DWR-510

State of California
The Resources Agency
Department of Water Resources
Bay-Delta Office

Administrative Draft
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Delta Drought Emergency Barriers

TABLE OF CONTENTS

Executive Summary

The Department of Water Resources (DWR) recommends that emergency temporary barrier(s) or operable barrier(s) [gate(s)] be installed in the Delta channel(s) if drought conditions persist. These emergency barriers will reduce salt water intrusion and, therefore, help protect the quality of Delta water supplies during a drought. This report presents an overview of the historic use of drought barriers, several current proposed barrier projects, and an analysis of the proposed emergency drought Delta barriers. The objective of this report is to identify potential locations for emergency drought barriers, compare their potential water quality benefits and costs, and provide recommendations for further evaluation.

Several temporary rock barriers were installed at Delta locations during 1976/77 to help in the mitigation of the effects of drought conditions on water quality and fish resources. These barriers were effective at maintaining lower EC levels which resulted in lower reservoir releases being required to maintain Delta water quality.

Several recent study projects are underway for the use of barriers in the same location as several of the proposed emergency drought barriers. These projects include Franks Tract Project as a programmatic action under the CALFED Ecosystem Restoration Program and the 2-Gate Project proposed by several State water contractors for possible implementation by DWR. These barriers include either rock or an operable barrier (gate) at various locations to achieve improved water quality and to provide protection of fishery resources.

Thirteen potential emergency barrier locations and sixteen barrier alternatives have been identified in the preparation of this report. The alternatives include both temporary rock barriers and/or operable barriers (gates). The selection of the type of barrier or combination of barriers has been evaluated based on location specific requirements and constraints.

Identification and screening of the sixteen alternatives was completed in two phases. Phase 1 consisted of identifying all possible locations where barriers could be installed to reduce sea water intrusion at the Banks Pumping Plant (SWP), Jones Pumping Plant (CVP), and the Contra Costa Water District Old River at Los Vaqueros Intake (CCWD OR). Water flow and water quality modeling analysis was conducted to determine which alternatives showed the potential to provide a five percent or greater reduction in electrical conductivity (EC) at the various pumping locations. Nine of the original sixteen alternatives showed this potential EC reduction and were advanced to a more detailed analysis under the second phase of screening, Phase 2. The Phase 2 screening analysis consisted of hydrology modeling for the period of 2007-2009, looking at construction methods, developing costs, and calculating the relative benefit-to-cost index (BCI) of the various alternatives for both a temporary rock or operable barrier.

The nine alternatives which show the potential to provide a 5% or greater EC reduction at the various pumping locations include:

1. Sutter Slough
2. Sutter Slough and Steamboat Slough
3. Threemile Slough
4. West False River
5. 2-Gate (Old River and Connection Slough)
6. Sutter Slough, Steamboat Slough and West False River
7. Sutter Slough, Steamboat Slough and 2-Gate
8. Threemile Slough and West False River
9. Threemile Slough and 2-Gate

Salinity reductions of up to 40% can potentially be achieved but the degree of reduction varies and is dependent on flows in the Sacramento River and the level of exports. The BCI has been calculated by applying a flow based weighting factor to the modeled EC reduction for a given barrier. This weighted reduction was then divided by the estimated barriers cost to result in a benefit-to-cost index value or BCI. A larger BCI value indicates that an alternative provides a better benefit for each dollar of cost. The alternatives with the highest BCI are a rock barrier in Sutter Slough (Alternative 1) and for rock barriers in Sutter Slough and Steamboat Slough (Alternative 2)

The analysis conducted in preparing this document was at a conceptual-planning level. Although the Sutter Slough and Sutter Slough/ Steamboat Slough alternatives provide higher BCIs it is not the only evaluation parameter and criteria that should be used to select a preferred or recommended alternative. At this conceptual-planning level, no refinement of the benefit analysis has been completed to consider and evaluate other impacts (or benefits). These other impacts or benefits include the environment, fishery resources, navigation, recreation, socio-economic, transportation, air quality, agricultural, as well as others. The purpose of this document is to serve as a basis for further evaluation and analysis of potential temporary emergency barriers. The further analysis will be necessary to consider all potential impacts (or benefits) and identify a recommended or preferred alternative(s).

