consulted. On September 11, 2015, in an email communication, CDFW noted that Suisun Marsh aster is not a State-listed endangered, threatened, or rare plant, and the incidental take of this plant during abutment removal would not affect the existing population of Suisun Marsh aster in the project area. On November 5, 2015, the Suisun marsh aster was incidentally taken during the abutment removal process on November 5, 2015.

During barrier removal, there was a single observation of a potential giant garter snake. On October 8, 2015, the water quality monitor was leaving the project site and observed what was thought to be a buoy light washed up on the riprap about a quarter mile east of the project site. When the presumed "buoy light was approached for retrieval," a snake was spotted, potentially a giant garter snake, in the riprap in a vegetated area immediately above the water line. Only the mid-section of the snake was observed, and it was startled and moved away. The head of the snake was not seen, and the observer did not have a camera available to take a photo. Personnel were made aware of the possible occurrence, but work was not altered because the snake was outside of the project area.

Several other reptiles were observed within or near the project site, including gopher snakes, king snakes, yellow-bellied racers, western fence lizard, and western pond turtle. On September 24 and 25, 2015, a western pond turtle was observed in water hyacinth near the barrier abutments. It is unknown if this was the same individual. On both days, the turtle was not in the immediate area of construction activities, and monitors observed the turtle throughout those two days to ensure that it did not enter an area where it could be directly affected. Various bird species representatives of the area were observed within or near the project site. Mammal species observed within or near the project site included sea lions, beavers, otters, minks, raccoons, coyotes, red-fox squirrels, and black-tailed jackrabbits. On October 13–19, 2015, an injured pied-billed grebe was observed near the abutment off Jersey Island, and monitors tracked the bird to ensure that it was not directly affected by project activities.

No additional noteworthy environmental observations were reported during removal activities or geotechnical explorations.

No pile driving occurred during barrier removal, but a vibratory hammer was used to assist in the removal of the abutment sheet piles. The sheet piles were cut at or below finished grade; however, the floating interlock connecting the piles became locked because of debris and deformation of the steel. In addition, there were challenges for pile removal associated with slag from the underwater cutting torch re-bonding to the piles. The vibratory hammer was used to free the interlock seam between the loose pile and the adjacent, in-place pile. Regulatory agencies were informed of the use of this technique prior to its implementation and that no sound monitoring was planned for this specific activity (email from Katherine Marquez on November 4, 2015).

Upon completion of barrier removal, materials installed for staging and exclusion fencing were removed and the levee roads and staging area were restored to pre-project conditions. On October 22, 2015, the staging area was hydroseeded. On November 17, 2015, all appropriate regulatory agencies were notified via email upon completion of removal and full demobilization.

The Water Quality Certification also included a requirement for a revegetation plan, managed through discussions with the SWRCB. A September 24, 2015, memo outlined a plan for monitoring hydroseeded staging for its effectiveness as an erosion control method. This plan included inspections every other month, from November to April 2016, and submission of a site report that includes pictures taken within one week of each inspection. These inspections were conducted on December 11, 2015; February 8, 2016; and April 4, 2016. All visits indicated that hydroseeding progressed as expected and no corrective measures were necessary.

3.3.2 Water Quality

DWR determined that water quality monitoring was necessary to assess effects from potential salinity barriers placed in selected locations in the west, central, and north Delta. The water quality monitoring activities regarding the 2015 EDB are summarized below with additional details available in the *2017 Emergency Drought Barrier Water Quality Monitoring Report* (California Department of Water Resources 2017).

In addition to turbidity and other monitoring during barrier construction, the EDB Project's water quality certification required an adequate network of monitoring stations to evaluate the presence of any adverse water quality effects attributable to the project. The SWRCB required that DWR develop a monitoring plan for their review and approval for inclusion in the water quality certification. DWR subsequently developed and implemented a water quality monitoring plan, *Water Quality Monitoring Plan, Emergency Drought Barrier, version April 24, 2015* (California Department of Water Resources 2015a).

Water Quality Monitoring during Barrier Construction

During barrier installation and removal, water quality measurements, including those for turbidity and settleable solids, were taken upstream and downstream of barrier construction at approximately 9 a.m., 12 p.m., and 3 p.m. each in-water work day. The water quality objectives, as outlined in the water quality certification issued May 4, 2015, were met on all occasions. During the installation and removal of the barrier, turbidity was monitored, confirming that project construction resulted in values below the background threshold of 150 Nephelometric Turbidity Units (NTU). Settleable solids did not exceed the 0.1 milliliter per liter threshold. During rock placement installation, the highest recorded turbidity measurement of 34.3 NTU occurred on May 15, 2015. During rock removal, the highest recorded turbidity measurement of 37.4 NTU occurred on September 11, 2015.

The ITP also included turbidity monitoring for overwater geotechnical activities. Condition 7.8 of the ITP stated that the permittee shall monitor turbidity 100 feet upstream from the source activity and 300 feet downstream of the source activity half-way through overwater geotechnical activities once each day. This condition includes a threshold of 15 NTU above baseline. All samples were well below the threshold.

Monitoring the water quality measuring for flow, temperature, salinity, turbidity, chlorophyll, and dissolved oxygen was conducted downstream of the project at the Jersey Point sampling station on the San Joaquin River. The water quality monitoring plan was included in the compliance report for installation. Real-time data from the continuous water quality monitoring plan, as well as the newly installed flow monitoring station on Fisherman's Cut, was graphically summarized in a Water Quality Monitoring Interactive Map.

Selecting Water Quality Monitoring Station Locations

DWR's North Central Region Office (NCRO) and Division of Environmental Services (DES) staff coordinated with the Bay-Delta Office's Delta Modeling Branch to determine if the existing network of 11 DWR and USGS water quality monitoring stations near possible barrier locations would suffice. Based on forecasted water quality needs, 10 additional sites were identified for installation to augment the existing data collection stations. The monitoring locations are shown in Figure 3-6 and provided in Table 3-3. The chosen locations for four of the 10 new stations (Miner Slough near Sacramento River [MIR], Sacramento River downstream of Isleton [SOI], Steamboat Slough near Sacramento River [SXS], and Fisherman's Cut [FCT]) were coordinated with the NCRO Flow Monitoring and Special Studies Section because these stations were to monitor both water quality and flow. The criteria for locating these stations was more critical for flow monitoring needs than for water quality, therefore site selection is discussed in more detail in Section 3.3.3 (Hydrodynamics).

The installation and maintenance of this monitoring network was a joint effort between DWR and USGS. All stations within the network utilize cellular telemetry to publicly provide real-time data through the California Data Exchange Center (CDEC). Table 3-3 provides the station name, coordinates, CDEC code, and the date each station was established.

New stations were installed in the North Delta, Central Delta, and Suisun Bay. Three new stations (MIR, SXS, and SOI) were installed in the north Delta to monitor salinity intrusion up the Sacramento River and into the Cache Slough Complex during the 2015 EDB project. For one existing station in the north Delta (Steamboat Slough below Sutter Slough [SUS]), telemetry was provided so that the data could be viewed in real time on CDEC. Stations FCT, Sacramento River at Twitchell Island (TWI), and Franks Tract, Mid Tract (FRK) were installed to evaluate how the West False River EDB impacted San Joaquin River and Fisherman's Cut water quality and especially Franks Tract salinity. Water quality modeler's results predicted longer term detrimental impacts on the State's water supply if Franks Tract were to become too saline. These stations helped determine whether the EDB successfully minimized the central Delta salinity intrusion. The four stations (Suisun Bay — Cutoff near Ryer Island [RYC], Grizzly Bay [GZL], Honker Bay [HON], and Sacramento River near Sherman Island [SSI]) in the Suisun Bay area provided details on the spatial extent of salinity intrusion.

All the new stations were provided with telemetry so that the data could be viewed on CDEC.

Figure 3-6 Locations of Water Quality Monitoring Stations

Table 3-3 Water Quality Monitoring Stations

#	Station Name	Latitude	Longitude	Date Established	CDEC Code	Operator
1	Miner Slough at Highway 84	38.29170	-121.63080	12/02/2009	HWB	USGS
2	Steamboat Slough below Sutter Slough	38.25250	-121.60140	02/04/1983	SUS	DWR
3	Liberty Island	38.24210	-121.68490	12/20/2010	LIB	USGS
4	Cache Slough at Ryer Island	38.21280	-121.66920	12/02/2009	RYI	USGS
5	Three Mile Slough at San Joaquin River	38.10330	-121.68610	06/17/2008	TSL	DWR
6	Old River at Franks Tract near Terminous	38.07110	-121.57890	05/19/2006	OSJ	DWR
7	San Joaquin River at Jersey Point	38.05200	-121.68900	12/01/2009	SJJ	USGS
8	False River	38.05580	-121.66690	02/09/2007	FAL	DWR
9	Bethel Island near Piper Slough	38.034023	-121.621266	06/17/2014	BET	DWR
10	Dutch Slough at Jersey Island	38.01300	-121.67100	12/09/2009	DSJ	USGS
11	Holland Cut near Bethel Island	38.01640	-121.58190	06/26/2006	HOL	DWR
12	Miner Slough near Sacramento River	38.23603	-121.66606	06/12/2015	MIR	DWR
13	Steamboat Slough near Sacramento River	38.19127	-121.63788	06/12/2015	SXS	DWR
14	Sacramento River downstream of Isleton	38.17548	-121.65686	06/12/2015	SOI	DWR
15	San Joaquin River at Twitchell Island	38.09746	-121.66872	06/19/2015	TWI	DWR
16	Franks Tract, Mid Tract	38.04642	-121.59810	06/05/2015	FRK	DWR
17	Fisherman's Cut	38.06782	-121.64884	04/20/2015	FCT	DWR
18	Sacramento River near Sherman Island	38.07415	-121.76174	07/29/2015	SSI	DWR
19	Honker Bay	38.07240	-121.93920	07/28/2015	HON	DWR
20	Suisun Bay – Cutoff near Ryer Island	38.083971	-121.995878	07/28/2015	RYC	DWR
21	Grizzly Bay	38.12425	-122.03812	07/29/2015	GZL	DWR

Water Quality Station Installation

Because there were no existing structures at the chosen locations for the new water quality stations, staff coordinated the installation of 10 new piles for the additional stations. A typical station consists of perforated polyvinyl chloride (PVC) piping attached to a 12-inch diameter pile using metal brackets.

Stations RYC, HON, and GZL were the only stations that experienced installation challenges. These stations are the westernmost stations and were difficult to install because their bay locations are susceptible to high winds and extreme tides. These three stations were fully installed in July 2015, after several delays caused by adverse weather and tidal conditions. Once the necessary piles were driven and the environmental permitting requirements were met, the installation of the other stations proceeded smoothly.

Water Quality Parameters Measured

Each station collected data for the following water quality parameters in 15-minute intervals at 1 meter of depth using Yellow Spring Instruments (YSI) V2 6600 and EXO2 sondes: water temperature in degrees Celsius (°C), dissolved oxygen in milligrams per liter (mg/L), specific conductance or electricalconductivity (EC) in microSiemens per centimeter (µS/cm), and turbidity in nephelometric turbidity units (NTU). These water quality parameters of concern were used because of their potential to be affected by the EDB and their importance to the ecosystem and consumptive use practices.

Discrete sampling of the following constituents was conducted monthly at each station:

- Chlorophyll-*a* (micrograms per liter [µg/L]).
- Pheophytin-*a* (µg/L).
- Dissolved ammonia (mg/L).
- Dissolved chloride (mg/L).
- Dissolved bromide (mg/L).
- Dissolved nitrite + nitrate (mg/L).
- Dissolved organic carbon (mg/L).

- Dissolved organic nitrogen (mg/L).
- Dissolved orthophosphate (mg/L).
- Total kjeldahl nitrogen (mg/L).
- Total organic carbon (mg/L).
- Total phosphorus (mg/L).

Nutrient data was collected to evaluate whether the EDB affected the accumulation and distribution of nutrients in the project area. Researchers are also interested in using this data to evaluate whether the EDB affected algal growth and blooms in the area.

Effects of the Barrier on Water Quality

As predicted by hydrodynamic modeling, the barrier prevented salinity intrusion. Field monitoring observed no major changes in water quality parameters coinciding with the presence of the EDB. At one station, BET, a single dissolved oxygen (DO) reading of 4.9 mg/L was observed on June 11, 2015, at 17:15. This was the only 15-minute data point below the 5.0 mg/L water quality objective observed during the drought monitoring period coinciding with the presence of the barrier. The results of organic carbon and nutrient analyses near Franks Tract show consistency in their levels and patterns between all stations from summer 2014 to spring 2016, irrespective of the presence of the EDB.

3.3.3 Hydrodynamics

Hydrodynamic models were used to estimate the channel velocities in the north and central Delta if three possible barriers were installed to help maintain fresh water conditions in the central Delta. Model results predicted that installation of rock barriers in West False River and the lower sections of Miner and Steamboat sloughs would increase velocities in Fisherman's Cut, the San Joaquin River, Dutch Slough, and the Sacramento River — possibly inducing scour. These barriers would likely decrease velocities in West False River adjacent to Bradford Island and certain parts of Miner an Steamboat sloughs — possibly leading to sediment deposition. Just over a month before barrier construction commenced, DWR decided to only install the 2015 EDB at West False River.

Establishing the four EDB-related flow stations (FCT, SOI, SXS, and MIR)

Four EDB flow monitoring station locations were chosen because they were either close to a potential barrier (Miner Slough and Steamboat Slough) or in a section of channel that hydrodynamic modeling suggested would experience increased velocity (Fisherman's Cut and Sacramento River downstream of Isleton) resulting from the 2015 EDB.

The primary challenges to establishing a new flow monitoring station are:

- A location with a relatively straight section of channel and relatively deep cross-section for accurate data collection.
- A cross-section devoid of submerged aquatic vegetation.
- An attachment structure on which to mount the flow station.
- Local landowner and reclamation district approval, when necessary.
- Environmental and right-of-way permitting to drive a pile if attachment structures are unavailable.

All four potential barrier locations were sited in areas where no adequate attachment structures existed. Because of the importance of monitoring changes to Fisherman's Cut flow, a temporary station was established on an existing pile to gather baseline readings. Rapid growth of aquatic vegetation around the pile quickly rendered this station ineffective. As a result, new piles had to be driven at all four flow station locations. Bathymetric data was collected at the proposed pile locations to confirm each site's adequacy to collect accurate flow measurements. Engineering drawings were developed for each site and provided to the contractor for pile installation.

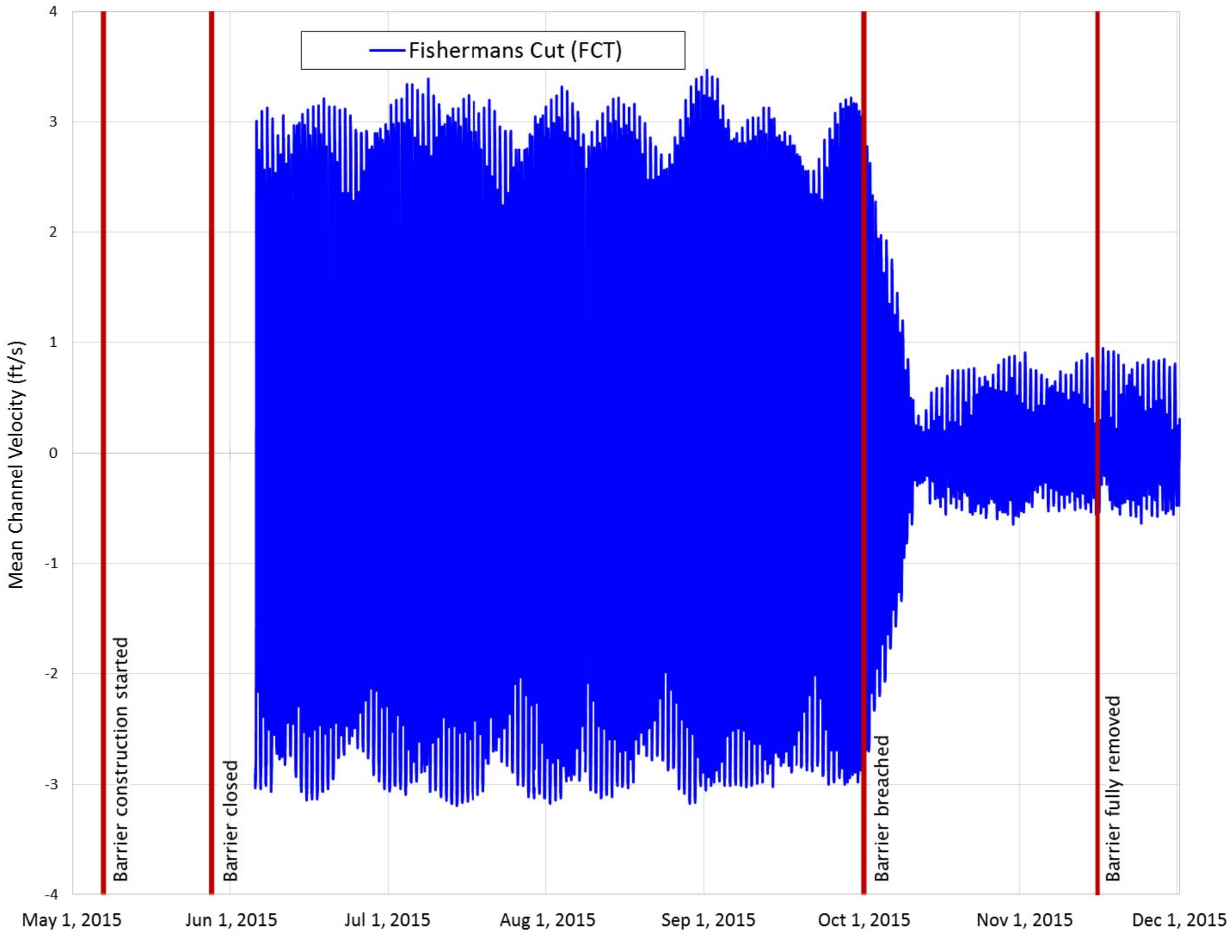
Velocity changes within the vicinity of the 2015 EDB

Hydrodynamic model results suggested that because of the construction of the 2015 EDB, velocities could change within Fisherman's Cut and in Dutch Slough. There were no flow stations within Fisherman's Cut prior to installation of the barrier; however, the USGS was already operating a flow station in Dutch Slough at Jersey Island. Consequently, pre-barrier baseline data was recorded by the USGS at this station. Modeling predicted that the most significant changes might occur in Fisherman's Cut, which turned out to be true.

On June 5, 2015, the Fisherman's Cut flow station was installed on its pile. On June 17, 2015, a 25-hour calibration flow measurement was performed. Flow and mean channel velocity data were telemetered to the California Data Exchange Center (CDEC), using the station code FCT, starting on June 24, 2015. This meant that velocity data wasn't publicly available until nearly a month after the barrier was closed. In addition, DWR was not able to measure any baseline velocity and flow data within Fisherman's Cut prior to installation of the barrier on the West False River channel. DWR modeling underpredicted the measured velocity increases within Fisherman's Cut by about 2–2.5 feet per second (ft/s).

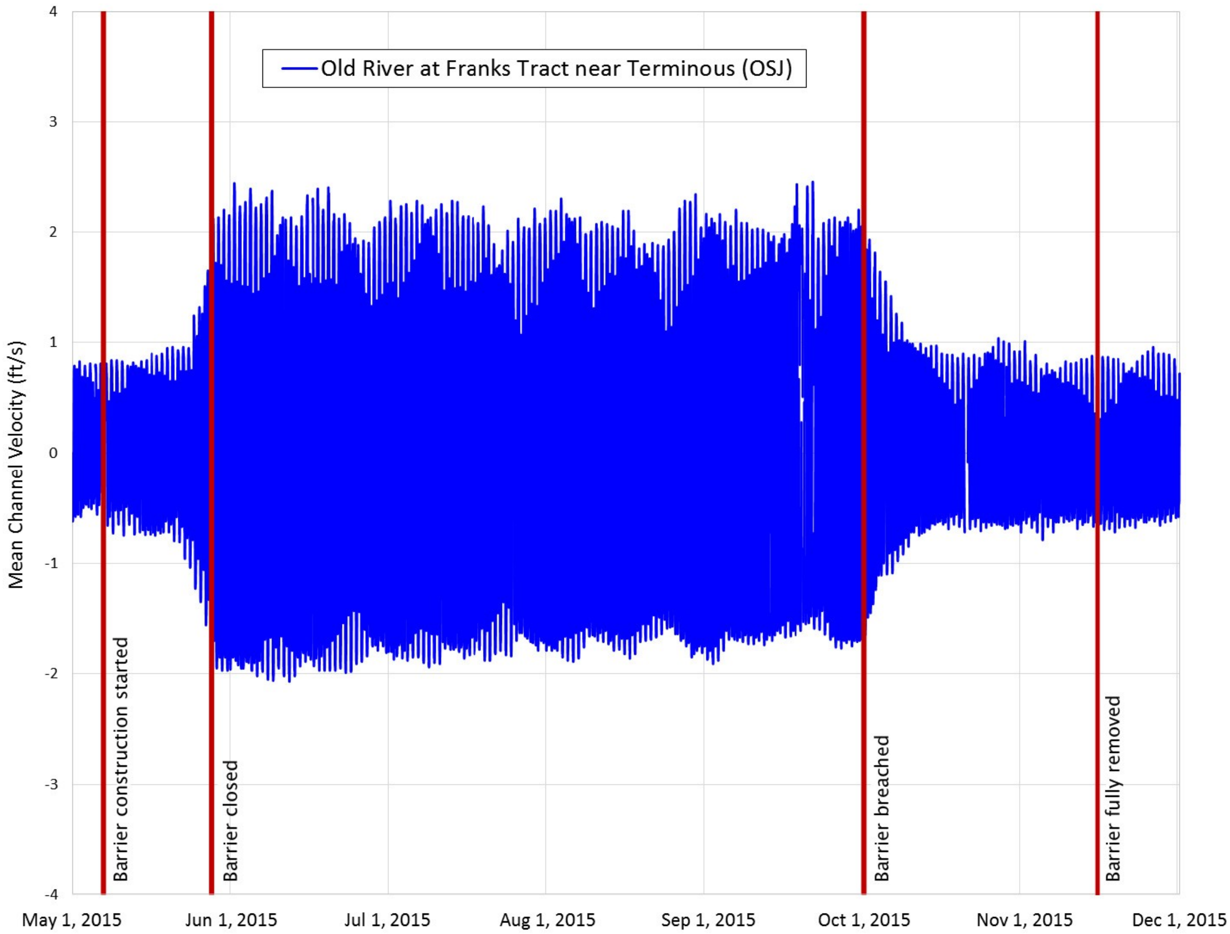
Figure 3-7 shows mean channel velocities at FCT from the time of station installation through November 30, 2015. While the EDB was in place, velocities within Fisherman's Cut typically ranged between +3.5 ft/s to -3.3 ft/s. After the barrier was completely removed, velocities within FCT reduced to a range of +0.9 ft/s to -0.6 ft/s.

Figure 3-7 Mean Channel Velocities at the Fisherman's Cut (FCT) Monitoring Station



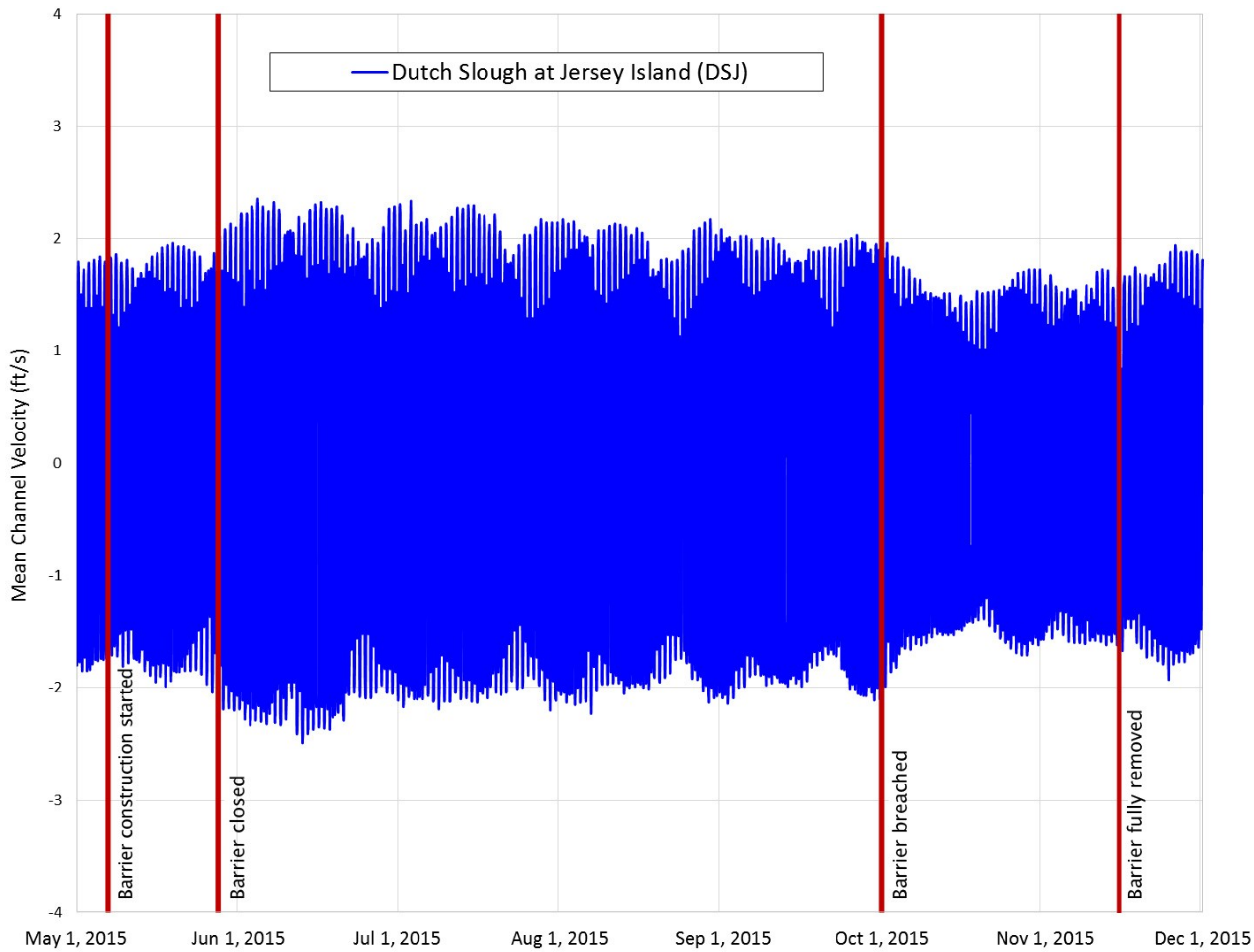
Velocities at the USGS Old River at Franks Tract near Terminous (OSJ) station were affected by the EDB installation as well. Generally, velocities ranged between +1.00 ft/s to -0.75 ft/s without a barrier. While the barrier was fully closed, velocities ranged from about +2.40 ft/s to -2.00 ft/s. See Figure 3-8 for more information.

Figure 3-8 Mean Channel Velocities at the Old River at Franks Tract (OSJ) Monitoring Station



Changes to velocities at the USGS Dutch Slough at Jersey Island (DSJ) station appear to be more subtle. Without the EDB water, velocities typically ranged between +1.75 ft/s and -1.75 ft/s, while barrier-in-place velocities ranged between about +2.30 ft/s to -2.40 ft/s. See Figure 3-9 for more information.

Figure 3-9 Mean Channel Velocities at the Dutch Slough at Jersey Island (DSJ) Monitoring Station



There appear to be no obvious changes to velocities within the three other pile-mounted flow stations that were installed in the north Delta: Sacramento River downstream of Isleton, Steamboat Slough near the Sacramento River, and Miner Slough.

3.3.4 Bathymetry

Bathymetry surveys were completed in areas near the 2015 EDB to help with planning, design, model improvement, and to measure the effects of the barrier. The surveys and findings are discussed below, and more information is available in the *2015 Emergency Drought Barrier, West False River Bathymetric Mapping, Spring and Fall 2015* (California Department of Water Resources 2016a). The areas bathymetrically measured are shown in Figure 3-10.

The pre-barrier survey area was determined largely from model results that showed where elevated channel velocities were likely to exist with the barrier installed. The post barrier measurement area is smaller because the extent of the priority impact areas was better understood. It focuses more on shorelines where scour is more important.

After the barrier was installed, areas to the east of Franks Tract in Old River experienced some flow increases. While tidal activity increased significantly during barrier installation here, scour was not an issue because of the relatively low velocities. The Franks Tract/Old River area was measured, along with the additional survey areas (shown in yellow in Figure 3-10), more for USGS flow station adjustments and model improvement than scour monitoring.

Challenges in Describing Eroded Levee Geometry

Pre-barrier bathymetry surveys identified vertical and undercut waterside levee slopes below the waterline along the levees in some locations near the EDB site. Figure 3-11 shows where vertical or undercut levees were found. The discovery of undercutting in the designed EDB alignment was alarming, but it was a beneficial discovery because it allowed the engineers and contractor to stabilize the levee adequately to prevent damage during and after construction.

Underwater levee slopes, water depths, and depth effects in most of the areas are best visualized as raster images or contour lines. Raster images are useful simplifications of the bathymetry data that allow very large and detailed point cloud data sets to be efficiently viewed on a variety of computer and paper platforms. The tradeoff when using raster images is that they fail to adequately describe channel banks and other objects when they have vertical or undercut surfaces that have been discovered in this area. Note that rasters, as they were implemented in this project, can assign only a single elevation value to a horizontal square foot in the area of interest. This is great for gradually varying surfaces typically seen on channel bottoms, but the West False River area is not typical. Vertical surfaces need more than one value in a horizontal square foot to be described properly.

Undercut areas are best viewed with the unfiltered X, Y, Z point cloud of bathymetric data, which is normally not easy to visualize on a map or computer screen. Figure 3-12 shows a point cloud representation of typical undercutting found in West False River.

Channel Bed Elevation Change Pre- and Post-Rock Barrier Installation

In all the areas where vertical or undercut levees were found, few significant changes occurred. But sediment movements in some areas near the barrier were altered. Locations with the most significant changes were in Fisherman’s Cut and on the tule berm found on the north side of Bradford Island.

A histogram of the elevation changes in three areas near Bradford Island are shown in Figure 3-13. The histograms show that most of the change was less than 1 foot. Fisherman’s cut had a moderate net loss of material, San Joaquin River north and west of Bradford Island had a minor net loss, and San Joaquin River at Twitchell Island had a net gain of material (more area on the positive side). A net flow analysis in Fisherman’s Cut was not conducted, but may be useful in determining possible material transport vectors.

Figure 3-10 Bathymetry Survey Areas

Figure 3-11 Areas of Levee Undercutting

Figure 3-12 Typical Levee Undercutting Plan and Profile

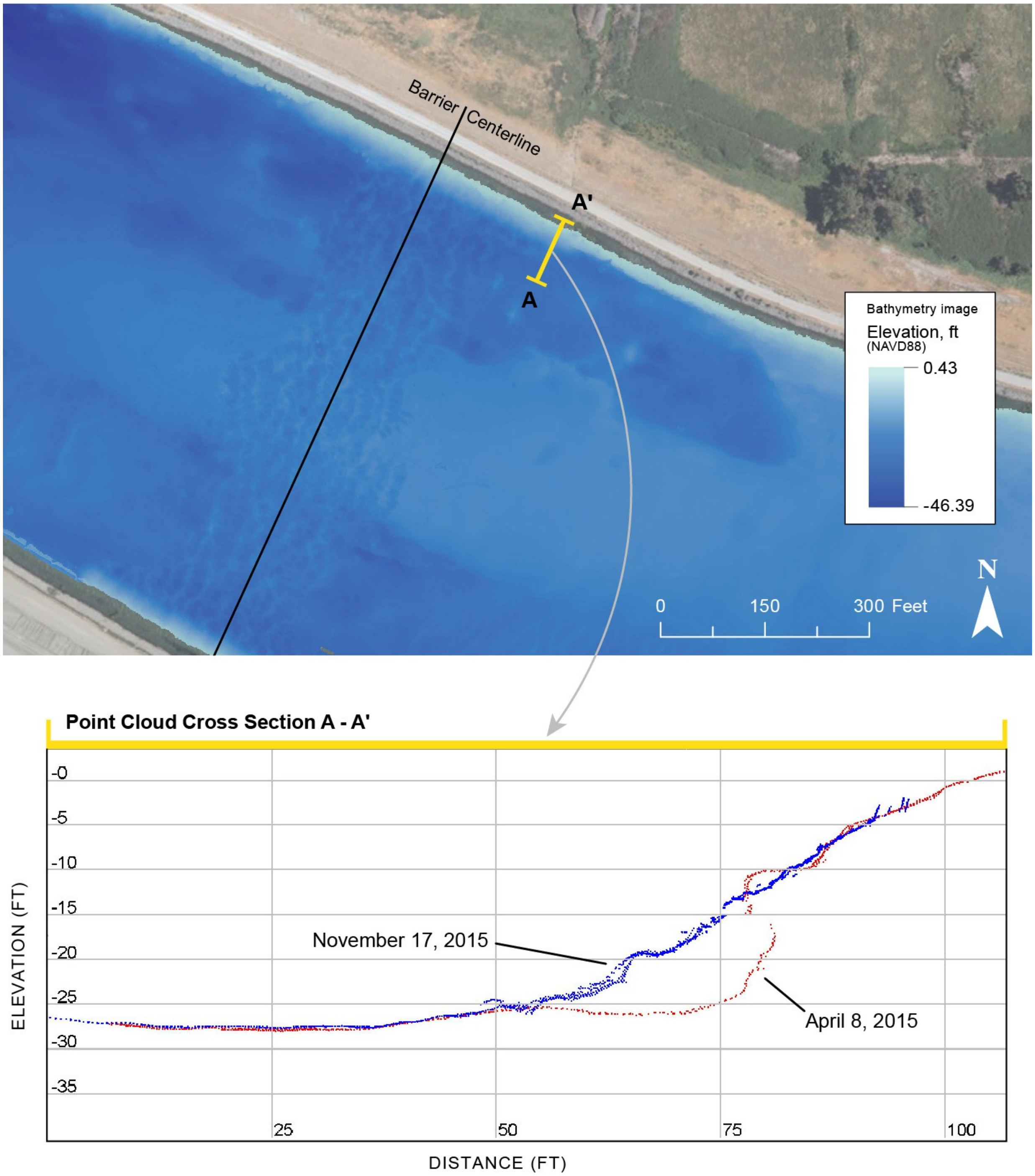
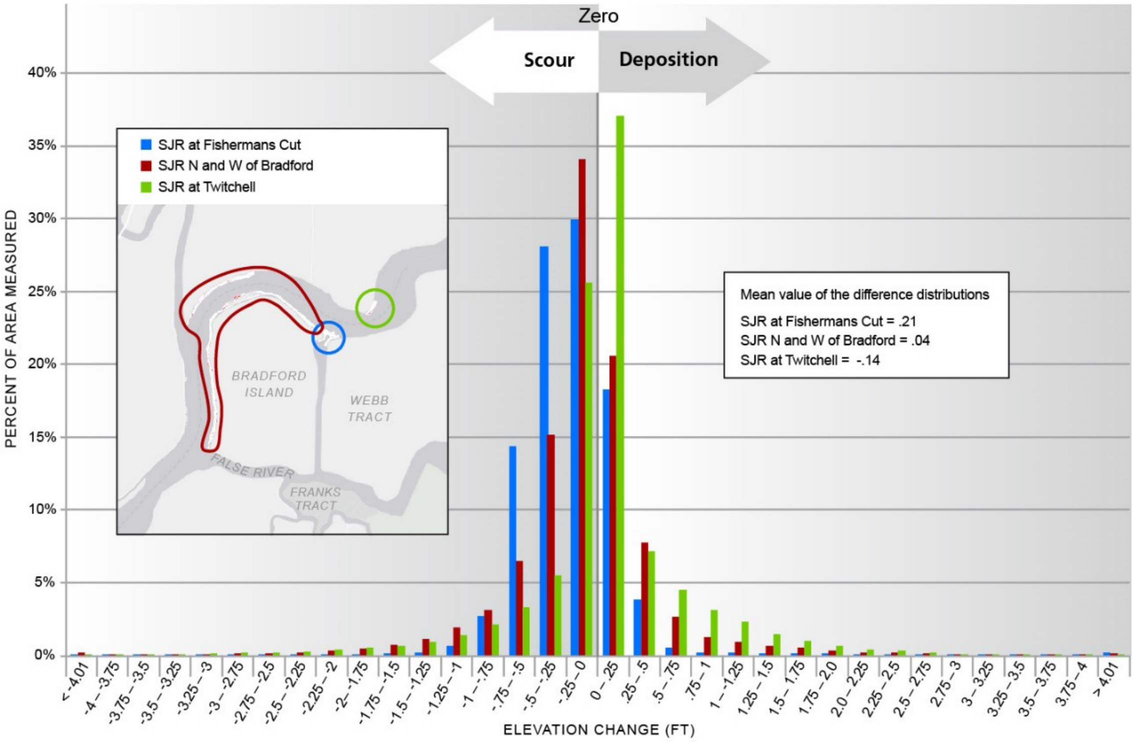


Figure 3-13 Histograms of Elevation Change at Various Locations



Note: This difference in elevations is expressed as percent area v. the amount of change seen in those areas.

The foot-by-foot bottom-elevation-change analysis performed throughout the area was calculated by comparing the raster values in ArcGIS, referred to as a *difference raster*. Figure representations of the difference raster were created and can be found in Appendix A.

3.3.5 Other Impacts

The sections below discuss other coordination, impacts, and mitigation related to the 2015 EDB Project, including air quality, boating, and navigation impacts.

Air Quality

Initial planning and preparation associated with CEQA indicated that the 2015 EDB Project would have resulted in air quality emissions above allowable thresholds. Prior to release of the draft IS/MND, DWR and consultants met with the Sacramento Metropolitan Air Quality Management District (SMAQMD) and Bay Area Air Quality Management District (BAAQMD). Initial air quality modeling was based on conservative construction assumptions, and the resulting offset fees for installation of three barriers totaled approximately $2 million. Following the meetings, DWR agreed on a method to record actual equipment usage and to calculate air quality impacts after installation and removal of the barrier.

SMAQMD also recommended the use of renewable diesel fuel. Once the Steamboat and Sutter Slough barriers were eliminated for further consideration, DWR no longer coordinated with the SMAQMD. Although the governor's executive orders exempted CEQA, and any air quality mitigation measures contained therein, DWR continued to consult with the BAAQMD. Consistent with the governor's executive order, DWR worked to minimize and fully mitigate project impacts, including impacts on air quality. The aim, if possible, was for the project to result in no long-term air quality degradation. The air quality considerations and mitigation for the 2015 EDB are summarized below, and additional details can be found in the July 2016 Memorandum to BAAQMD, the *Emergency Drought Barrier Construction Mitigation and Ferry Retrofit* (McQuirk 2016).

Construction-related air quality emissions associated with the 2015 EDB Project were generated from tugboats and barges, workboats, construction equipment, and on-road vehicles. The construction contract was completed in an expedient manner and although there was a provision requiring renewable diesel usage, there was no incentive to use the renewable product and no penalty for not using it. Consequently, the contractor did not use renewable diesel fuel and was able to successfully get the requirement dropped by claiming the fuel was not supported by various diesel engine manufacturers. While coordinating with the contractor following the barrier removal, DWR and the consultant had difficulty in obtaining equipment and usage information that was not explicitly required by the construction contract from the contractor; however, enough information, combined with experience, allowed DWR to conduct air quality modeling. The estimated total construction emissions were compared to the BAAQMD thresholds over the duration of the total project (46 work days for the installation phase and 108 work days for the removal phase). The project's construction-related NOx emissions were found to exceed the BAAQMD allowable limits by approximately 19.6 tons of NOx.

Because of an increase in channel velocity in Fisherman's Cut, the DFA's Victory II ferry had difficulty maneuvering and could no longer maintain the level of service prior to the barrier. Since the real property easement required no impacts on the DFA, DWR negotiated a plan to repower the Victory II. This requirement also presented an opportunity for DWR to mitigate air quality emissions. As discussed with the BAAQMD, DWR followed the example of the Carl Moyer Memorial Air Quality Standards Attainment Programs, which provide grant funding for cleaner-than-required engines and equipment. As part of modifying the Victory II to overcome the maneuverability problems, DWR removed the old technology diesel engines and installed new state-of-the-art, Tier III diesel engines. The air quality benefits associated with the new engines more than offset the impacts of construction, as discussed in the *Emergency Drought Barrier Construction Mitigation and Ferry Retrofit Memorandum* dated July 18, 2016. The memorandum states that the modifications to the Victory II “would achieve lifetime emission reductions of at least 33 tons of NOx” emissions. Consequently, the 2015 EDB Project was a net benefit to air quality.

Boating and Navigation

The 2015 EDB project required boating and navigation coordination with the U.S. Coast Guard and the Delta Ferry Authority. Discussions of these coordination efforts are provided in the subsection below.

Coordination with U.S. Coast Guard

DWR coordination with the U.S. Coast Guard (USCG) on navigation was one of the issues that needed to be addressed for implementation of the 2015 EDB. For the 2015 EDB, DWR’s BDO established contact with the USCG Alameda Headquarters Office, District 11. Notices to Delta boaters and navigation aids needed to be provided for the EDB, as well as for the 10 new monitoring station piles installed in the north Delta, central Delta, and Suisun Bay as part of the 2015 EDB Project. Details needed to be provided for the navigational aids plans, the construction schedule, and the details for driving the piles that would house the monitoring network equipment and safety lights. Navigation aid anchorage piles were also proposed upstream and downstream of the EDB, as shown in Figure 3-14 and summarized in Table 3-4.

Figure 3-14 Location of Navigational Aid Ball Float Anchorage Piles

Table 3-4 Navigational Aid Ball Float Anchorage Piles at EDB Site

Pile #	Latitude	Longitude	Length	Tip Elevation	Head Elevation
Pile 1	38.0568901	-121.6725178	40 feet	-28.0 feet	+12 feet
Pile 2	38.0589375	-121.6713667	40 feet	-28.0 feet	+12 feet
Pile 3	38.0584605	-121.6701145	40 feet	-28.0 feet	+12 feet
Pile 4	38.0563749	-121.6712871	40 feet	-28.0 feet	+12 feet

The USCG was provided a map depicting the locations of the monitoring piles upstream and downstream of the proposed EDB, a table showing the longitude and latitude of the new monitoring station piles, an exhibit showing the alignment of the drought barrier with the locations of proposed navigational aid anchorage piles upstream and downstream of the barrier, and a picture showing a typical pile with monitoring equipment mounted on it. Additionally, a schedule was provided specifying that the construction of the drought barrier would start on May 7, 2015, with anticipated completion date of June 21, 2015. The USCG were also informed that the barrier would remain in place until October 1, 2015, with breaching of the barrier beginning that day and complete removal by November 15, 2015. The BDO requested the USCG to consider this correspondence to be the DWR's official notification and to provide listing in their weekly publication, "Local Notice to Mariners."

To mitigate navigational impacts, a navigational aid plan was prepared by DWR and provided to USCG. The plan was approved by USCG and implemented during installation, operation, and removal of the 2015 EDB. During pile installation, efforts were made to stay out of the navigation channel; most piles were about 15 to 30 feet away from the shore, with only two in open water because of channel bottom conditions. Signage and lights were installed upon completion of pile driving per USCG requirements, including a white light with a visibility of 3 miles that flashes every 4 seconds for 0.5 second per flash and an 18 x 18 inch "Danger" sign on top of each pile. All piles remained in the channel. No navigational incidents were reported during any phase of the 2015 EDB Project.

Delta Ferry Authority Mitigation

Background

In April 2015, DWR and RD 2059 executed an encroachment permit and agreement that acknowledged the ferry as the sole means of vehicle access to Bradford Island and included an agreement that "...in the event that the installation and/or operation of the EDB should negatively impact the operation of the Ferry, Permittee and the DFA shall work collaboratively to identify solutions to remedy the issue(s), and a mutually agreeable solution or solutions shall be immediately implemented at the sole expense of Permittee."

After installing the EDB in May 2015, the DFA, who operates the Victory II ferry between Jersey Island and Webb Tract and Bradford Island, began experiencing higher than normal flow velocities in Fisherman's Cut near the Bradford Island landing. The ferry experienced control problems that prevented safe ferry operations entering and exiting the landing, particularly during peak ebb tides. The high flows/velocities were perpendicular to the ferry as it entered/exited the landing and on occasion forced the ferry off its normal path — on at least one occasion forced the ferry onto a nearby tule berm and damaged both propellers. The DFA decided to cease operations on the ebb tides that occur during the ferry's normal operational daytime hours to prevent further damage to the ferry and ensure safety of the ferry riders and vehicles. The interruptions in the ferry operations continued during the time the EDB was in place until the barrier was removed in fall 2015.

Negotiations and Mitigation Agreement

After receiving complaints from the DFA, in addition to establishing the June 2015 damage agreement discussed in Section 2.2.2, DWR staff began discussions and conducted regular meetings with the DFA and representatives of RD 2059. The status of the meetings, agreements, and resulting mitigation work with the RD and DFA regarding the ferry was provided in weekly DWR Drought Emergency Management System (DEMS) updates. The following are summaries of those early weekly updates:

- On June 8, DWR staff met with RD 2059 and DFA personnel to discuss alternative solutions to ensure the Jersey Island to Bradford Island/Webb Tract ferry can fully operate. DWR and DFA personnel began investigating the proposed alternatives and expected to implement a selected alternative in the following weeks.
- On June 19, staff met with personnel from RD 2059 and DFA and agreed to make modifications to the ferry drive system to improve the ferry's ability to navigate and dock at the Bradford Island landing when ebb tide velocities are high (because of the presence of the EDB). The DFA would contract with a local marine architect and contractor to design and implement the modifications, and DWR will reimburse the authority for reasonable expenses. Work would entail repowering the ferry with replacement/upgrade engines, transmissions, and propellers. This one-time mitigation would enable the ferry to fully operate for the remainder of the time the 2015 EDB Project was in place as well as during any future installations of the EDB. A reimbursement agreement was prepared by Real Estate staff and executed with the DFA on June 26.
- On July 15, DFA staff indicated the design by a marine architect was completed. USCG design approval was needed and would take about 30 days to obtain. Equipment needed to upgrade engines, transmissions, and propellers was selected and cost quotes were being obtained. Costs and schedule for the repowering work were available. Work began on the ferry in September. A replacement ferry (Real McCoy) was leased during the time the Victory II was in dry dock for the repowering work.

- On July 22, DFA staff indicated they had requested a quote from the local marine repair company, Bay Ship & Yacht Co., who were available to do the work. Quotes were also obtained from suppliers for engines, transmission, and propellers. Work on the ferry was estimated to begin in early September and take about 4–5 weeks to complete.
- On July 28, the DFA provided the coordination group with a rough estimate (approximately $250,000 to $300,000 and five weeks in dry dock) received from Bay Ship & Yacht for the repowering work, with equipment provided by the DFA. This estimate was based on a previous similar repowering effort done for a Caltrans ferry. A more detailed and accurate quote was prepared prior to initiating work once the ferry was inspected by the contractor in dry dock. DFA also stated that the engine manufacturer, Cummins Pacific, LLC, indicated that the existing transmissions might be compatible with the new engines and therefore not require new transmissions — saving about $36,000 for the equipment and installation costs.

Subsequent Events

As repowering quotes, estimates on time needed for inspections, delivery estimates for engines and propellers, and the availability of the Real McCoy replacement ferry were updated, it became clear that the repowering work would not begin as early as planned. Combined with agricultural harvest timelines on Webb Tract that could not be completed without the Victory II loading capacity, the repowering was delayed to late December 2015 through January 2016.

- Difficulties and delays arose in getting USCG certification of the Real McCoy for use as a replacement ferry while the Victory II was in dry-dock for repowering. Eventually, the Real McCoy went into drydock in late January 2016, with USCG inspections beginning in February. Over the next several months, further USCG inspections, repairs, and improvements made to the Real McCoy to comply with USCG regulations, and the need to obtain USCG certifications from USCG headquarters in Washington D.C., delayed delivery of the Real McCoy for sea trials, crew training/checkout, and eventual service until June 2016.

- The Victory II ferry finally was placed in dry dock for repowering in early July 2016 after the Real McCoy was placed into service. The repowering work for the Victory II continued through late October after several months of drydock work, repairs to damage incurred during transportation to drydock, USCG inspections and additional compliance work, sea trials, and additional work necessary following the sea trials. The ferry was back in service at the end of October 2016 after over a year of multi-agency discussions, planning, design, and execution of the repowering work.

4.0 EDB Efficacy

The following sections present changes in observed salinity propagation patterns in 2015 that support the utility of the barrier. Hindcast simulations were also employed, with and without the barrier, to try to describe how conditions might have been different if the EDB had not been constructed. The hydrodynamics behind changes in salinity (tidal water levels, flow, and velocity) are described and further detailed, following discussions of salinity patterns.

4.1 Water Quality

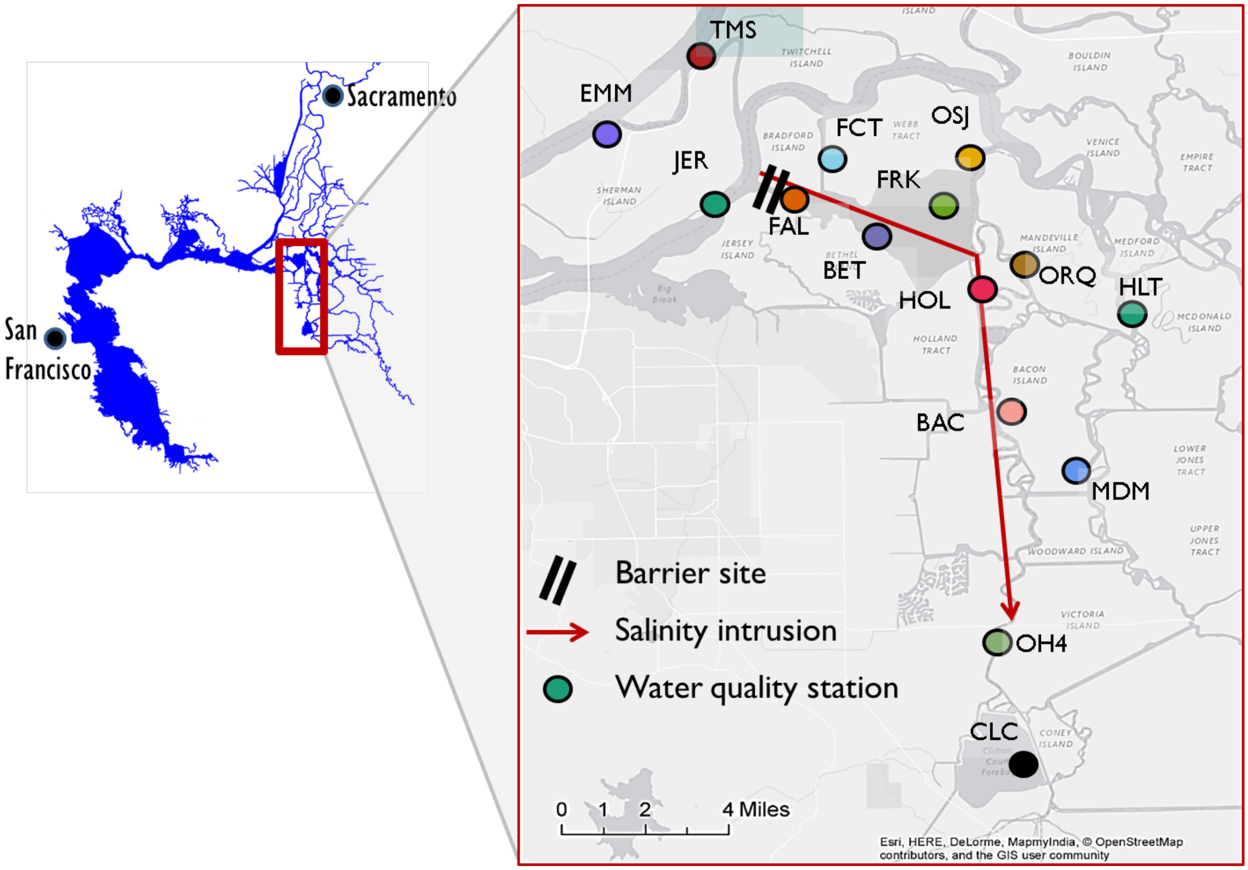
Water quality-related analysis was performed to assess whether the barrier reduced salinity intrusion into the Delta, and how this affected water supply (water cost or water savings). Both an analysis of measured data and simulation modeling were performed to inform these questions.

Also of interest is whether the barrier contributed to unanticipated adverse changes in Delta water quality constituents other than salinity. The impact to bromide levels are discussed further in section 4.1.2. Water quality in a broader sense is addressed in the *2017 Emergency Drought Barrier Water Quality Monitoring Report* (California Department of Water Resources 2017), which cites no major water quality impacts.

4.1.1 Comparison of Measured (Observed) Salinity Intrusion before, during, and after EDB installation

Figure 4-1 shows the typical path of salinity intrusion that the EDB was intended to arrest, as well as the water quality stations used in analysis and discussion.

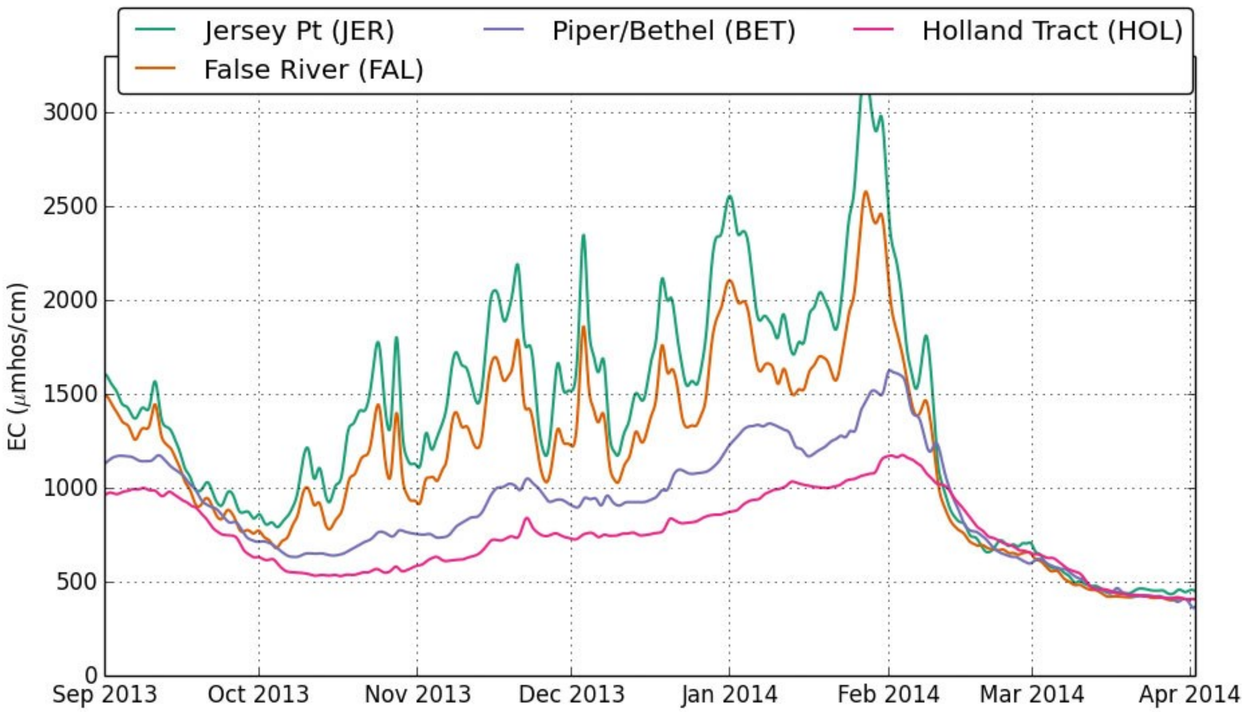
Figure 4-1 Main Salinity Intrusion Pathway and Water Quality Stations Used for Comparison



One way to illustrate that the EDB warded off salinity intrusion near Franks Tract is to compare how salt propagated through False River and Old River during high salinity periods from 2013–14 and 2014–15, a period without the EDB installed, and a period with the EDB installed, recognizing of course that other factors are also at play in any historical record.

Figure 4-2 shows the tidally filtered conductivity time series at several stations in and around Franks Tract, which is the main salinity intrusion pathway, from September 2013 through April 2014. The 2013–2014 pattern can be thought of as typical of most high-salinity seasons with no barrier. Trends in salinity are transmitted north to south — high salinity pulses that reach Jersey Point are usually felt at False River and then in dampened/delayed form at the Piper Slough/Bethel Island station in Franks Tract and just south at Holland Tract. The Bethel Island station in Franks Tract reaches 1600 µS/cm of conductivity, which is not unusual during sustained periods of 2000–3000 µS/cm of tidally filtered conductivity at Jersey Point. The 2013–2014 response is typical of most high-salinity seasons with no barrier.

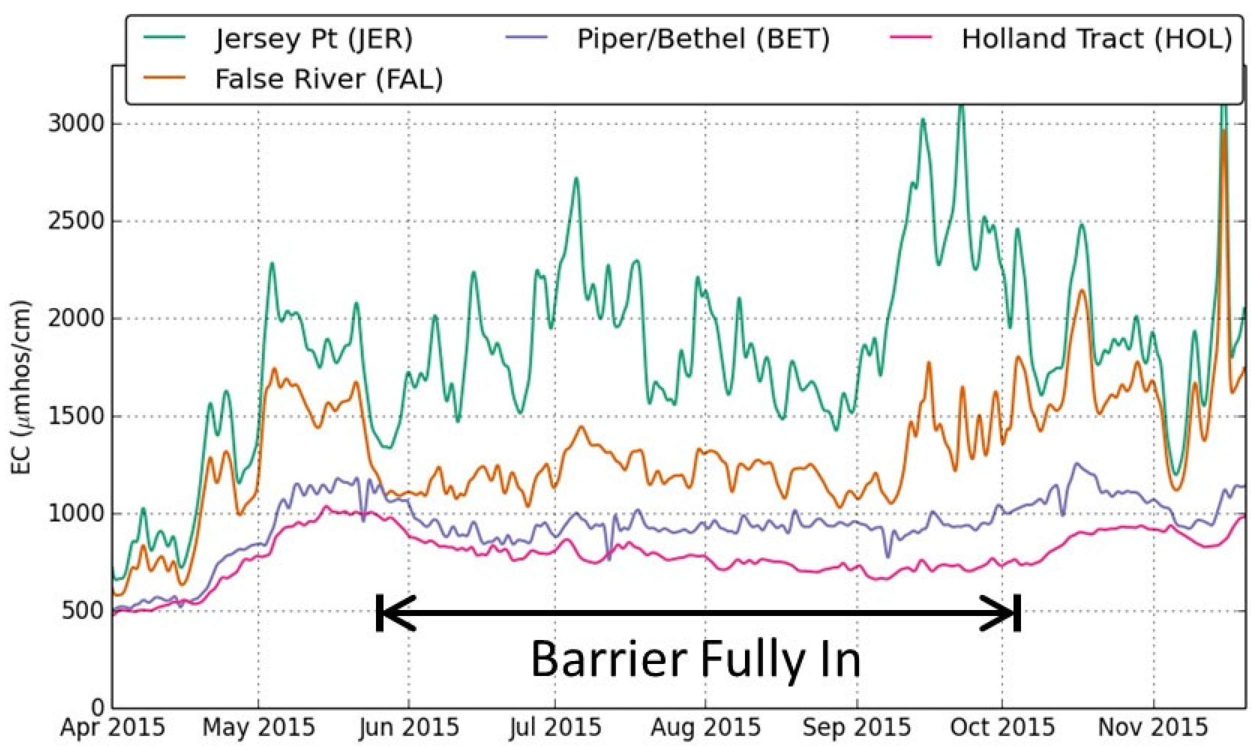
Figure 4-2 Tidally Filtered Salinity at Stations Along the Intrusion Pathway in 2013–2014



In early 2015, salinity patterns again began to set up similar to fall 2013/winter 2014. Figure 4-3 shows tidally filtered conductivity time series at the same key sites, leading up to, during, and immediately after EDB installation.

Salinity propagation exhibits the north-south pattern between stations, similar to the phenomenon shown in Figure 4-2, until the EDB was installed in late May. At that point, the stations upstream (south) of the EDB (FAL, BET, HOL) decoupled and ceased to react to San Joaquin River salinity even though the San Joaquin River was saltier and more dynamic at Jersey Point in 2015 than it was in 2013–2014. The False River station (FAL), which normally mimics the Jersey Point station closely, had a lower salinity level. Also, flows at the False River station were lower, from a tidal range of +/-45,000 cfs to a leakage of +/-2,000 cfs. The Bethel Island station (BET), which normally would be expected to reach at least 1,500 µS/cm during high salinity events at Jersey Point, instead slowly decreased in salinity and stabilized at a lower level, generally staying below 900 µS/cm. The normal relationships, with FAL trending close to JER, quickly reestablished in early October once the EDB was breached.

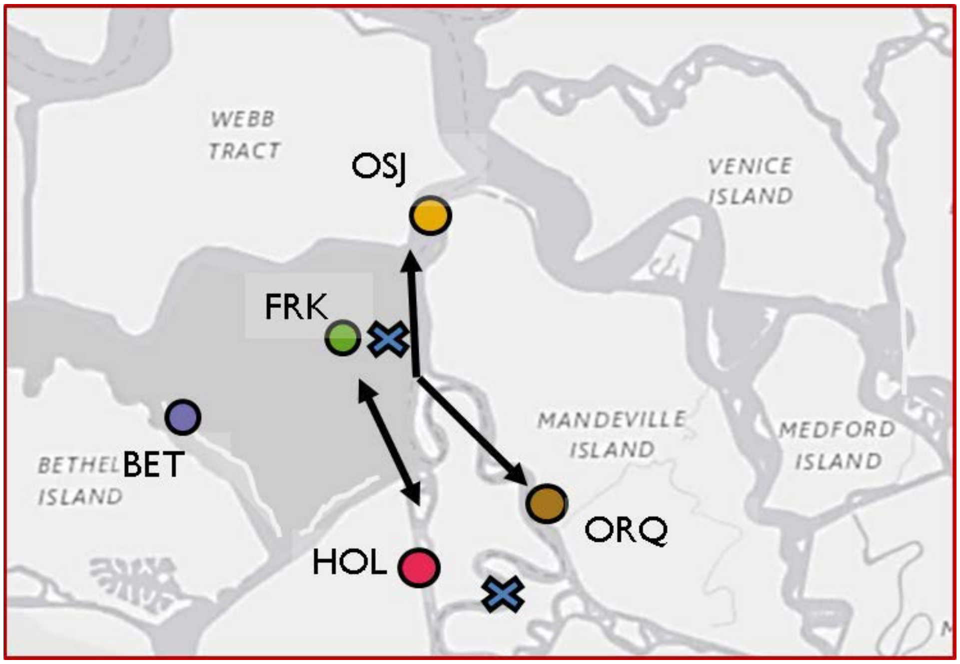
Figure 4-3 Tidally Filtered Salinity at Stations Along the Intrusion Pathway in 2015



The EDB certainly appears to have been effective at preventing further salinity intrusion after closure. It should also be mentioned that at least two other factors may have limited the rate at which fresher water reached the central Delta: (1) poor lateral mixing into the flooded island of Franks Tract from the channels running east of it, and (2) the low degree to which fresher Middle River water crosses over into the Old River system.

Poor lateral mixing into Franks Tract controls whether fresher Mokelumne River water is retained. The stations in or near Franks Tract that illustrate the lack of mixing are mapped in Figure 4-4 and plotted as time series in Figure 4-5. Salinity levels quickly equilibrated between the Old River at Quimby station (ORQ) and Old River at the mouth of San Joaquin River station (OSJ), more so than in prior years. Connectivity between the two is stimulated by increased tidal excursion at OSJ. Another station, Holland Cut (HOL), appears to be more strongly associated with the Franks Tract station (FRK). Neither of the stations in this second pair equilibrates with the fresher flows of OSJ and ORQ. This is an important consideration because low-flow Holland Cut is representative of the water quality that eventually propagates further south. The cause of low lateral mixing is likely related to submerged aquatic vegetation (SAV), which was dense enough in 2015 to effectively form a wall isolating the eastern side of Franks Tract. The influence of SAV on Franks Tract circulation is well known; however, SAV's influence was potentially greater in 2015 because it reduced fresh water inflows to Franks Tract and points south when they were needed the most.

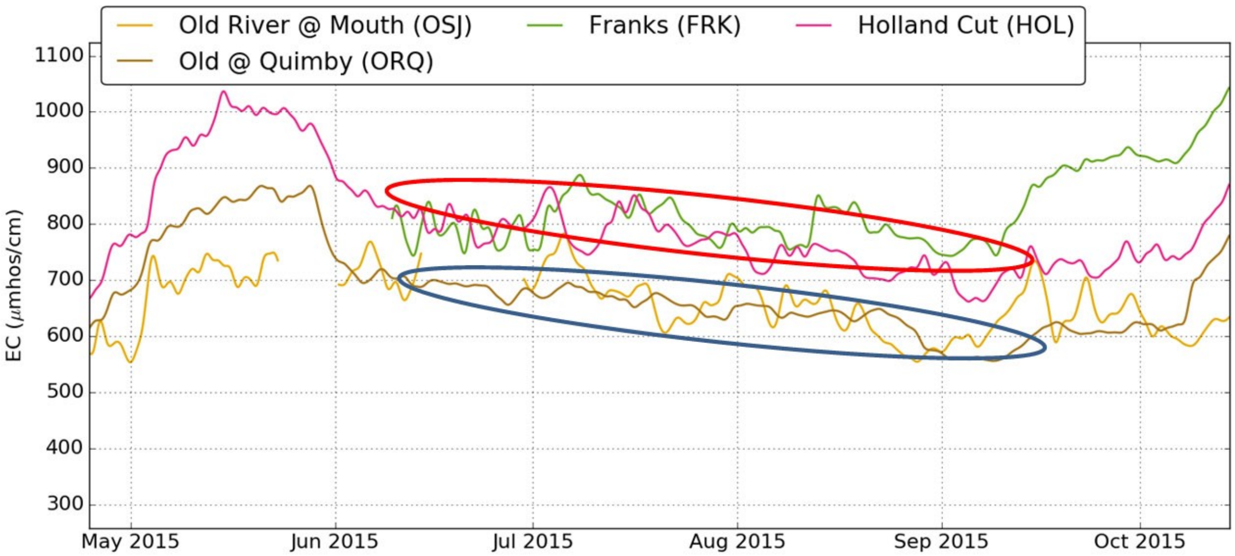
Figure 4-4 Pairs of Stations That Equilibrate in Salinity



Note: The pathways marked with an X are ones across which limited mixing probably occurs.

A second factor affecting performance in the southern part of the system is how little fresh Middle River water crosses over into the Old River system. Although the two systems have never fully mixed historically, observations in 2015 suggest that Old River south of Franks Tract was particularly isolated. In Figure 4-5 below, note the relatively close average EC of OSJ with ORQ and the relatively close trending of FRK with HOL mid-June through mid-September 2015.

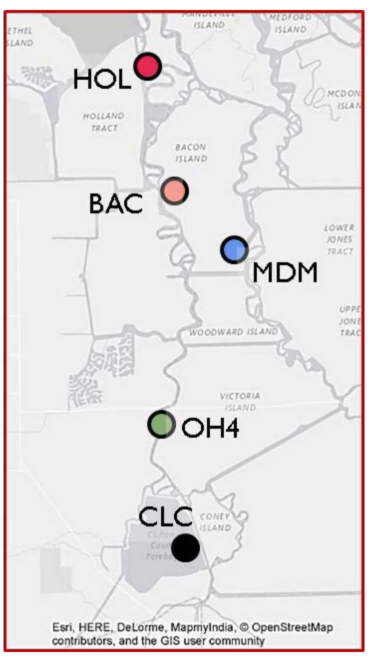
Figure 4-5 EC Stations Spanning the Eastern Side of Franks Tract



Note: Ovals illustrate the coherence between pairs of stations shown in Figure 4-4, which in turn demonstrates lack of lateral mixing.

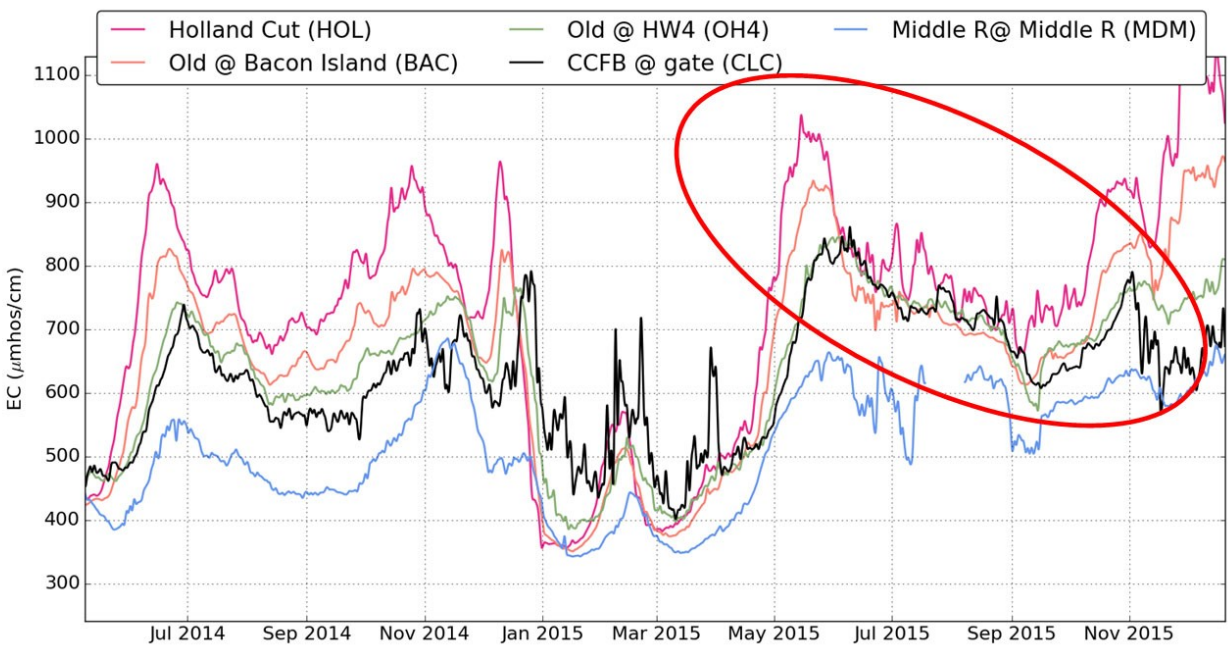
Figure 4-6 below, shows the location of four continuous water quality stations on Old River, from Holland Cut (HOL) to Clifton Court Gates (CLC), along with one reference station, Middle River (MDM).

Figure 4-6 Stations Used to Examine Old-Middle River Mixing



Tidally filtered conductivity at these Old River and Middle River stations is plotted in Figure 4-7. During the period of lowest pumping, from May until late August 2015, the time series for the Old River stations and Clifton Court are tightly banded, suggesting little influence from the surrounding lower salinity Middle River water. This banding is atypical of other recent years (e.g., 2014 can be seen in Figure 4-7). For efficacy, this raises certain questions: (1) Was reduced cross-system mixing caused by tidal changes attributable to the EDB? (2) or was it a result of other drought factors unrelated to the EDB, such as low residual flow toward the pumps? Pumping and net flow do affect the blend in Old River — the early September increase in pumping before the barrier breach re-establishes a gradient from north-to-south. To have better understood the relative influence of the EDB and net flow on regional mixing, flow, and water quality data could have been collected in Railroad Cut, North Victoria Canal, and Woodward Canal.

Figure 4-7 Stations South of Franks Tract on Old and Middle River



Note: The red oval highlights the period of banding with low north-south concentration gradient.

4.1.2 Modeled Comparisons of Barrier versus No Barrier

Retrospective modeling allows DWR to compare conditions in the Delta in 2015 with the EDB and without the EDB (i.e., the no-project alternative). The simulations presented are similar to studies conducted prior to EDB installation and issuance of the Temporary Urgency Change Petition (TUCP). The simulations differ from those studies in two important ways:

1. Flow, atmospheric, and tidal conditions are better known in hindsight.
2. The model employed a variant of the 3D Bay-Delta SCHISM model specifically refined and validated for flows with/without the EDB (i.e., not DSM2).

The simulations are based on historical flows, gate operations, and atmospheric and tidal forcing, except for sensitivity experiments involving the Sacramento River flows noted below.

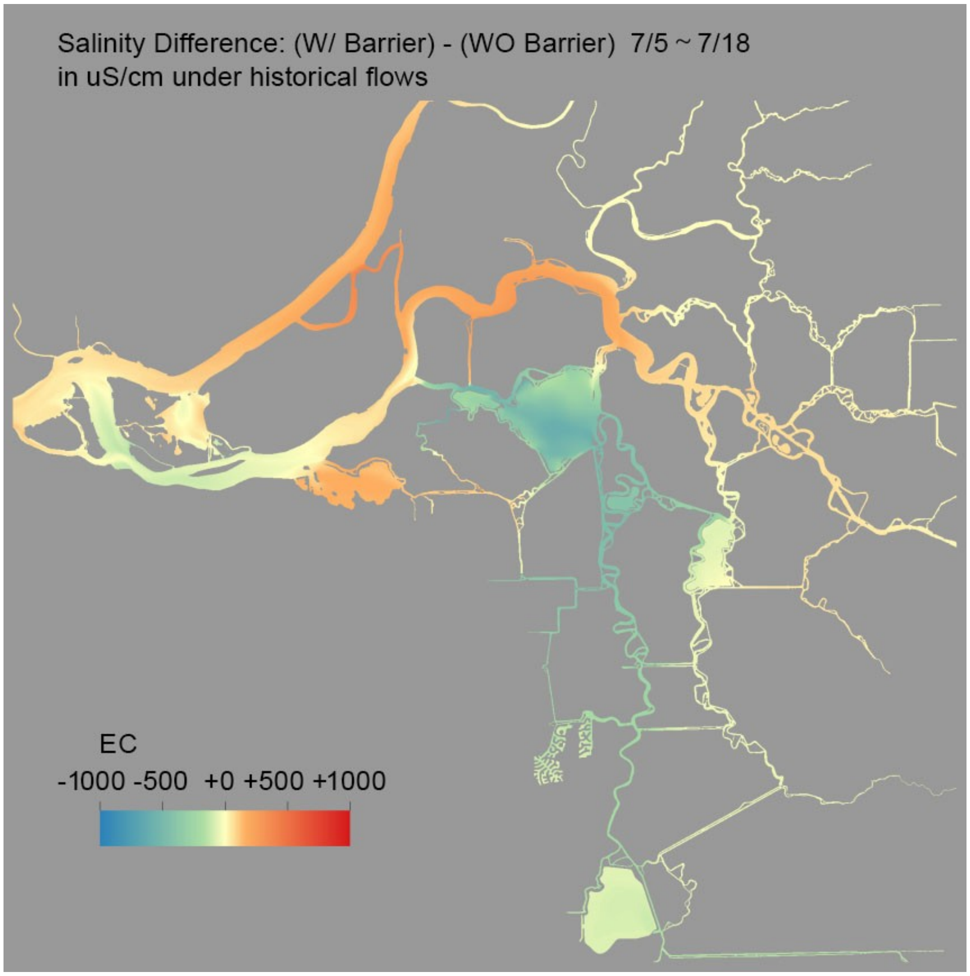
DWR modeled salinity impacts from two perspectives. The first is the water quality perspective, in which inflows are held equal at historical levels from 2015 and a comparison is made of water quality results between alternatives regardless of whether water quality exceedances occur. The second is the water cost perspective, in which a water quality goal is fixed and a comparison is made of how much water is needed to meet that goal under each alternative. It is often assumed that these goals are complementary; however, there is an important paradox that makes this untrue. Because the EDB reduces salinity upstream but not downstream where the controlling station for D-1641 is often located, it is possible for the EDB to improve water quality in non-controlling locations and still not save water.

Water Quality Perspective

The water quality impact of the EDB is straightforward — the EDB shields the mid-Delta from salinity intrusion. Figure 4-8 shows the EC difference during an averaged 14-day period in the beginning of July. The model used historical inflows and operations for both scenarios. Red areas on the map indicate saltier regions with the EDB and blue areas represent fresher areas with the EDB. Consistent with the data analysis in the previous section, modeling results indicate that the EDB reduced salinity in the interior Delta, particularly on Old River, by as much as 300 µS/cm EC.

The model also indicated an increase of salinity within the Sacramento River and around the Sacramento River-San Joaquin River confluence. Salinity increases in the west and north were similar to the decrease in the central Delta in absolute units but smaller in terms of relative change. Nonetheless, some such changes can be important because they play a role in D-1641 compliance or other DWR contractual obligations.

Figure 4-8 Conductivity Differences July 5–18 Resulting From the Barrier



Water Cost Perspective

To achieve water quality compliance during a drought, water cost is an important metric, requiring a clear definition of what is to be achieved or "bought." As DWR initially prepared to respond to the drought, DWR analyzed how much water would have been required to meet D-1641 objectives compared with how much water would have been required if the TUCP request was granted. This analysis concluded that the adjustment of the Emmaton EC objective to Three Mile Slough under the TUCP represented a substantial savings in water, a savings which would be expected to be evident both in modeled analysis and in actual operation.

DSM2 simulations did not predict that the EDB would contribute to additional water cost savings in the same, readily calculable way; what these simulations showed was that without the EDB, multiple stations would be on the verge of exceedance, but with the EDB, a single station would be the bellwether of compliance performance. Therefore, the EDB was expected to make compliance more readily achievable. The number of stations on the verge of exceedance relates to water cost indirectly in that with imperfect ability to predict what water quality distribution will occur, to be assured of compliance, an operator might have to over-release (compared to how the model would operate) to be confident of avoiding exceedance in real-world operations.

Subsequent analysis leads to the same conclusions, but events during the summer of 2015 also suggested ways in which D-1641 compliance may not be the only basis for water cost. The other bases for water cost are described below.

Controlling Stations Drive Outflow and Water Cost; Emmaton Challenging

Compliance is generally determined by one or two “controlling” stations. Under a low-flow hydrology, the D-1641 objective that usually determines outflow and water cost is the EC objective at Emmaton. This objective is so challenging in a critical, low export year that meeting it implies objectives at neighboring stations (e.g., Jersey Point, Rock Slough, San Andreas Landing) will be met with some margin to spare. Thus, Emmaton was the ideal location for a TUCP request because allowing intrusion upstream of it saves water (e.g., hundreds or perhaps thousands of cfs of outflow) without immediately shifting the burden of compliance to other locations.

Next-Most-Challenging Stations: Three Mile Slough, Jersey Point, Rock Slough/Bacon

As a result of the successful appeal to the SWRCB (the TUCP), the Emmaton objective was moved upstream to Three Mile Slough in 2015. This location is a balance point, where water quality at the stations at Three Mile Slough, Jersey Point, and Rock Slough (aka Bacon Island at Old River or “Bacon”) are all possible limiting factors depending on flows, DCC operations, and the presence of the EDB. Figure 4-9 (with the EDB) and Figure 4-10 (without the EDB) show modeled EC at these locations from June 1 through August 15, 2015. The simulations used historical flows and operations and included a simulation performed with historical flows incremented by 500 cfs, which would be the approximate amount needed for full compliance for either with or without the EDB (historically, there was a brief period of exceedance in July). The modified D-1641 objectives for each location are indicated with a gray line. Note though, that the agricultural objectives at Three Mile Slough and Jersey Point do not apply after August 15.

The sets of simulation results shown in figures 4-9 and 4-10 suggest similar water costs of (modified) D-1641 compliance, with differing controlling locations. For example, both simulations, with or without the EDB, require an additional 500 cfs to achieve full compliance. The two simulations differ though, with regard to the controlling location. Threemile Slough was the limiting location in the with-barrier simulations, and Rock Slough (Bacon) for without-barrier simulations. With the EDB, the limiting objective is at Three Mile and the concern is limited to Three Mile Slough and Jersey Point. Without the EDB, the limiting objective is at Rock Slough (Bacon); however, the limiting objectives at Three Mile Slough and Jersey Point are also threatened, exhibiting three competing concerns for water operators and a saltier central Delta overall. Without the additional 500 cfs of flow, months-long exceedance likely would have occurred, accompanied by high values everywhere in the central Delta. By contrast, the modeled historical (with EDB) exceedance at Three Mile Slough in early July was relatively brief, as shown in Figure 4-9. This exceedance of D-1641/TUCP objectives occurred because of a surprisingly large, offshore, low-pressure event — such events cause water levels in San Francisco Bay and the Delta to rise, which increases salinity intrusion. Water operators normally provide a safety margin to accommodate such an increase, and in the case of a surprisingly strong event would rely on export cuts as a rapid response. The model results for with EDB fit well with historical records.

Other Water Quality Constituents

The foregoing discussion has focused on the D-1641 salinity objective, the only water quality goal governing operations in the summer of 2015 for the central Delta. Nevertheless, an additional consideration is that informally, water operators also sought to maintain sufficiently low bromide concentrations to offer relief to water agencies in the South San Francisco Bay. Under the no-barrier alternative, the EC in the mid-Delta reached close to 1,000 µS/cm all season long, which would not have maintained a corridor of sufficiently low bromide water during an emergency. For this purpose, an EC at Banks of 700–800 µS/cm was considered to be on the high end of acceptable, and this is what was achieved in 2015 with the barrier.

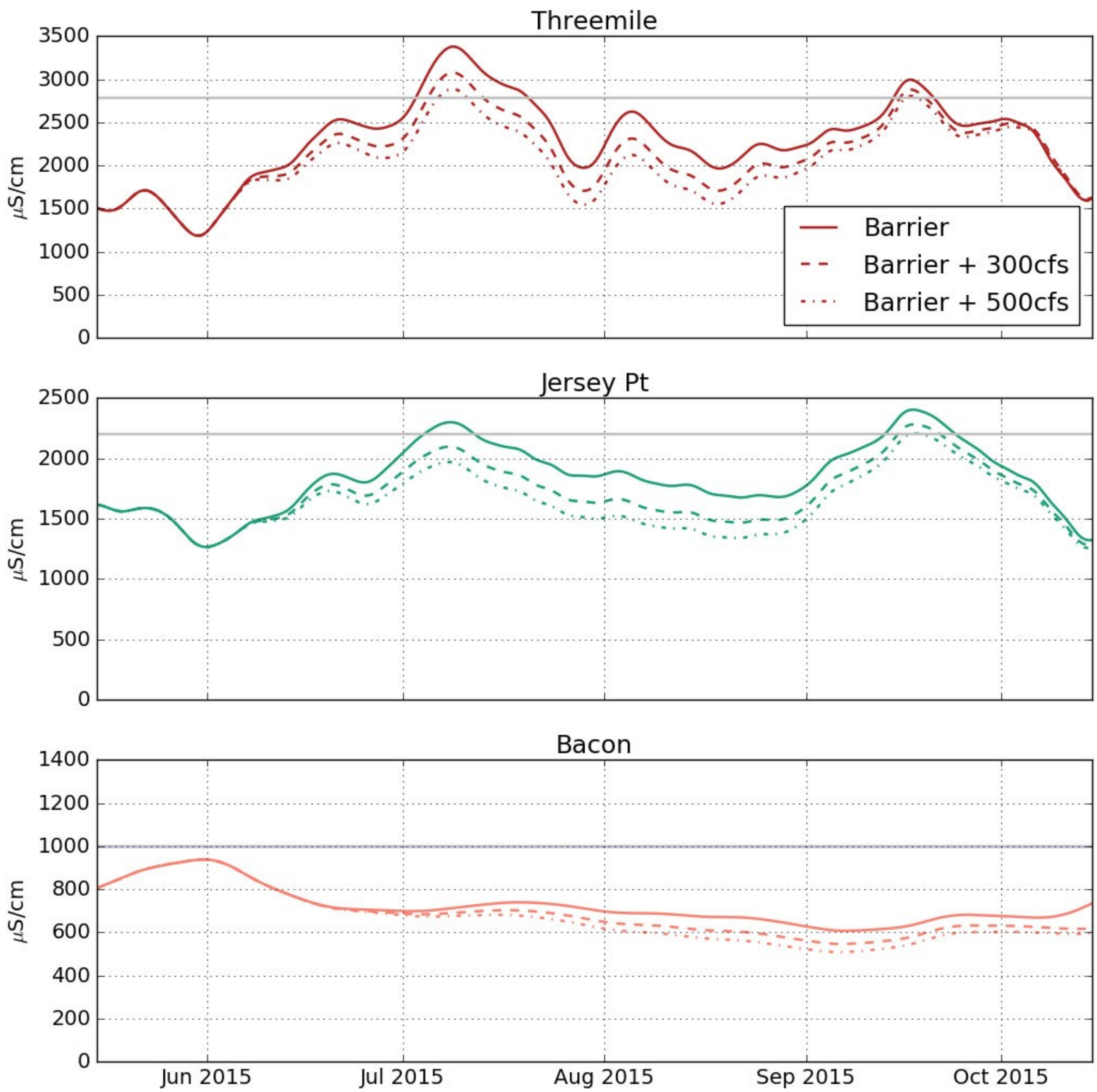
Synthesis of Analysis Regarding Water Cost

Synthesizing the analyses, DWR's Bay Delta Office derived a range of estimates for water cost savings associated with the 2015 EDB Project:

1. The strictest estimate is based on idealized D-1641 compliance alone. By this standard, the EDB yielded no marginal savings readily quantifiable by comparing DSM2 simulations, but offered risk and complexity reductions supporting the achievement of water cost benefits attributable to the 2015 TUCP (approximately 100,000 acre-feet).
2. An intermediate estimate allowed for brief historical exceedances downstream of the barrier since there was strict D-1641 compliance in the interior and south Delta where salinity is harder to flush out. Simulations indicate that without the EDB, an increment of flow (over 500 cfs) would have been required over a longer period to achieve compliance (at Rock Slough) than would have been required with the EDB. The presence of the EDB consequently saved the SWP approximately 75,000 acre-feet of water.
3. The highest estimate of marginal savings resulted from a simulation that required the same salinity that was achieved in the central Delta in the summer of 2015 with the barrier be matched in a simulation without the barrier. The actual levels of salinity achieved in the summer of 2015 provided a safety margin for bromide for municipal uses and thus reduced risk. DWR estimates achieving this level of salinity protection would have required an additional 150,000 acre-feet of water.

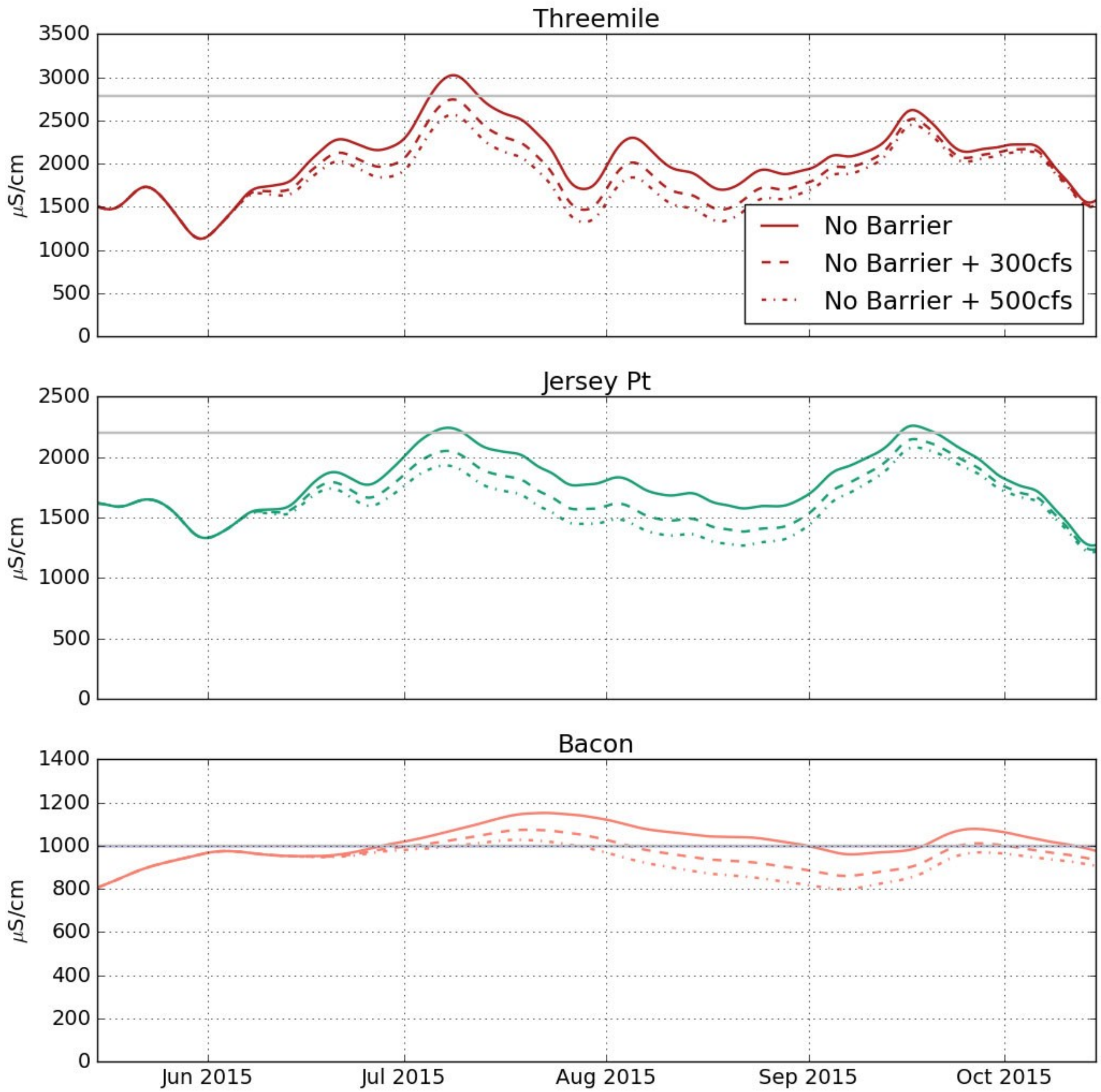
These savings estimates are increments above the savings already provided by the TUCP, which the EDB greatly facilitated. In the design phase of the EDB analysis, DWR predicted water savings from the agricultural objective component of the TUCP to be approximately 100,000 acre-feet. Although these estimates have not been updated, it appears the actual savings may have been higher according to DWR's Operations and Maintenance Division staff.

Figure 4-9 Modeled Conductivity at the Three Most Likely Limiting Compliance Locations Under the TUCP with Barrier: Three Mile Slough at the Sacramento River, Jersey Point, and Bacon Island at Old River



Note: The gray line shows the applicable D-1641/TUCP objective; note that Three Mile Slough and Jersey Point are agricultural objectives that do not apply after August 15.

Figure 4-10 Modeled Conductivity at the Three Most Likely Limiting Compliance Locations Under the TUCP With no Barrier: Three Mile Slough at the Sacramento River, Jersey Point, and Bacon Island at Old River



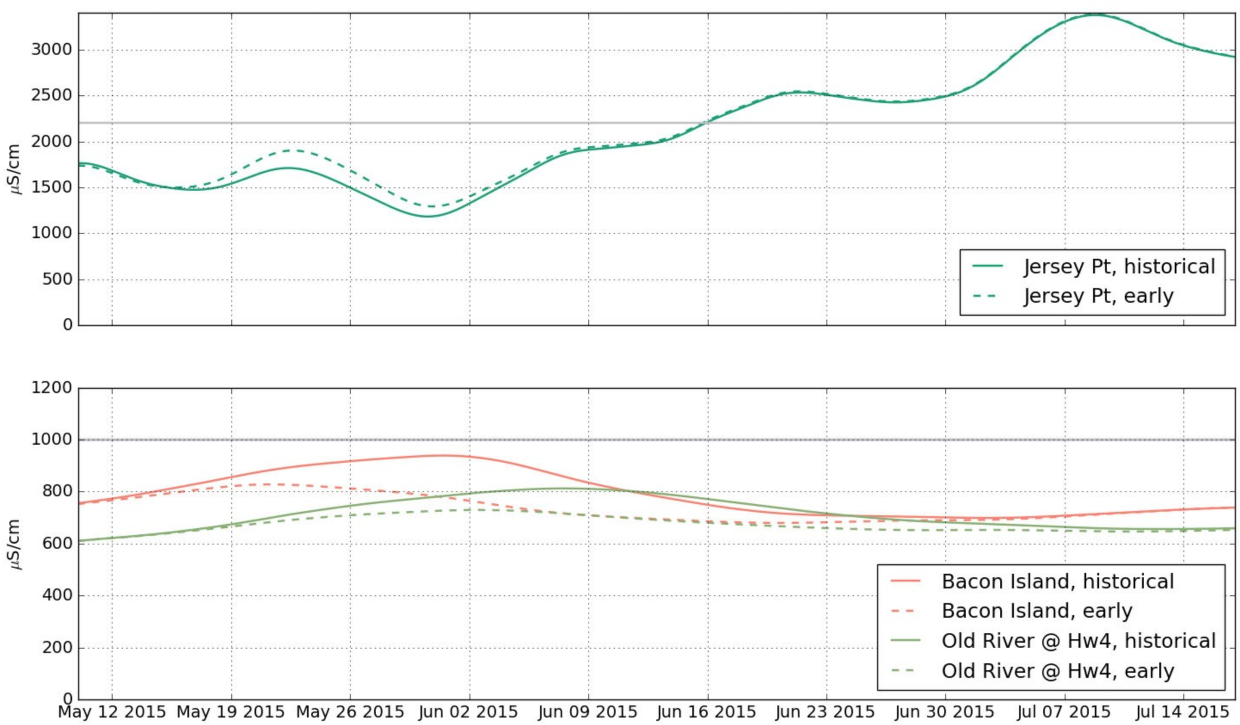
Note: The gray line shows the applicable D-1641/TUCP objective; note that Three Mile Slough and Jersey Point are agricultural objectives that do not apply after August 15.

The Importance of Barrier Installation Timing on Efficacy

The foregoing analysis has assumed that the EDB be installed with the historical timing with which it was installed in 2015, or that it not be installed at all. To inform possible future barrier installations, the following analysis determines how the timing of barrier installation and removal may changed its effectiveness.

In 2015, the EDB was completed at a time when salinity intrusion had already started to reach the central Delta, even though conditions were well within historical limits. Modeling results suggested a closure timing shift two weeks earlier than the actual installation would have enhanced the EDB efficacy by avoiding the surge in salinity that occurred in early June as a result of wind and offshore barometric forcing. Those benefits would have extended through June, as shown in Figure 4-11. Simulations conducted with lower salinity than actual initial conditions similarly held on to this low salinity state for more than a month, and this duration agrees with the residence time in the channels of the central Delta and the pumping rate. Because the EDB was fully operational for approximately four months, this period of improvement could have been significant.

Figure 4-11 Effect of Advancing the Closure Date by Two Weeks at Jersey Point (Top) and Bacon Island and Hwy 4 (Bottom)



4.2 Hydrodynamics

The EDB produced numerous changes in water levels and the flow near Franks Tract. DWR analyzed changes in tides (water levels), flows, and velocity, using both models and field data to track secondary effects and better understand the circulation changes. Overall, the EDB diverted tidal energy from West False River through the San Joaquin River up and around Bradford Island, consequently increasing excursion. Although the EDB did change tidal patterns through the region, impacts on scouring and water level were minimal; the greatest effects were noticed at Fisherman's Cut.

4.2.1 Tidal Water Levels

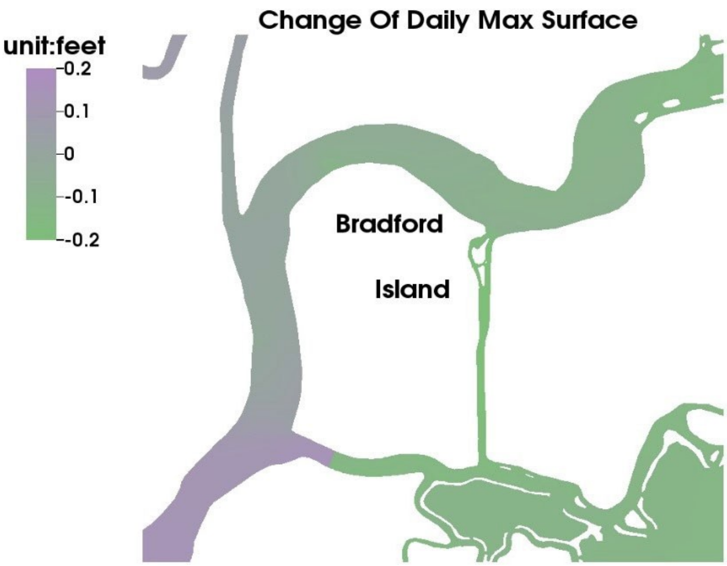
The main effect of the EDB on water levels was that tidal water travelled over a longer path through Franks Tract. Consequently, tides (both low and high) were 3–4 hours out of phase on either side of the EDB, and the juxtaposition of two different phases of the tide cycle produced measurable water level differences. Aside from these timing differences, the changes in tidal range caused by the EDB were modest.

Local stakeholders expressed concern about water levels near Bradford Island. RD 2059 identified four low spots on the levee that may have been vulnerable to changes in stage. This concern presented an opportunity to study water level differences. DWR used both models and traditional tide analysis to verify how high-water levels and tidal amplitudes may have altered the efficacy of the EDB. The main result of this investigation was that the EDB caused a local water level increase on the San Joaquin River just upstream of the EDB and a reduction of tidal maximum water levels at the four low spots. Tidal effects in the region were minimal, less than 0.2 feet of change in peak tide and amplitudes. This change is minor when compared to normal daily tidal fluctuations, storms, and other sources of seasonal water level variations.

Figure 4-12 Low / Vulnerable Sections of Levees Identified by DWR and RD 2059

The modeling studies supporting this conclusion were simulated “with EDB (actual)” and “without EDB” using the 3D Bay-Delta SCHISM model. Figure 4-13 shows an overview of the changes in high tide and the difference in maximum water levels on June 16 (spring tide) resulting from the introduction of the EDB. Some areas on the west side of Bradford Island may have experienced increases in tidal maxima of up to 0.01 foot (roughly a tenth of an inch). The remaining portions of Bradford Island experienced a reduction as previously mentioned.

Figure 4-13 Change in Daily Maximum Water Levels (Barrier Minus No Barrier) for June 16, 2015 (Spring Tide)



The modeled differences introduced by the EDB at the individual levee “low spots” are shown as time series in Figure 4-14 through Figure 4-17. At all four locations, the EDB caused a minor reduction in maximum water levels, typically around 0.1 foot but up to 0.2 foot at Low Spot #4.

Figure 4-14 Simulated Water Levels for Low Spot #1 With Daily Maximum Values Labeled

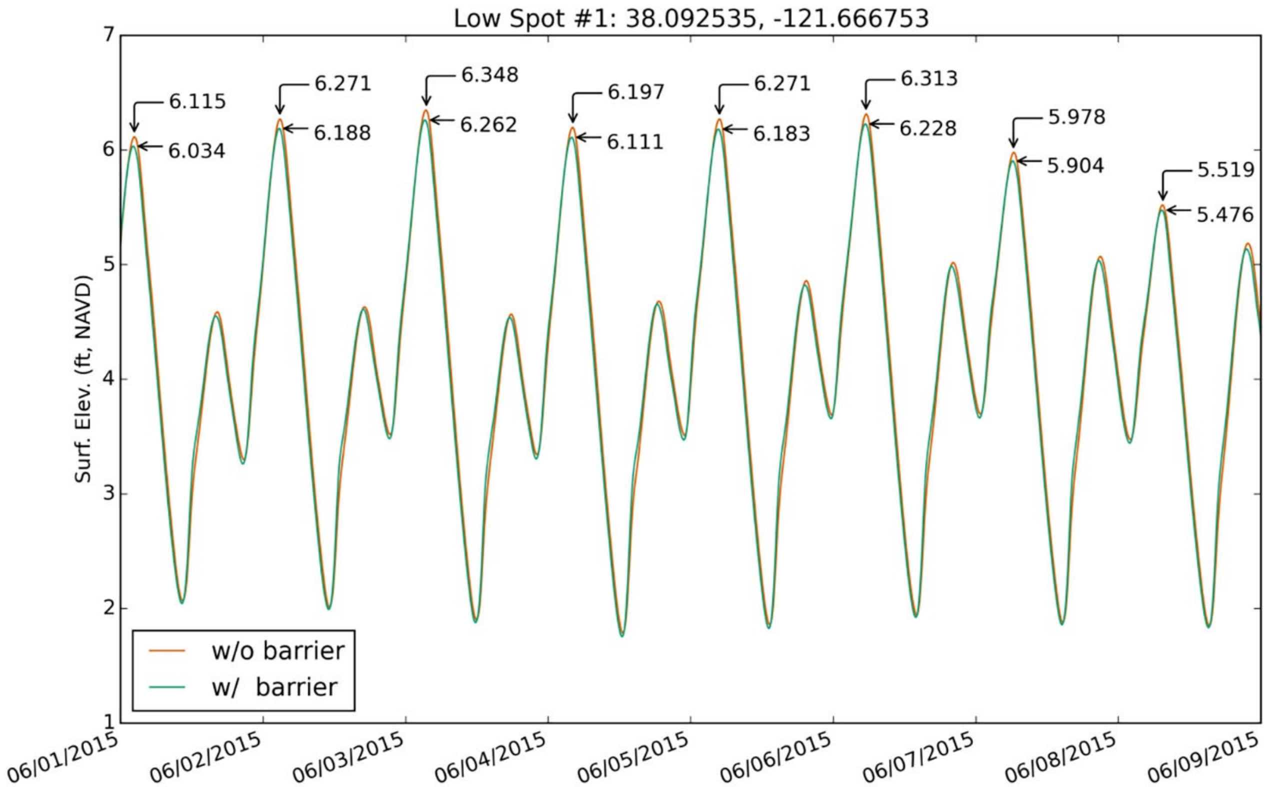


Figure 4-15 Simulated Water Levels For Low Spot #2 With Daily Maximum Values Labeled

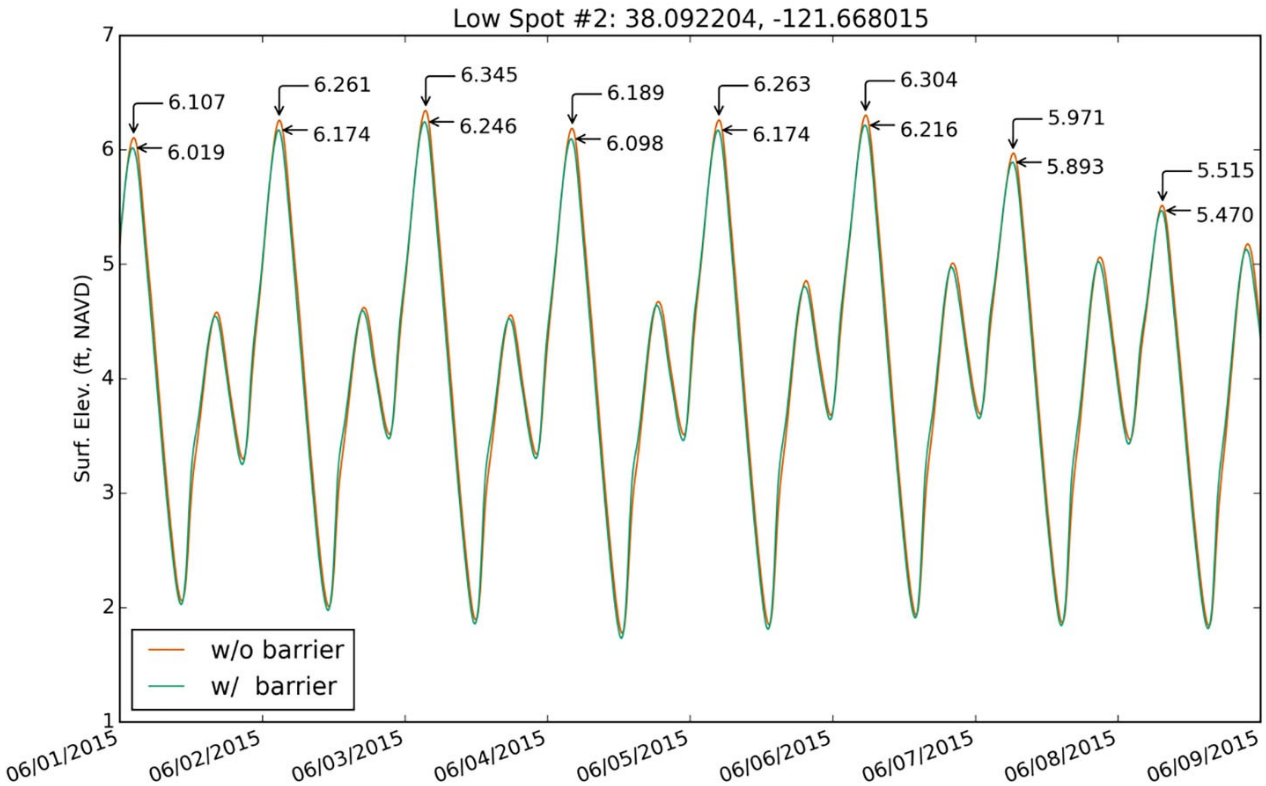


Figure 4-16 Simulated Water Levels For Low Spot #3 With Daily Maximum Values Labeled

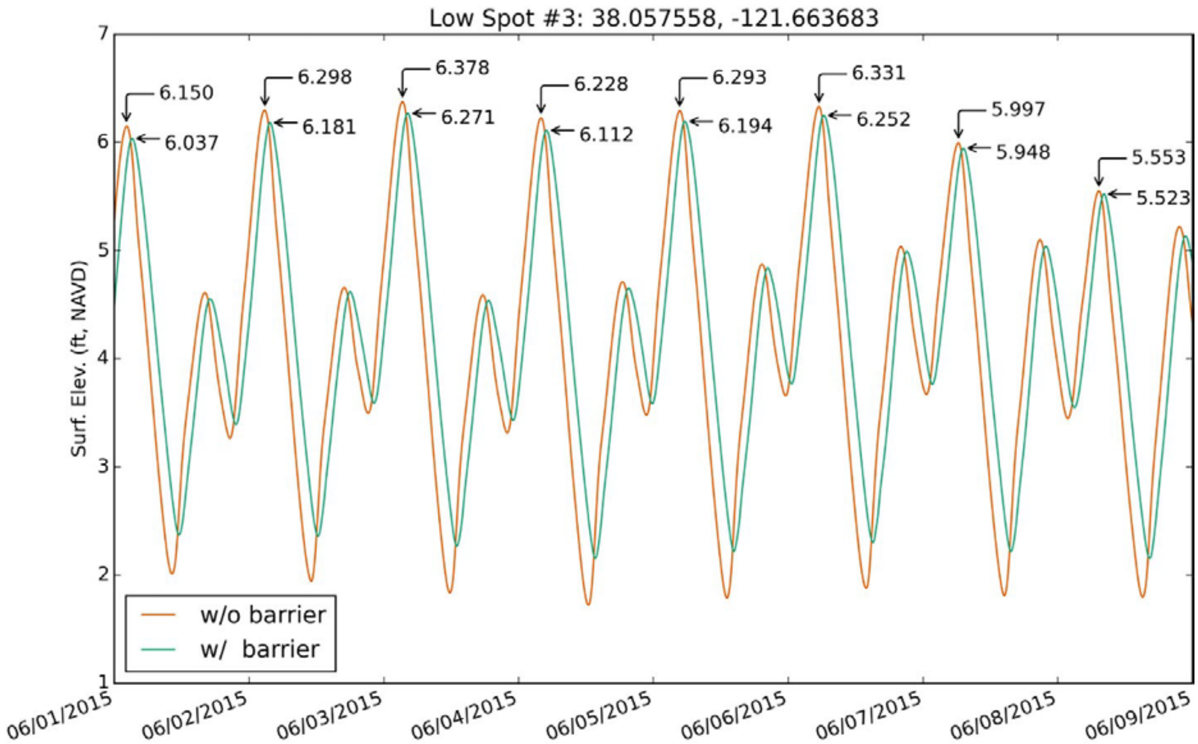
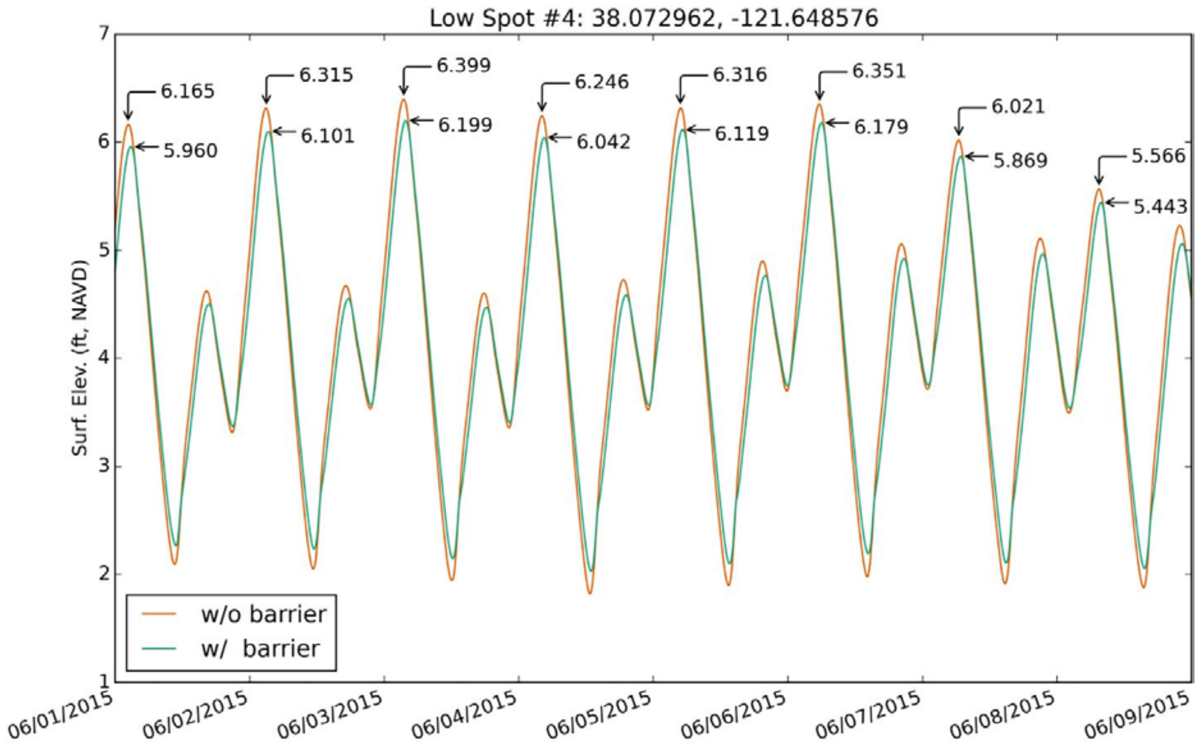


Figure 4-17 Simulated Water Levels For Low Spot #4 With Daily Maximum Values Labeled



Tidal analysis based on field data

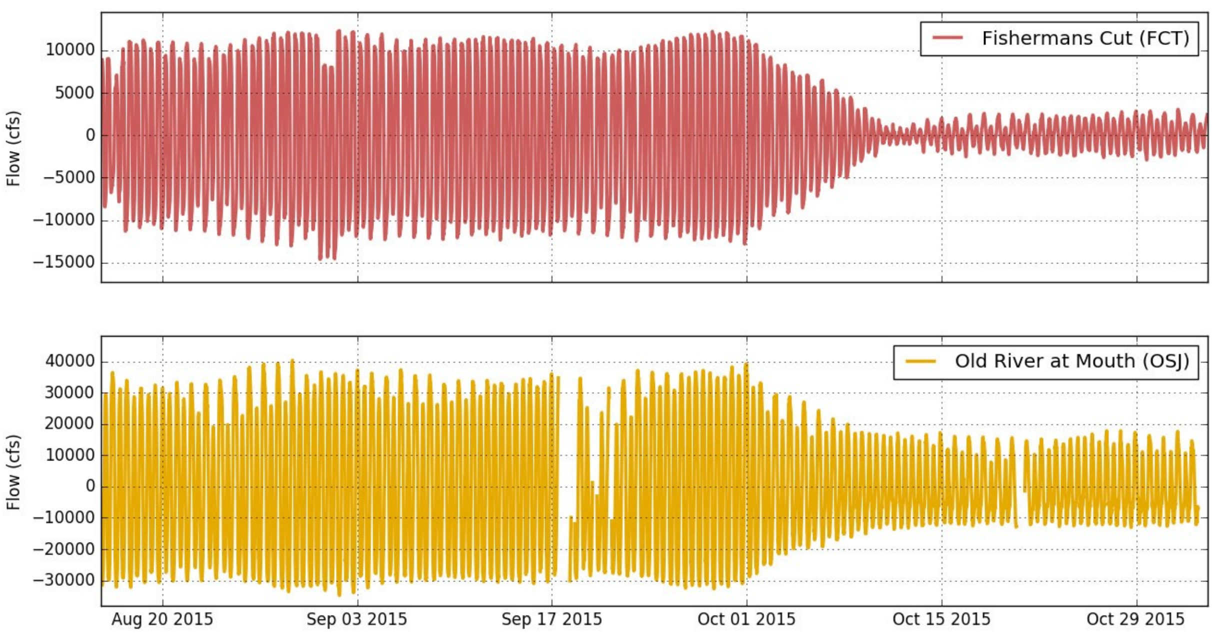
In addition to modeling, DWR performed traditional tidal analysis at the USGS False River location before and after installation of the EDB, using only observed data. Tidal analysis is analogous to a prism separating light: tidal analysis separates the tide into its main constituents (frequencies related to astronomical cycles) and estimates its strength before and after the EDB. The advantage of tidal analysis is that it provides a before-and-after comparison of local water-level field data while properly accounting for the hydrodynamic differences that would be expected over time. The tidal analysis was repeated in one month blocks, with several periods in spring, to confirm the expected natural variation in results from small changes in the analysis period. The tidal analysis confirmed that a statistically detectable change had occurred, amounting to a reduction of approximately 0.1 foot in the amplitude of the largest two tidal constituents (M2 and K1) for the site at False River where changes were largest. The reductions in tidal constituent amplitudes were expected to reduce the overall tidal range at False River by 0.1–0.2 foot during spring tides.

4.2.2 Flow

The EDB had a relatively large effect on tidal range near Franks Tract. The False River tidal range decreased from 50,000 cfs (without EDB) to approximately 2,000 cfs (with EDB) based on modeled and measured results. As False River no longer conveyed flow because of the EDB, Fisherman's Cut and Old River (at the mouth of the San Joaquin River) became the main pathways of tidal flow entering and exiting the Franks Tract area. Fisherman's Cut and Old River experienced the most prevalent changes in local velocity, tidal flow, and net flow. The timing or phase of the tide was also affected because of the longer tidal propagation route around Franks Tract. The two stations both experienced significant increases in the tidal range of discharge with the EDB in place.

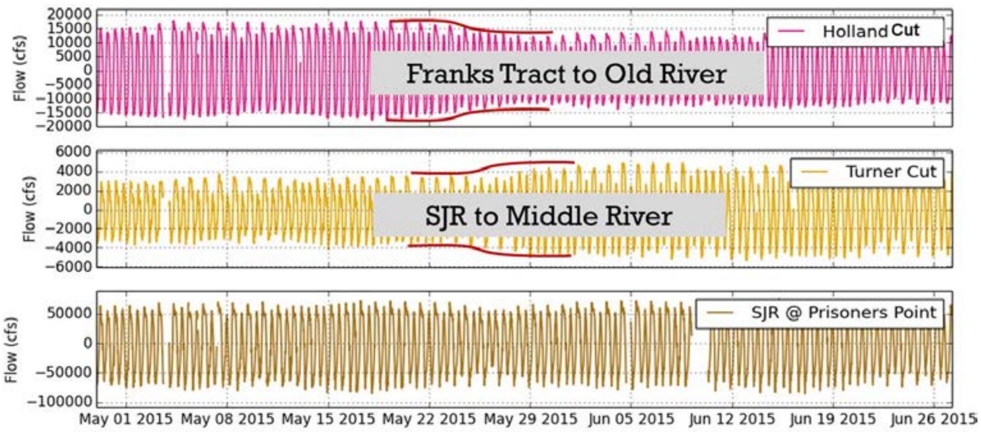
Figure 4-18 shows the tidal range by plotting the flow at Fisherman's Cut and Old River for a period before and after the EDB was breached. The normal flow regime returned once the EDB was fully removed.

Figure 4-18 Changes in Tidal Range of Flow, Fisherman's Cut and Mouth of Old River



The EDB affected tidal exchange (but not net flow) on other channels as well. Figure 4-19 shows tidal ranges at the Holland Cut, Turner Cut, and San Joaquin River at Prisoner's Point stations. Holland Cut is typical of channels south of Franks Tract, where tidal range was reduced. Turner Cut is typical of the connections between the San Joaquin River and Middle River, where tidal range was increased. Minor changes were observed in the San Joaquin River.

Figure 4-19 Changes in Tidal Range at Holland Cut, Turner Cut, and the San Joaquin River at Prisoners Point

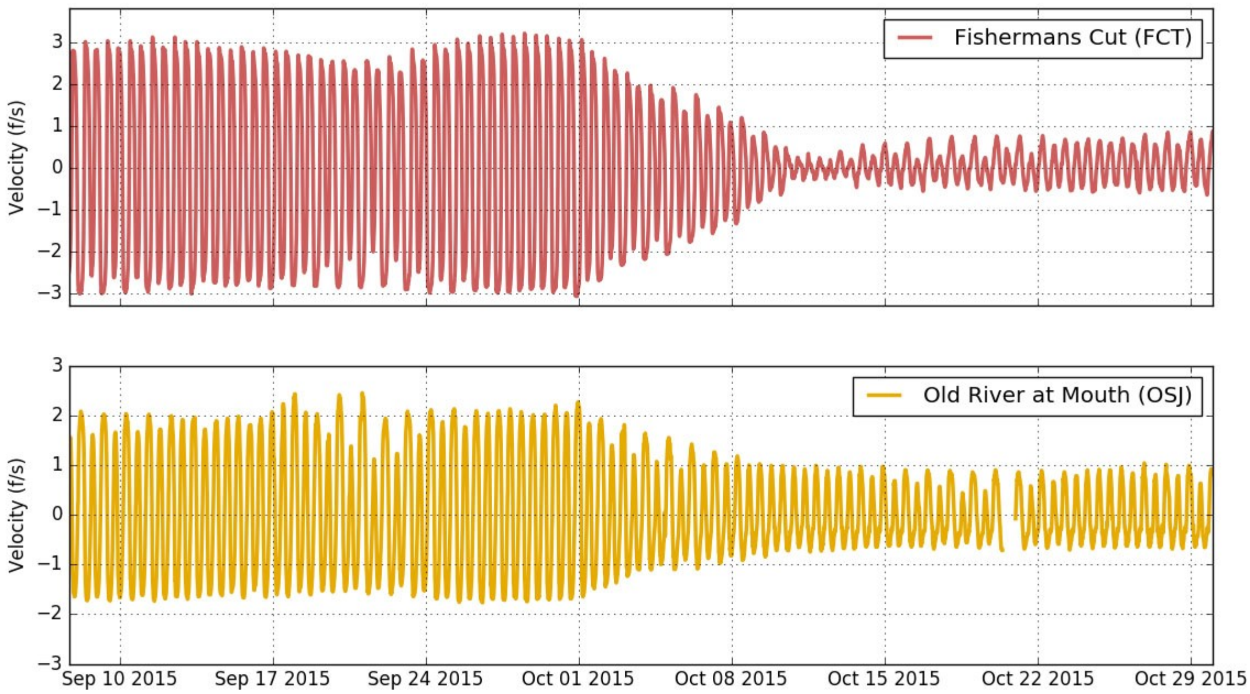


4.2.3 Velocity

DWR tracked velocity changes for multiple reasons during operation of the EDB. Concerns included detection of any waterways with unacceptably increased scour potential and detection of the effects of velocity changes on ferry operations.

DWR initially identified Fisherman's Cut as a monitoring area because of the magnitude of change experienced with the EDB when compared to the baseline conditions in preparatory simulations. Employing high-resolution levee and scour monitoring, DWR collected the data supporting the following figures. Figure 4-20 shows the change in range of velocity before and after the EDB was removed. Patterns of change in velocity closely mirror changes in flow. At Fisherman's Cut, the velocity range changed from less than 1 foot per second (ft/s) post-EDB to just over 3 ft/s while the EDB was in place.

Figure 4-20 Changes in Tidal Velocities Around the Time of Breach at Fisherman's Cut and the Mouth of Old River (OSJ)



Velocity analysis (boat-based acoustic Doppler current profiler [ADCP] velocity mapping and high-resolution modeling) conducted near the Bradford Island Ferry launch indicated that local velocity similarly increased from 1 ft/s to 3–3.5 ft/s. Figure 4-21 and Figure 4-22 show velocity observations using ADCPs tides at peak flow before and after the EDB installation, respectively. Strikingly, this comparison shows that velocities substantially increased in Fisherman’s Cut but not in False River upstream of the EDB.

Figure 4-21 Observed (ADCP) Velocities on 4/22/15 Before the Barrier Installation at Peak Flow

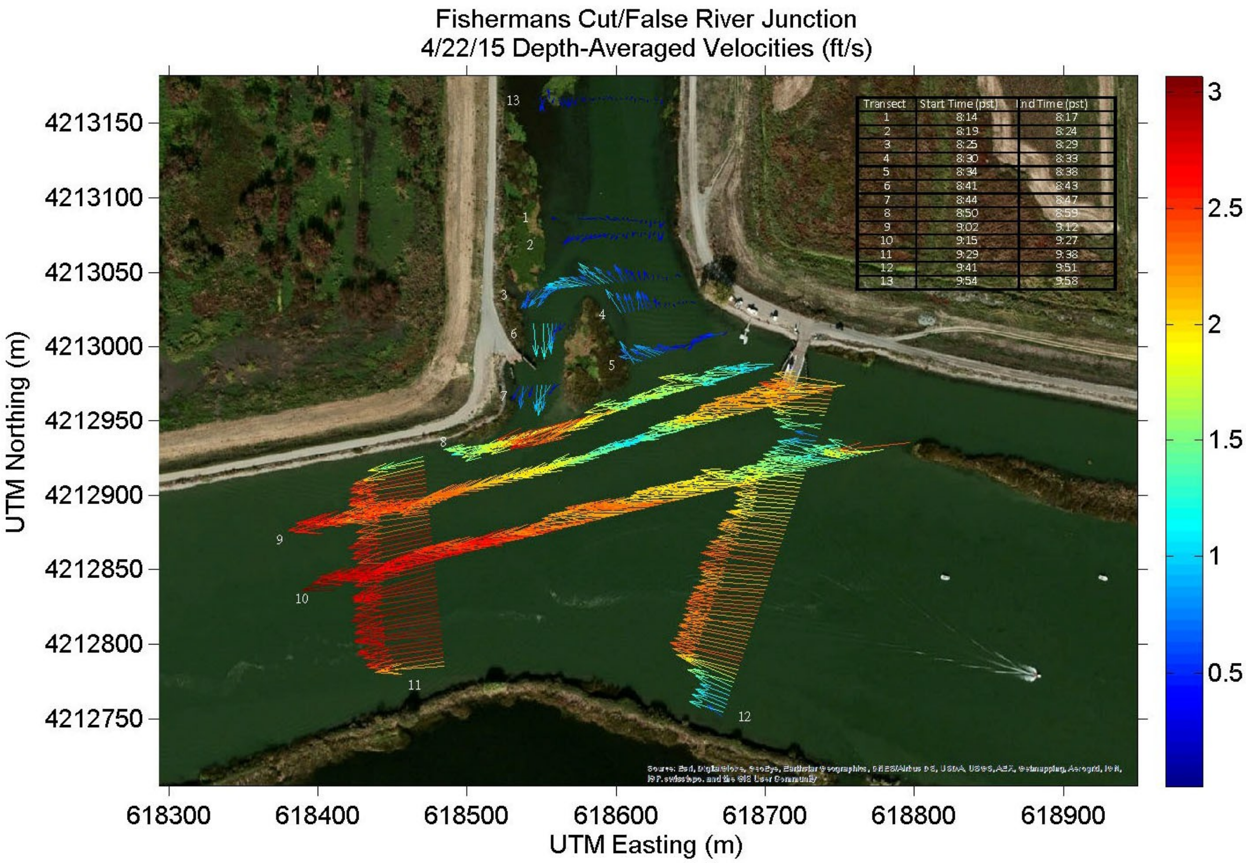
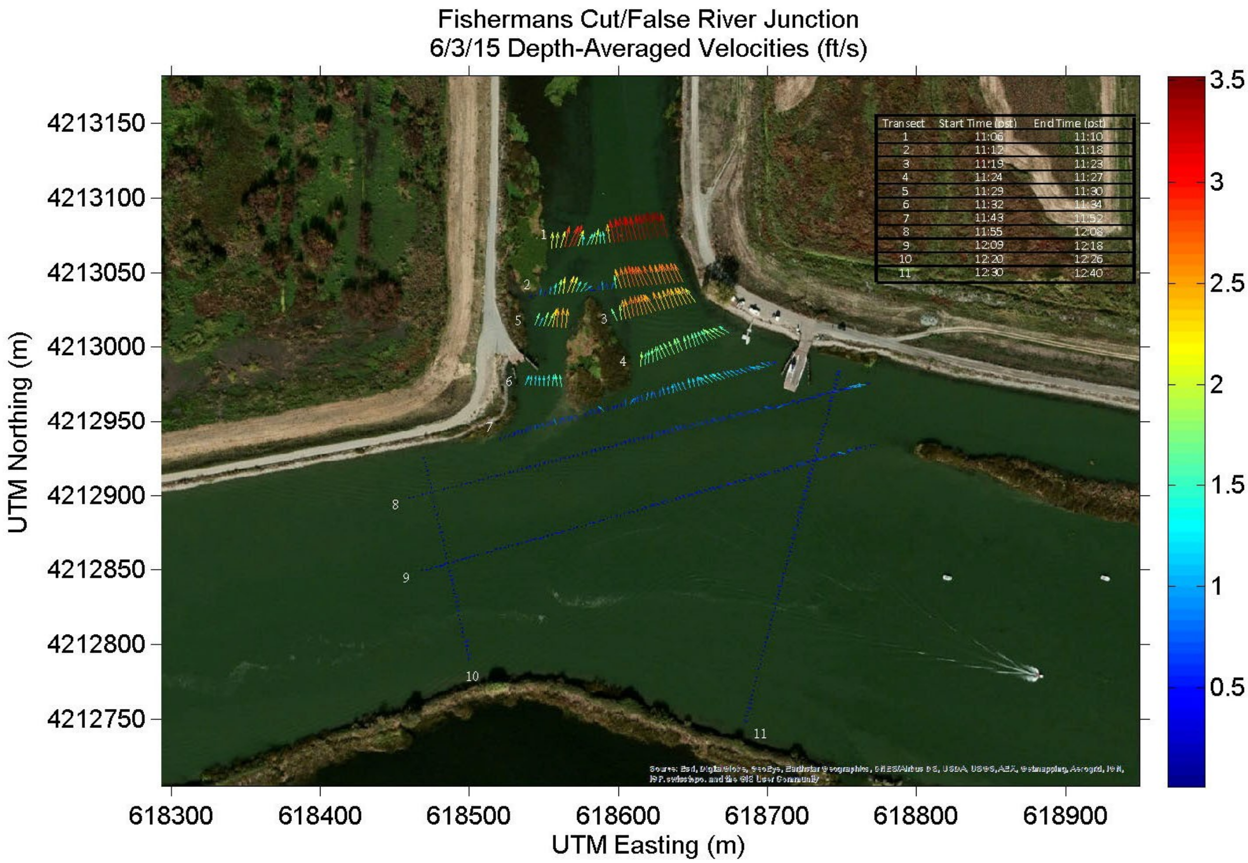


Figure 4-22 Observed (ADCP) Velocities on 6/3/2015 With Barrier Closed at Peak Flow



5.0 Conclusions

The principal purpose of the 2015 EDB was to reduce salinity intrusion into the central Delta. Analyzing the effectiveness of the barrier in achieving this goal shows that:

- The EDB operations successfully shielded the central Delta from salinity intrusion. It slightly increased salinity on the mainstem Sacramento and San Joaquin rivers but not beyond acceptable levels.
- The EDB conserved approximately 100,000 acre-feet of water.
- The TUCP was important to the success of the EDB. The EDB would not have conserved water absent the TUCP (i.e., under the ordinary D-1641 objectives in a critical year) because it did not shield channels on its downstream side from salinity, and the two “limiting” stations for compliance, Emmaton and Jersey Point, are both downstream.

The EDB project was also successful by several other metrics:

- Successful preparation.
    - DWR developed positive relationships with landowners.
    - DWR coordinated with the U.S. Coast Guard, which resulted in listing the project on the U.S. Coast Guard Local Notice to Mariners webpage and the installation of navigational aids to address navigation and boating issues. No navigational incidents were reported during any portion of the 2015 EDB Project.
- Successful monitoring and compliance. Through the monitoring efforts conducted as part of the 2015 EDB Project, not only were project effects documented, project impacts were minimized. Types of data collected included fish and wildlife environmental compliance, water quality, hydrodynamics, bathymetry, air quality, and boating and navigation.
    - <u>Fish and Wildlife</u>. Construction impacts on fish and wildlife were minimized because of measures that were implemented and mitigation that was purchased. Compliance with all the conditions of the environmental compliance permits and approvals were met.
    - <u>Water quality</u>. Daily water quality measurements taken upstream and downstream of the barrier during in-water work

documented full compliance with the water quality objectives as outlined in the Water Quality Certification issued May 4, 2015.

- Successful adaptation to unforeseen circumstances. When the increase in channel velocity in Fisherman's Cut adversely impacted the DFA Victory II ferry operation between Jersey Island and Webb Tract and Bradford Island, DWR entered into a Damage Agreement which included further mitigation for the Victory II ferry itself, repowering the ferry with replacement/upgrade of engines and propellers. This one-time mitigation enabled the ferry to fully operate for the remainder of the time the 2015 EDB Project was in place as well as during any future installations of the EDB. The air quality benefits associated with the new engines installed for the DFA's Victory II ferry fully offset the air quality impacts of construction.

For future efforts, it should be noted that:

- Unforeseen circumstances from the 2015 EDB project should be anticipated in future projects.
- The amount of lead time needed for permitting was significantly reduced by the Governor's Drought Emergency Declaration. DWR should plan for future drought circumstances and mitigating measures.
- The timing with which a salinity barrier is employed can be important to its effectiveness. Modeling suggested that if the 2015 EDB had been installed two weeks earlier, it would have been even more effective, possibly avoiding the surge in salinity that occurred in early June as a result of wind and offshore barometric forcing.
- Collected data showed the following regarding hydrodynamics and physical site characteristics:
    - The EDB diverted tidal energy from West False River to the San Joaquin River upstream of Bradford Island.
    - The EDB increased velocities within Fisherman's Cut and at the USGS Old River at Franks Tract near Terminous (OSJ) station and at the USGS Dutch Slough at Jersey Island (DSJ).
    - Impacts on scouring and water level were minimal in most locations with the greatest impacts noticed at Fisherman's Cut.
    - Tidal travel paths led to tidal stages 3- to 4-hours out of phase on either side of the EDB producing measurable water level

differences across the EDB, including a local water level increase on the San Joaquin River just upstream of the EDB and a reduction of tidal maximum water levels at the locations RD 2059 identified as low spots in its levees.

 - Bathymetric surveys were used to review impacts on the bed of the channel from the 2015 EDB project. The surveys identified sediment movements in some areas near the barrier, including Fisherman's Cut and on the tule berm found on the north side of Bradford Island. Most of the changes were less than 1 foot. Scour near the barrier was not an issue and the identified undercut levees experienced no significant changes from the EDB.

- Modeled and field-collected data tended to predict/record site conditions similarly.
- No major unanticipated changes were observed in flow, velocity, or water quality parameters coinciding with the presence of the EDB.

5.1 Lessons Learned

With the large effort in project initiation, planning, designing, constructing, and monitoring for the 2015 EDB, many lessons were learned from the experience. Approximately 25 key staff participated in a Lessons Learned workshop on September 2, 2015, to strategize for upcoming efforts. Items in this section are drawn in part from the workshop, and in part from subsequent discussion among individual DWR units involved in the project.

5.1.1 Team Structure and Internal Communication

As with many large efforts, communication among the approximately 100 involved staff throughout DWR was both essential and a challenge. The Emergency Declaration enabled DWR to proceed more quickly with some steps of project preparation, but in practice, it effectively doubled the communication chain, with two executive sponsors, the SWP Deputy Director and the Security and Emergency Management Deputy Director, as well as the Director, heavily involved. Staff observed that for the project the two deputy directors avoided duplication of effort by specializing in their areas of expertise and responsibility. The Emergency Management Deputy Director was closely involved with the Governor's Office and the financial aspects of the project, while the SWP Deputy Director focused more on the staff coordination aspects of project oversight. Having two “chains of command” involved did complicate communication somewhat. During the Lessons Learned workshop, the SWP Deputy Director deferred to the Emergency Management Deputy Director as the more logical choice for Executive Sponsorship in a future drought emergency.

In future efforts, DWR could choose to organize staff into a project-level team structure by DWR chains of command, by ICT, or by some other model. A hybrid Incident Command System Project Management structure was initially chosen as the structure for EDB Removal, which was treated as a distinct project referred to as 2015 EDBR (Removal).

5.1.2 Planning

Although few staff had memory of the rock barriers installed as drought mitigation measures in 1976 and 1977, planning nonetheless benefitted from that precedence because a record existed of what had been considered or tried in the past. The running start that the preparation to possibly install salinity barriers in 2014 offered was at least as valuable.

In a future effort, staff indicated it would be beneficial to begin many tasks sooner:

- Defining and communicating the project description.
- Planning for resources (i.e., human resources and funding).
    - When funding was not in place when needed, contract invoices and temporary funding sources were used, creating additional complications and administrative work to back out charges later when funds became available.
    - Site monitoring requires organization of substantial numbers of environmental scientists.
- Preconsultation regarding environmental aspects, physical data collection (e.g., bathymetry data).
- Allowing time for reviewing and revising design concepts that may have been developed by other groups, which was the case with the 2015 EDB.

Before project management was elevated to Executive, it resided in DWR BDO. Modeling was a key planning activity to assess conditions and suggest potentially effective drought barrier sites. DWR BDO and DWR O&M had forecast modeling processes to assess conditions, and had access to the *Delta Drought Emergency Barriers* report (California Department of Water Resources 2009) as a reference source for potential barrier sites.

Public Outreach is another key component of both project planning and execution. The importance of early and transparent communication with the public, with relatable language (e.g., volumes of water in terms of “basketballs,” distances in terms of football fields) and illustrations (e.g., maps) were key take-homes regarding Public Outreach in planning.

As DOE Real Estate Branch develops real estate access for such a project, the REB and the PAO should work together on future public meetings to give all stakeholders associated with a project site a contemporaneous opportunity to be a part of the planning process. Making technical information that underpins the project description (modeling data, engineering designs) available to stakeholders early on also builds trust and facilitates REB efforts to obtain entry permits and agreements. While the REB did an exceptional job of handling property owners’ issues, having a centralized point of contact (Project Manager or PAO) would be helpful in a future project. The same point of contact could be responsible for keeping city or county public works managers informed to ensure they are aware of the project in their area and DWR’s projected schedule and associated impacts.

In the lessons learned workshop there was management support for these types of communication improvements, and a request that DWR Executive be notified whenever DWR staff are gearing up to engage Delta groups.

Environmental planning included high-level communication about environmental aspects, permitting, and planning the fish and wildlife environmental monitoring and compliance team activities (DES, DOE). The environmental monitoring and compliance team voiced a desire for more streamlined communications and took satisfaction in adapting to changing circumstances.

Planning for water quality impacts included NCRO and DES staff working together to establish water quality monitoring stations. The monitoring network planned was extensive enough to allow meaningful reporting on water quality near the barrier and Franks Tract.

5.1.3 Modeling

There were areas that modeling was well prepared for and areas that could be improved.

DWR had forecast modeling processes in place to assess conditions.

- DWR had modeling tools that could assess water costs given inputted operation changes.
- DWR and consultants utilized different Delta Models available to validate the potential drought effects by comparing results from the different models.
- DWR had the *Delta Drought Emergency Barriers* report (California Department of Water Resources 2009) as a reference.

Areas for Improvement:

- Agricultural net channel depletion data needs improvement especially in drought conditions when a small change in flow results in a large salinity change.
- Model output for stakeholders was expanded beyond what is currently provided for other DWR program needs. Having a streamlined process for distributing output in place prior to the drought would have been more efficient.
- DSM2 modeling results underestimated the velocity change in Fisherman's Cut post EDB construction. This resulted in unanticipated expenditures to upgrade the DFA Victory II ferry because of navigational difficulties.

Modeling studies that include variables other than salinity, as shown in the 2009 Barrier Report (California Department of Water Resources 2009), would have been helpful. Because other factors (e.g., water levels and velocities) were not evaluated in the 2009 report, water levels and velocities were later evaluated in parallel with the 2015 EDB planning process. If the water levels and velocities with the selected barriers from the 2009 report had resulted in significant adverse impacts, then it may not have been feasible to install the barriers that were selected based only on salinity benefits.

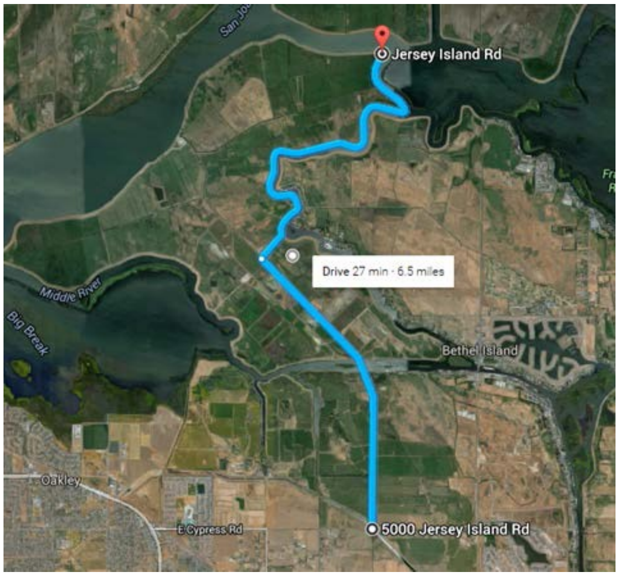
This report includes some discussion of bromides specifically, as well as salinity more generally. It could be beneficial to better understand the distribution of bromides, or to better explain how bromide concerns may be addressed with salinity data.

5.1.4 Public Outreach

The public outreach process for the 2015 EDB provided and reaffirmed several lessons, including:

- Transparency is the best policy. Informing the public in advance about what is going to be done or is being planned to be done keeps the public aware of what is going on. DWR PAO received numerous emails from individuals who live or work in the Delta who were concerned about the barriers. PAO updated those people on barrier-related developments, including sending them press releases as they were issued.
- All information going out to the public must be vetted through PAO. Talking points help DWR with consistent messaging.
- Maps can help the media. The media rendezvous spot for the May 8, 2015, construction event was on the far northeast corner of Jersey Island. A Google Maps screen shot (Figure 5-1) was included in the media advisory packet giving precise directions on the route and travel time from a starting point. In addition to the provided map, a project person was stationed at the key intersection on the island to help if needed.
- Mobile phones are essential in maintaining efficient communication among all PAO personnel. Unexpected developments are inevitable during the production of a major media event at a location far removed from DWR’s headquarters. It is, then, critical for all PAO personnel to monitor their mobile phones and respond as quickly as possible to calls as they arrive.

Figure 5-1 Google Map of Rendezvous Location of May 8, 2015, Media Event



5.1.5 Real Estate

Many real estate lessons can be learned from the 2015 EDB project. From the onset of the project it was clear that a public meeting that included stakeholders on both sides of the West False River project, Jersey Island and Bradford Island, must take place. One or more public meetings should be held locally to incorporate the concerns and views of all stakeholders. Those affected by a project need to be given the opportunity to be a part of the planning process. The Bradford Island stakeholders believed they were less important than the Jersey Island stakeholders, and therefore trust and customer relations with the Bradford Island stakeholders was an issue. The perception of stakeholders' preference should be anticipated, and steps taken to clarify project objectives.

Technical information used to develop the project description and engineering designs should be available to stakeholders. For example, modeling data that was used in showing why the barrier and sheet piles were needed in 2015 was not readily available to stakeholders early in the process. This created stakeholder distrust and impacted other project activities such as the REB efforts to obtain entry permits and agreements.

As part of negotiations with the RDs and property owners, it was necessary to have complete design plans to review and discuss. The design of the EDB changed often, which caused an issue with the permissions granted by the owners, as they had agreed to certain specifications which later changed and so required amending the agreements.

A centralized point-of-contact to answer all questions and concerns from the public is preferred over multiple project contacts, which can result in inconsistent information exchanges. This would have been extremely helpful for the REB in building rapport and trust with the Jersey Island and Bradford Island boards of trustees.

DWR should contact the city or county public works manager to ensure they are aware of the project in their area, DWR's projected traffic impacts resulting from construction, the identification of haul routes, the hours of project operations, the contact person name/number, the overall description of project, and the length of time required for the project. If there are changes to the schedule or modifications to the contract that might impact the area near the construction, this information should be shared with the relevant public works representative as they occur.

Before contacting any public works department to provide project information, it is important to have information available regarding the Victim Compensation Board, such as who to contact, the process to file a claim, and victim contact information.

It is particularly important to document road conditions for heavy use roads via photos and/or video prior to the project, during the project, and after the project is completed. This documentation can be used to support DWR in any claims against the State for damages. Photo documentation should also be performed for any area of work that is required to be returned to original conditions after the project is completed.

5.1.6 Design and EDB Construction

The design of the West False River Barrier was mostly completed a year prior, in early 2014, when it was thought that it might be needed that year. After it was determined to not be needed in 2014, all design effort stopped, even though geotechnical information on the existing levees and river bottom was still lacking. As result of the work being postponed, the geotechnical information was collected after the EDB design was completed in 2015 instead of when it should have been collected, which was as early in the process as possible.

The contracting phase for the installation contract of the barrier used the informal bid process because of the short time frame between the decision to install the barrier and the time by when it had to be installed. Every aspect of DOE's normal contracting process was shortened to meet the schedule. All the standard steps of the contracting process were preserved, except for the standard bid time length.

Erosion at the levees included undercut areas. This required additional material to restore the levee cross section, which increased construction costs. A bathymetry survey with side-scanning sensors using point clouds revealed the steep and undercut slope conditions and enabled the barrier cost to be more accurately determined.

The volume of rock removed was less than estimated. Some of the rock became embedded in the soft surface of the riverbed. This should be considered in future barriers, reducing the estimated material that will need to be removed, and thus reducing estimated removal costs.

Cutting the sheet piles and appurtenances at each end of the barrier was time consuming, expensive, and required underwater work which introduces safety risks for divers. Regulatory approvals were pursued to leave the sheet piles in place but were denied. If future barriers are likely to be in the same location(s), planners should again pursue regulatory approvals to leave the sheet piles in place, assuming they are needed.

5.1.7 Fish and Wildlife Environmental Monitoring and Compliance

Communication was the biggest success for environmental services. Good communication allowed DWR to adapt to changing situations and was helpful dealing with the relationships among the regulatory agencies. Some of the issues included DWR management communication, project management organization, and internal decision making. The compressed schedule and frequent requests from upper management sometimes led to a duplication of effort. There were often several levels of management asking the same questions of the same people, and answering those questions took a lot of time and sometimes led to miscommunications as the answers went up the chain of command. Also, the project management organization was changed multiple times during implementation, and these changes were hard to follow while everyone was still actively working on the project. This led to delays in process, as it was not clear who needed to be included in reviews and who was the final decision maker.

5.1.8 Water Quality Monitoring

Setup at almost all water quality station sites went flawlessly. NCRO and DES management staff secured the PVC sonde housing to piles using two stainless steel brackets fabricated by a local machine shop. The stainless-steel brackets are easy to install, durable, secure, and minimize the risk of equipment loss. All the new piles were driven in sections of the channels that had adequate flow and were representative of overall channel conditions. The largest obstacle for securing high-quality data in the Delta is aquatic vegetation and algae. Both can wrap around the sonde housing and interfere with the sonde’s sensors.

Additionally, high winds and extreme tides limited the opportunities to service certain stations (FRK, GZL, RYC, HON, SSI, and TWI). NCRO and DES staff visited each drought station every three-to-four weeks to clear away any surrounding vegetation and algal growth and replace the deployed sonde with a clean and calibrated one.

During the drought monitoring period, NCRO staff had the opportunity to deploy Yellow Springs Instruments’ (YSI’s) new water quality sonde, the EXO2, at three drought monitoring stations — HOL, FCT, and TSL. NCRO has used YSI’s 6-Series multi-parameter water quality sondes for the past 10 years. YSI plans to discontinue support of the 6-series by 2020. The extended monitoring network provided a good opportunity to test the EXO2 and determine if YSI products will continue to meet NCRO needs. The EXO2 is fundamentally like the 6-series but provides easier and quicker calibrations and an improved data management system. The EXO2 central wiper is marketed as an improvement in anti-fouling technology, but NCRO has yet to determine if the EXO2 has a significant anti-fouling advantage over the 6-series.

NCRO’s Water Quality Evaluation Section (WQES) provided weekly water quality reports to the Bay-Delta Office, and these reports were placed on the DWR internet site for public viewing. These reports focused on the EC levels at key stations (DSJ, SJJ, FAL, FCT, and HOL) in the Central Delta near the

EDB and Franks Tract. The monitoring network was extensive enough to allow meaningful reporting on water quality near the barrier and Franks Tract. In addition, the current extent of monitoring on the Sacramento River and Cache Slough Complex would provide sufficient information if barriers were implemented on Steamboat Slough and Miner Slough in subsequent years. Nevertheless, the monitoring network could be improved with new stations in key locations along with additional transect monitoring. Suggested monitoring network expansion and studies are explained in the following paragraphs.

An additional station installed between SOI and Walnut Grove could be beneficial for observing how much saltwater is being pushed upstream in the Sacramento River before reaching Georgiana Slough and the Delta Cross Channel. In addition, flow and water quality stations are recommended on both Railroad Cut and Woodward/North Victoria Canal. Under normal conditions, Middle River and Old River experience an exchange and mixing of water, with Middle River bringing lower salinity water into the Old River system. This mixing occurs through the two cuts on the north and south sides of Woodward Island, the Railroad Cut on the north and Woodward/North Victoria canal on the south. In past years, monitoring along the length of Old River between Franks Tract and Clifton Court showed reductions in EC south of these cuts. For example, in August of 2013, EC levels at Old River near Bacon Island at USGS Pile (OBI) were between 600–800 µS/cm, while upstream at Old River at Highway 4 (OH4), EC levels were consistently 100–150 µS/cm lower. This is an established water quality trend in this reach of Old River, occurring in the summer and fall months. During the installation of the EDB, EC levels were consistent from Franks Tract to Clifton Court. No reduction in EC occurred between OBI and OH4.

During August of 2015, EC levels at OBI were again in the range of 600–800 µS/cm, but OH4 generally remained within 10–20 µS/cm of the OBI reading. Baseline data collected before another installation of the EDB is necessary to determine how much the barrier affects mixing between Old and Middle River.

More information is needed on the spatial distribution of salinity within Franks Tract and the surrounding channels. Although the EDB reduced salinity within Franks Tract, salinity levels in Franks Tract were still higher than the salinity coming into Franks Tract from Old River in the north. The salinity in the middle of Franks Tract (at FRK) exhibited little mean change and little tidal variation. It is unclear whether this is a result of high residency time or a sustained flux of salinity from a local source within the system. To further study this issue, it is recommended that several salinity-monitoring excursions, using a boat with a water quality monitoring flow-through system, be performed in the area during the different stages of the spring-neap tide cycle. These monitoring excursions should take place under normal conditions and again during the presence of a future barrier.

5.2 Future Planning

Future drought conditions are inevitable so it is likely drought barrier(s) will be needed again. As was identified as a goal in the lessons learned workshop, for non-emergency preparation, planning activities should be carried out at the Division level rather than the Deputy Director level. When drought conditions begin to develop, DWR staff should conduct project planning and prepare environmental permit applications (e.g., Clean Water Act Sections 401 and 404, Streambed Alteration Agreement, Incidental Take Permit, Initial Study/Mitigated Negative Declaration) for a single rock barrier at West False River for the spring of a future year. This planning would continue, and permit applications would be submitted to regulatory agencies if extended drought conditions persist and it is likely that a TUCP will be needed to temporarily adjust D-1641 requirements. If conditions improve in Year 2, the effort could be paused. The barrier should be installed in the same location with the same configuration as the 2015 EDB; however, buttress rock along the levee base, piping preventer sheet piles on the levee crown, and steel abutments in the channel would not need to be installed. DWR should request installation of the barrier to begin as early as April 1 and removal by November 30 with the understanding the April 1 start could be delayed because of salmon and Delta smelt concerns by fishery agencies. Preparing the documents early would streamline the process of obtaining approvals to install the barrier using normal rather than emergency permitting processes, sufficiently ahead of the need for the barrier. DWR should prepare a comprehensive planning/engineering document (e.g., roadmap) that supports future drought barrier actions and expedites the planning/permitting process when needed.

DWR should investigate long-term, or programmatic approaches for future drought salinity barrier(s). The long-term approach could include consideration of one or two barrier(s) at Miner’s Slough, Sutter Slough, or

Steamboat Slough. The northern barriers would only be considered if drought salinity conditions were expected to become worse than conditions experienced in 2015. These additional barriers would likely be installed using emergency permit processes.

6.0 References

Ateljevich E. 2002. "Optimal Control of Delta Salinity." Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 23rd Annual Progress Report. Chapter 10. State of California, Department of Water Resources.

Ateljevich E. 2014. "SELFE Development Status." Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 35th Annual Progress Report. Chapter 2. State of California, Department of Water Resources.

California Department of Water Resources (DWR). 1978. *The 1976-1977 California Drought, A Review*. State of California, The Resource Agency, Department of Water Resources. May.

California Department of Water Resources (DWR). 2016. *Drought & Water Year 2016: Hot and Dry Conditions*.

DWR. 2009. *Delta Drought Emergency Barriers Administrative Draft*. State of California, The Resource Agency, Department of Water Resources, Bay Delta Office. April.

DWR. 2015a. *Water Quality Monitoring Plan, Emergency Drought Barrier*. State of California, Department of Water Resources. Version April 24.

DWR. 2015b. *Emergency Drought Barrier Project Environmental Permit Compliance Report: Installation*. 2015. State of California, California Natural Resources Agency, Department of Water Resources, Bay-Delta Office. July.

DWR. 2015c. 2015 *Emergency Drought Barrier Project (Removal) and West False River Salinity Barrier Geologic Exploration Project, Environmental Permit Compliance Report, Annual Status Report, and Final Mitigation Report*. State of California, California Natural Resources Agency, Department of Water Resources, Bay-Delta Office. December.

DWR. 2016a. 2015. *Emergency Drought Barrier, West False River Bathymetric Mapping, Spring and Fall 2015*. Prepared by Shawn D.

Mayr. State of California, California Natural Resources Agency, Department of Water Resources, Division of Integrated Regional Water Management, North Central Region Office. June 30.

DWR. 2016b. *2015 Delta Emergency Rock Barrier Design and Construction Report*. State of California, California Natural Resources Agency, Department of Water Resources, Division of Engineering. July.

DWR. 2017. *2015 Emergency Drought Barrier Water Quality Monitoring Report*. State of California, California Natural Resources Agency, Department of Water Resources. January.

Mahadevan N. 1995. *Estimation of Delta Island Diversion and Return Flows*. State of California, Department of Water Resources Division of Planning.

McQuirk J, DWR, & Lu G. AECOM. 2016. *Memorandum to Bay Area Air Quality Management District: Emergency Drought Barrier Construction Mitigation and Ferry Retrofit*. July 18.

Roy Sujoy et al. 2014. *Salinity Trends in Suisun Bay and the Western Delta: October 1921 – September 2012*. Prepared for San Luis and Delta Mendota Water Authority and State Water Contractors. Paul Hutton Technical Representative.

Smith Tara. 2014. “Delta Modeling for Emergency Drought Barriers.” Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 35rd Annual Progress Report. Chapter 6. State of California, Department of Water Resources

University of Arizona. 2016. “Millenium-length evaluation of Sierra Nevada snowpack.” Nature Climate Change DOI:10.1038/nclimate2809.

7.0 Appendix A

Figure A-1 Sediment Change Pre / Post Barrier Around the Confluence of San Joaquin River and False River

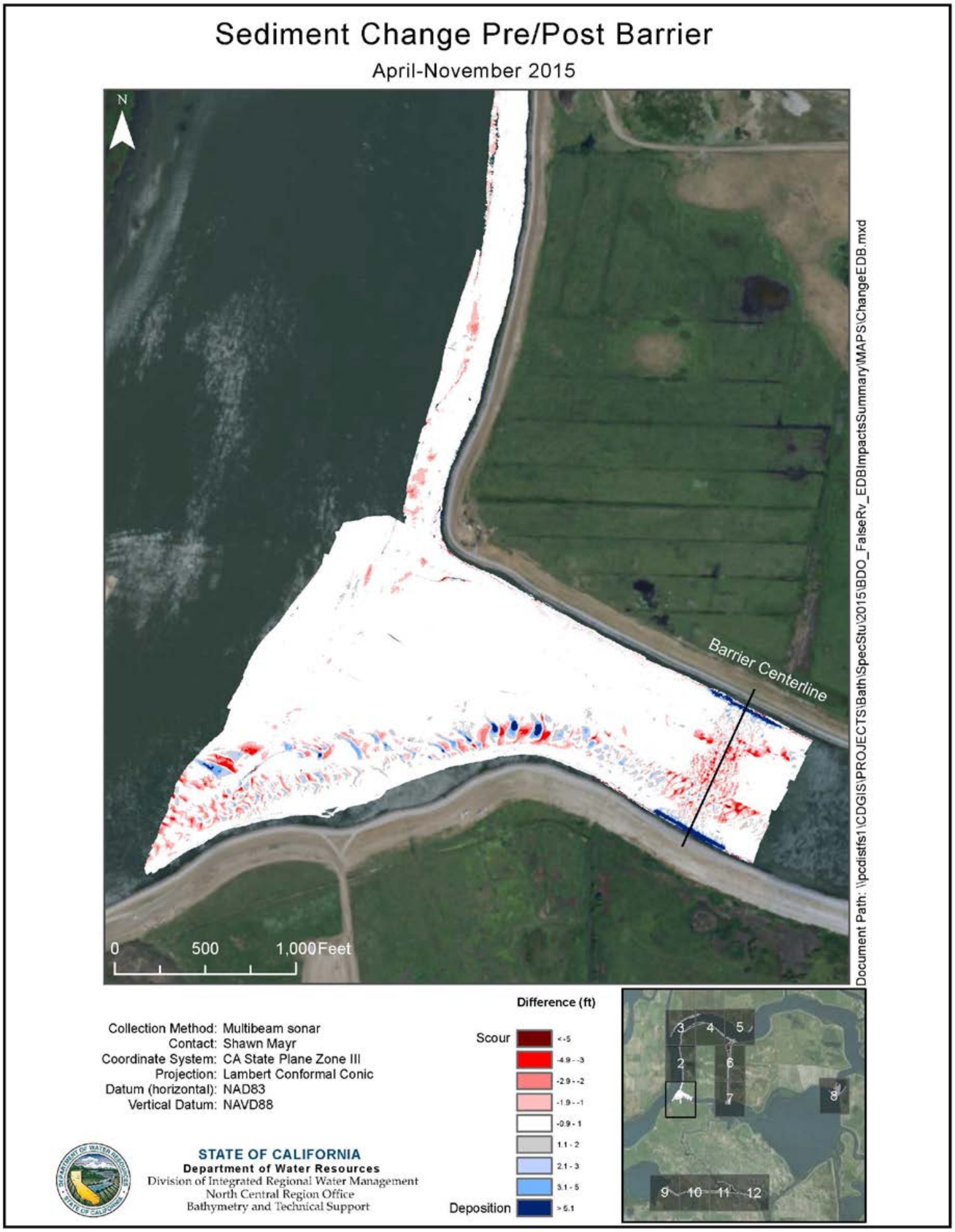


Figure A-2 Sediment Change Pre / Post Barrier on the West Shore of Bradford Island Along San Joaquin River

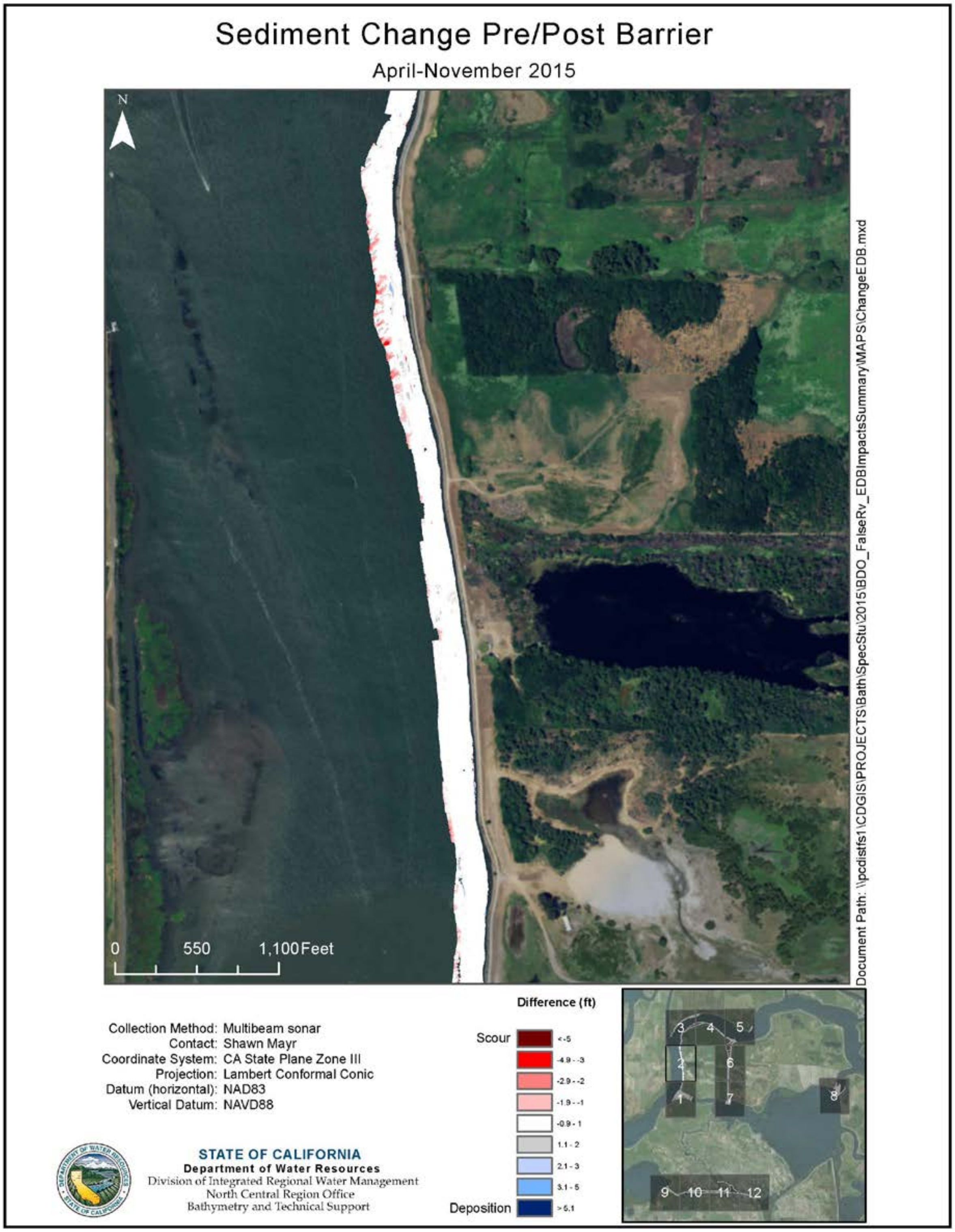


Figure A-3 Sediment Change Pre / Post Barrier on the Northwest Shore of Bradford Island and Souhwest Shore of Twitchell Island Aong San Joaquin River

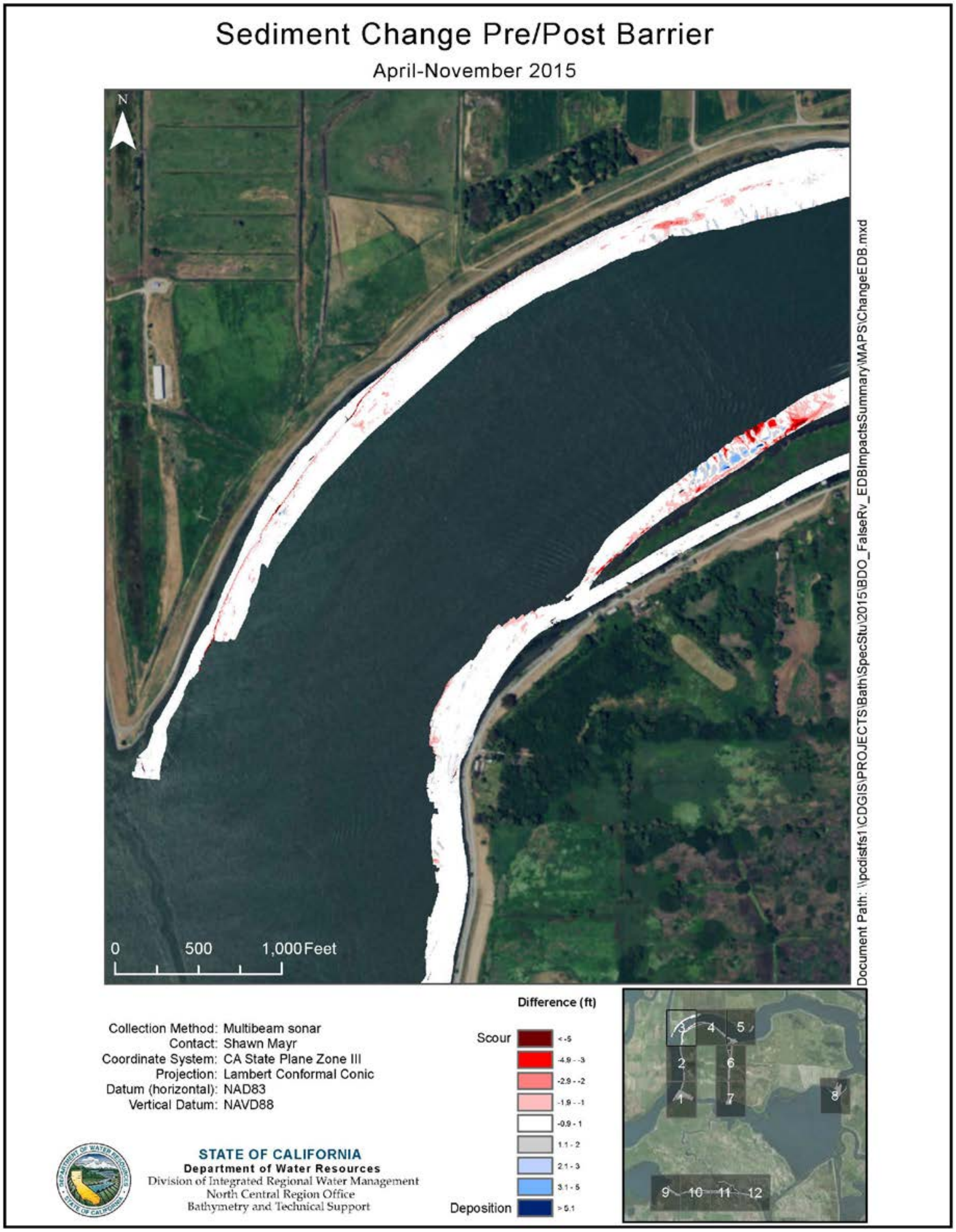


Figure A-4 Sediment Change Pre / Post Barrier on the North Shore of Bradford Island Along San Joaquin River

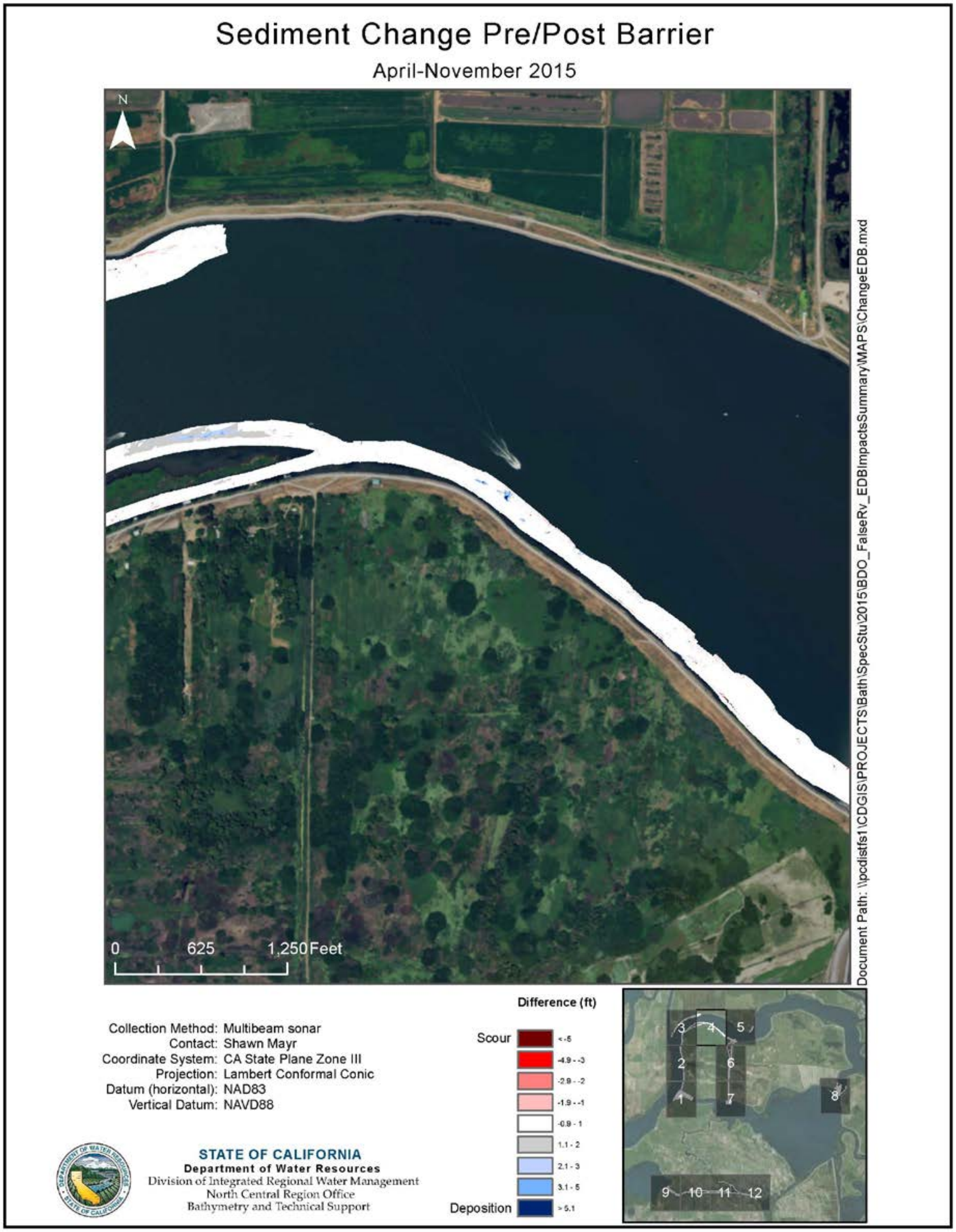


Figure A-5 Sediment Change Pre / Post Barrier Around the Confluence of San Joaquin River and Fishermans Cut, and the Southeast Shore of Twtichell Island

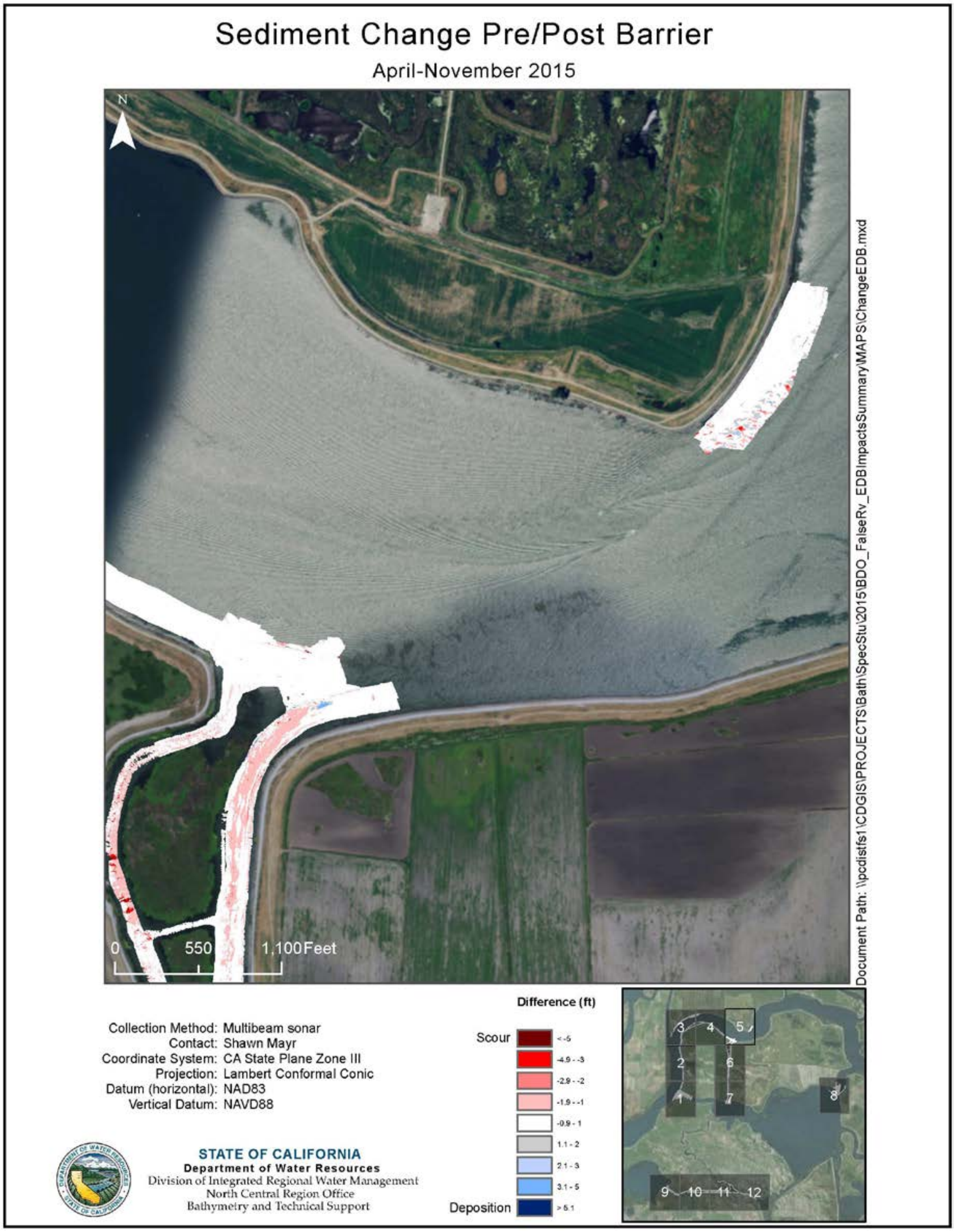


Figure A-6 Sediment Change Pre / Post Barrier Between Bradford Island and Webb Tract Along Fishermans Cut

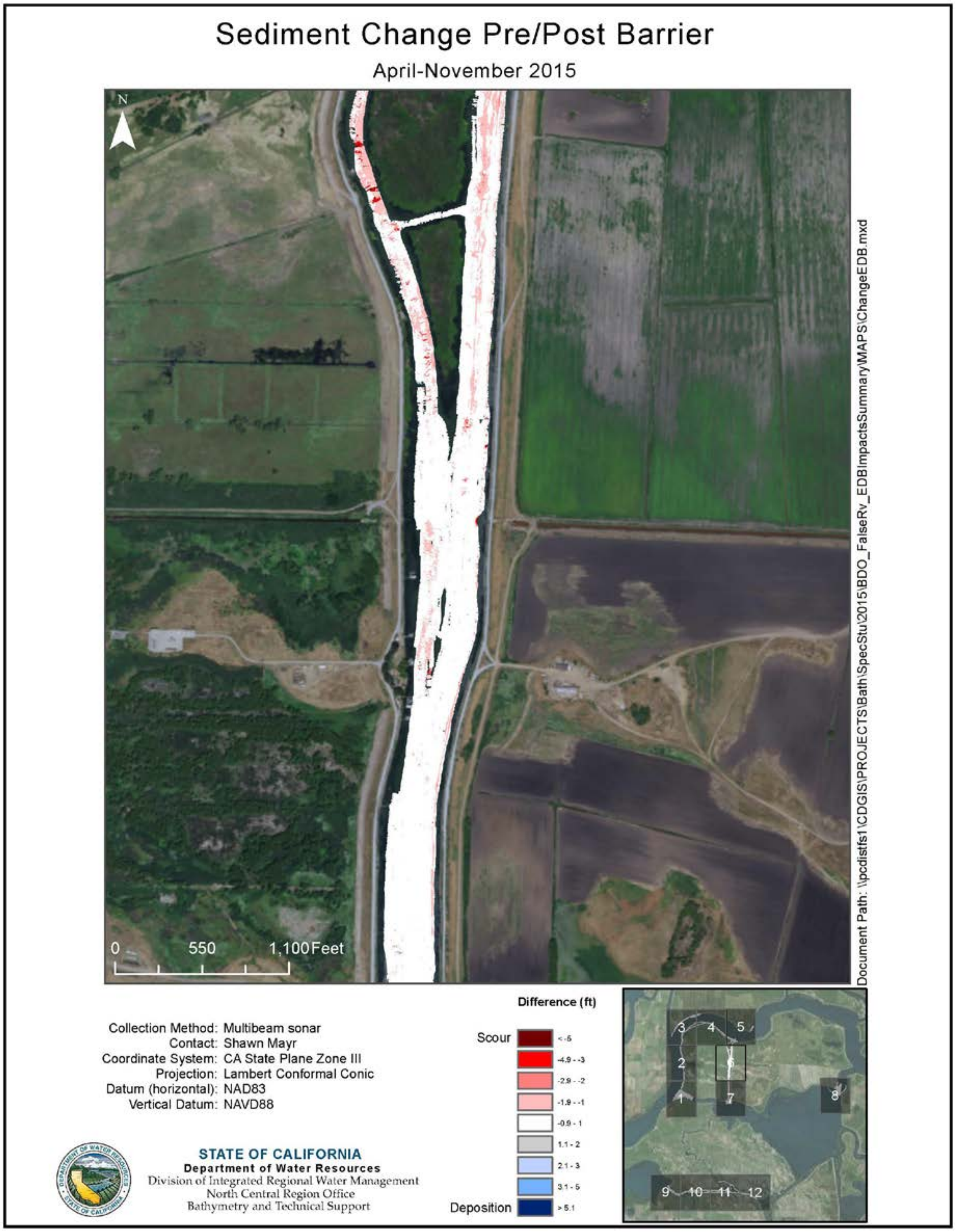


Figure A-7 Sediment Change Pre / Post Barrier Around the Confluence of False River and Fishermans Cut Between Bradford Island and Webb Tract

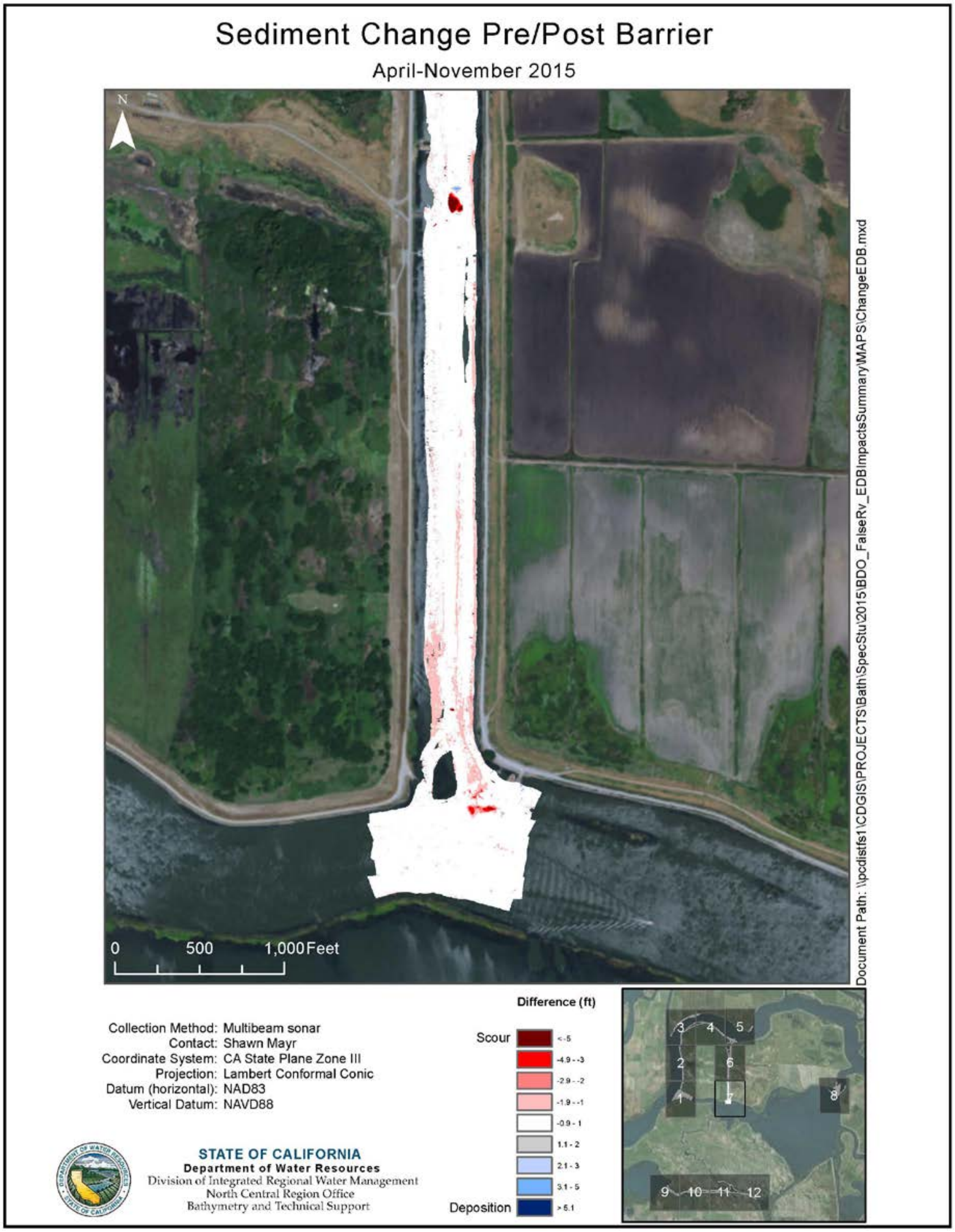


Figure A-8 Sediment Change Pre / Post Barrier Along Old River Near Franks Tract

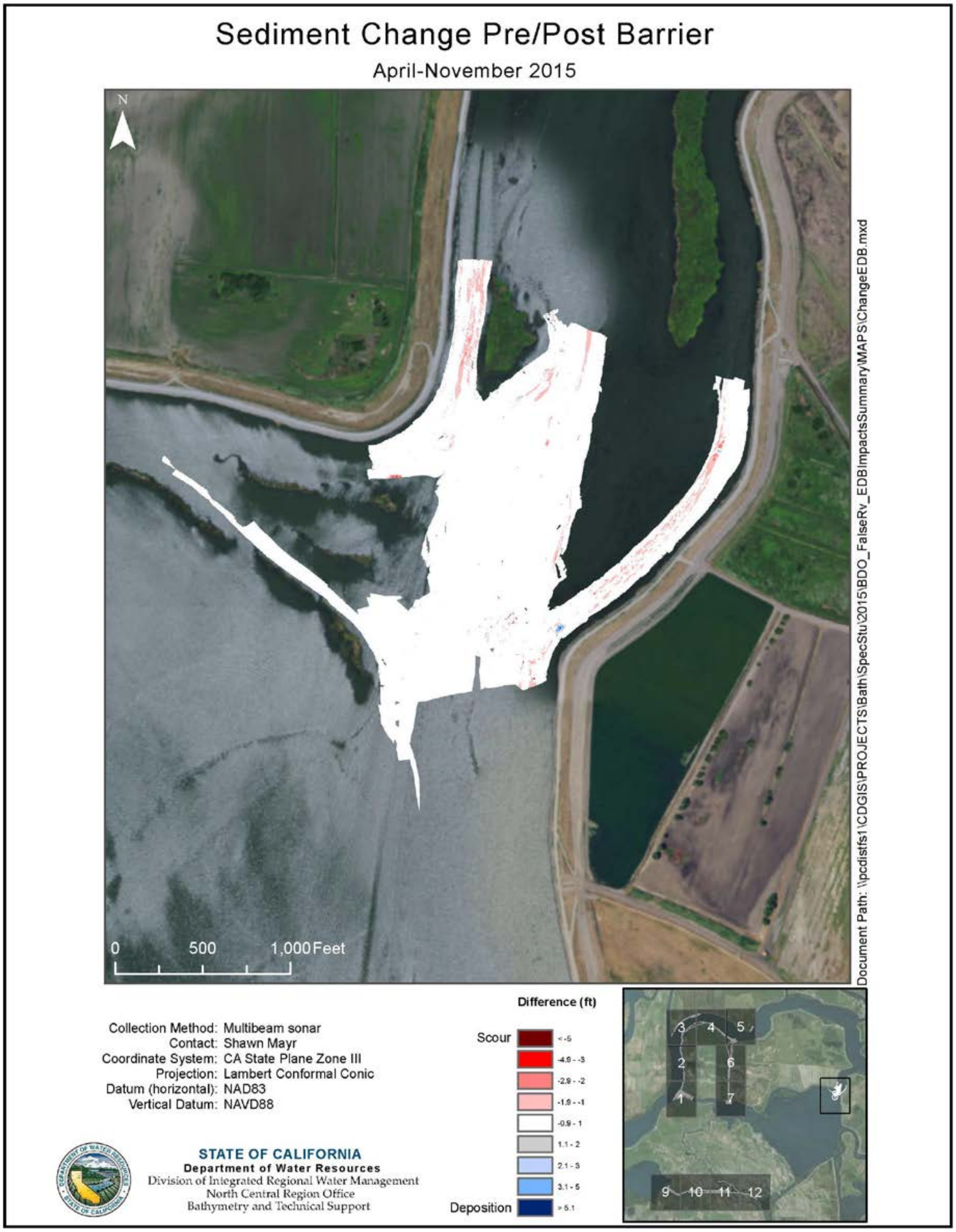


Figure A-9 Sediment Change Pre / Post Barrier Along Dutch Slough Near Big Break

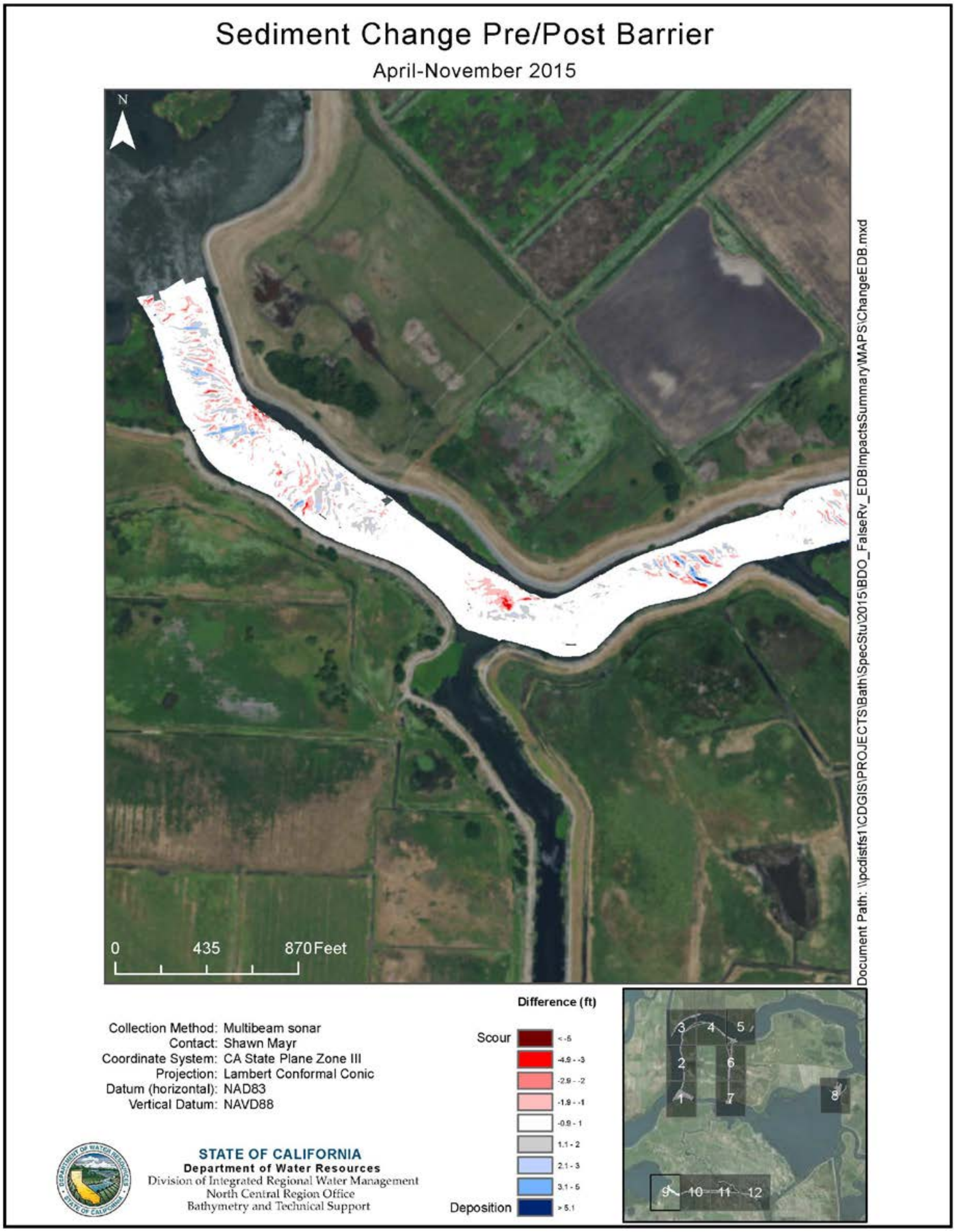


Figure A-10 Sediment Change Pre / Post Barrier along Dutch Slough Near Jersey Island Road

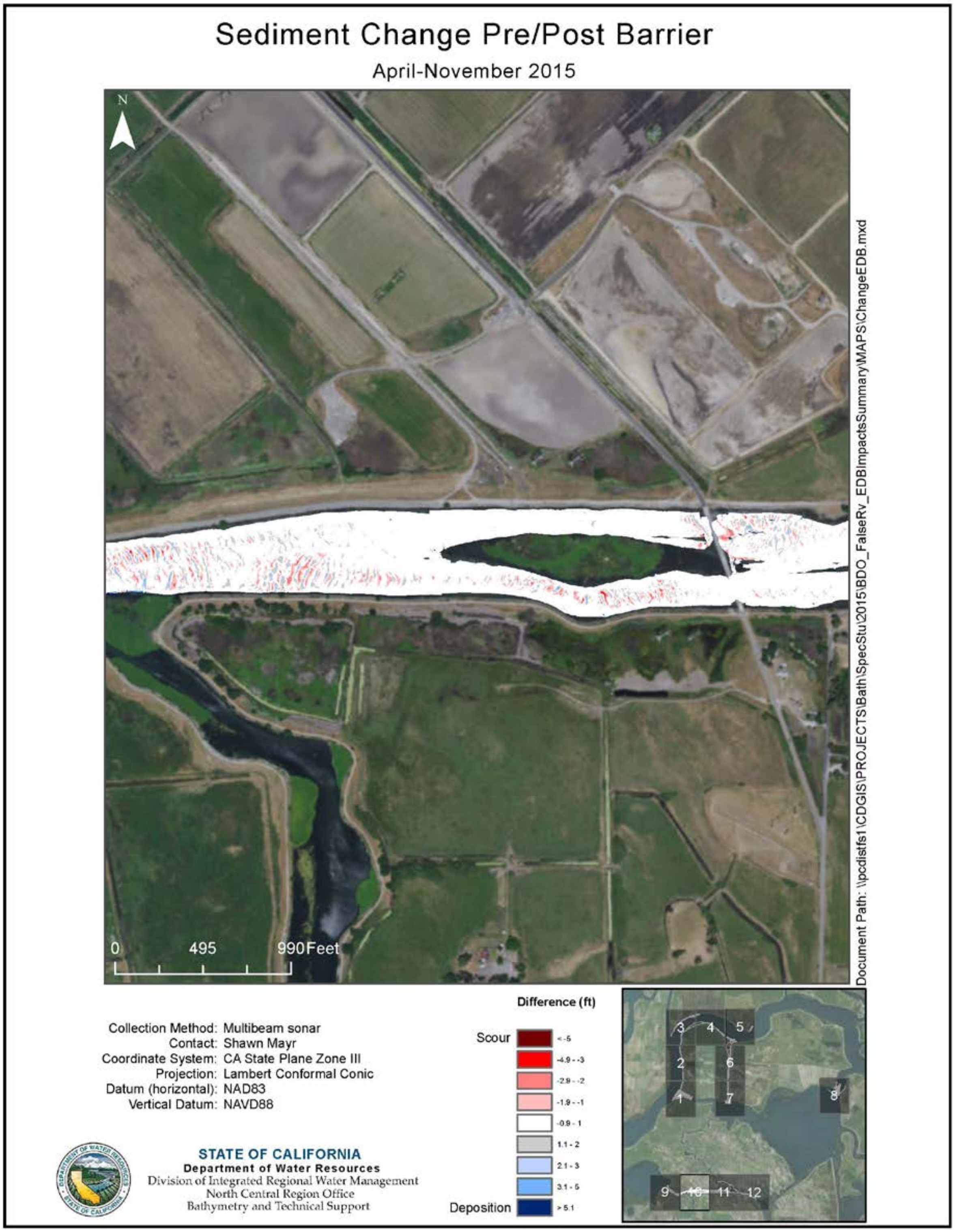


Figure A-11 Sediment Change Pre / Post Barrier Along Dutch Slough and Taylor Slough

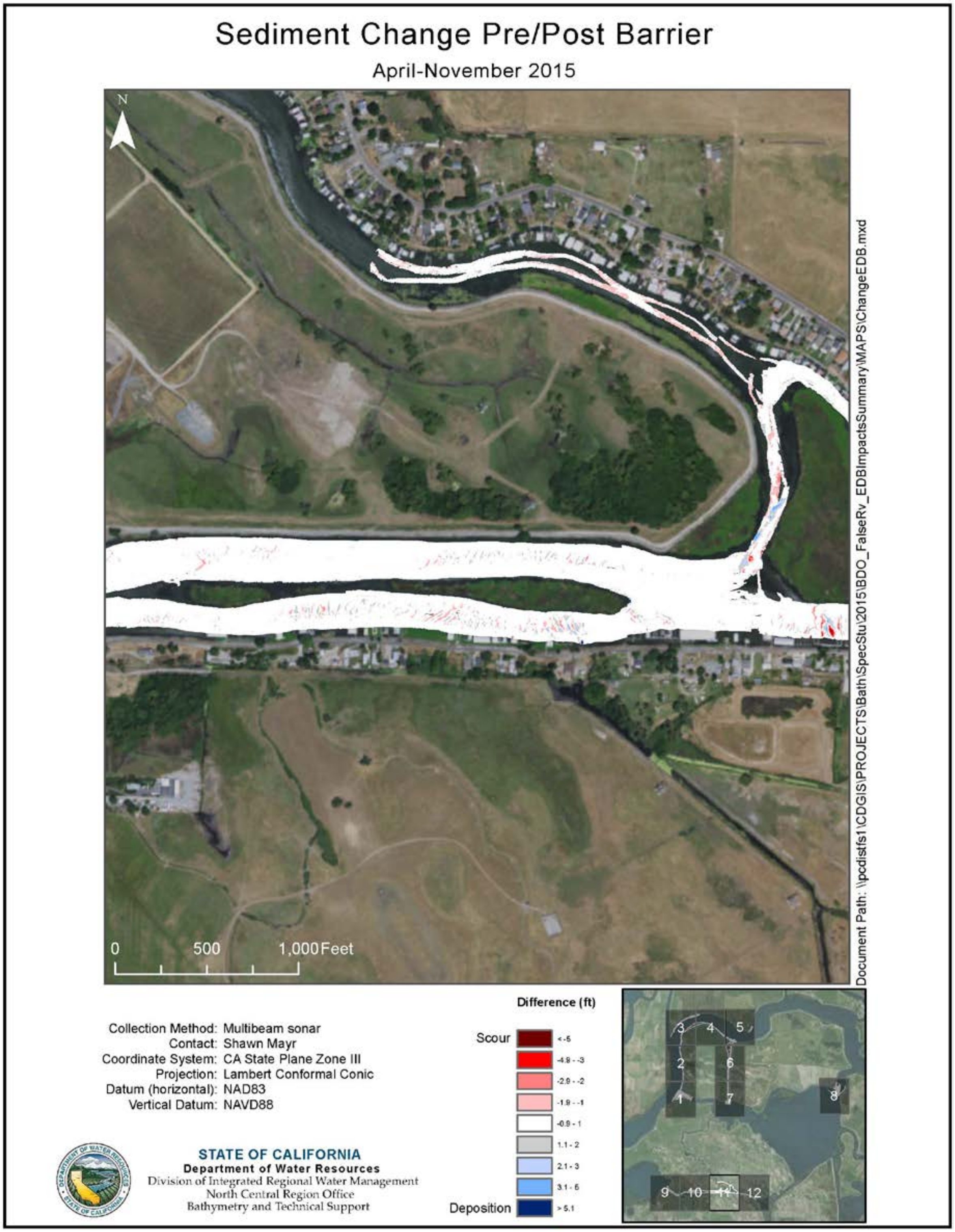


Figure A-12 Sediment Change Pre / Post Barrier Along Dutch Slough Near Bethel Island Cove