1 INTRODUCTION

This report presents a summary and conceptual-planning level analysis of potential temporary emergency barriers that could be installed in the Delta to mitigate the effects of drought conditions on water quality. The report comprises a brief summary of the use of temporary rock barriers during the drought of 1976/77, several recent planning projects for the use of barriers in the Delta, and the identification and analysis of sixteen potential Delta barrier alternatives.

The objective of this report is to identify potential locations for emergency drought barriers, compare their potential water quality benefits and costs, and provide recommendations for further evaluation. The purpose of this report is to serve as a basis for further evaluation and analysis of potential temporary emergency barriers for determining possible recommended alternatives after considering all potential impacts and benefits.

2 BARRIERS INSTALLED IN 1976 and 1977

Several rock barriers were installed at Delta locations during 1976 and 1977 to help mitigate for drought conditions. Barriers were installed at two different locations during 1976. One barrier was installed at Sutter Slough to help meet water quality criteria, to conserve water during the drought, and enable increased SWP pumping. The second barrier was installed at the head of Old River to protect fishery resources in the Delta.

As drought conditions continued, barriers were installed at six different locations in the Delta in 1977. In addition, control facilities were built at two additional locations. The six barrier locations were: Old River east of Clifton Court, San Joaquin River near Mossdale, Rock Slough, Indian Slough, Dutch Slough, and the head of Old River. The barriers served different purposes such as increasing water circulation and quality, reducing salinity, and allowing water users to pump at a constant rate. The barrier at the head of Old River helped to protect fishery resources. Further details on the 1976-1977 barriers are provided in Appendix A.

3 BARRIERS CONSIDERED IN RECENT STUDIES

Several studies considering the use of barriers or gates are underway. The studies include the Franks Tract Project and the proposed 2-Gate Project. These studies provide significant information regarding barriers or gates to address water quality and fishery impacts in the Delta.

Four of the alternatives evaluated in this report have been extensively analyzed in these recent studies: Threemile Slough, West False River, and 2-Gate (Connection Slough and Old River.) The Threemile Slough and the West False River site have been evaluated under the Franks Tract Project initiated by the CALFED Record of Decision (August, 2000). The California Department of Water Resources (DWR) and U.S. Department of the Interior, Bureau of Reclamation (Reclamation) conducted numerous studies to evaluate the feasibility of modifying the hydrodynamic conditions near Franks

Tract to improve Delta water quality and enhance fish protection. After extensive study three alternatives emerged. These alternatives include an operable gate in Threemile Slough, an operable gate in West False River, and combined operable gates in both West False River and Threemile Slough

Two other barrier locations have been extensively analyzed in a recent study. These alternatives are located in the area of the proposed 2-Gate Project. The 2-Gate Project includes the installation and operation of removable gates in two key channels in the central Delta (Old River and Connection Slough) in order to control flows and thereby help reduce entrainment of delta smelt and other sensitive aquatic species at the Banks Pumping Plant (State Water Project, SWP) and Jones Pumping Plant (Central Valley Project, CVP) export pumps. The 2-Gate Project would be a demonstration project that is intended to improve Delta water management activities for the benefit of delta smelt and other listed species.

Appendix B contains additional information on the Franks Tract Project and the 2-Gate Project.

4 DROUGHT EMERGENCY BARRIER ALTERNATIVES

Sixteen potential emergency barrier locations or alternatives were identified in the preparation of this report. Identification and screening of these alternatives was conducted in two phases. Phase 1 consisted of identifying all possible locations where barriers could be installed to reduce sea water intrusion at SWP/CVP pumps during drought conditions. A modeling analysis was conducted on all the barriers identified in Phase 1 and alternatives that provided substantial reductions in electrical conductivity (EC) at the pumps were carried forward into Phase 2. Phase 2 consisted of a more detailed analysis of these alternatives, nine in total, which provided substantial reduction in EC.

4.1 Phase 1 - Identification of Alternatives

A comprehensive list of alternatives was investigated to identify the potential alternatives that would substantially reduce salt water intrusion into the central and south Delta, thereby protecting the quality of water supplies at the south Delta export locations. The river channels listed below were identified for installation of temporary rock barrier(s) or temporary operable gate(s) at single or multiple river channels. Figure 4-1a and 4-1b show the location of these barriers. The identification of these alternatives was based on; (1) drought barriers installed in 1976/77, (2) barriers considered in the Franks Tract Project, (3) barriers considered in the 2-Gate Project, and (4) knowledge of Delta hydrodynamics.

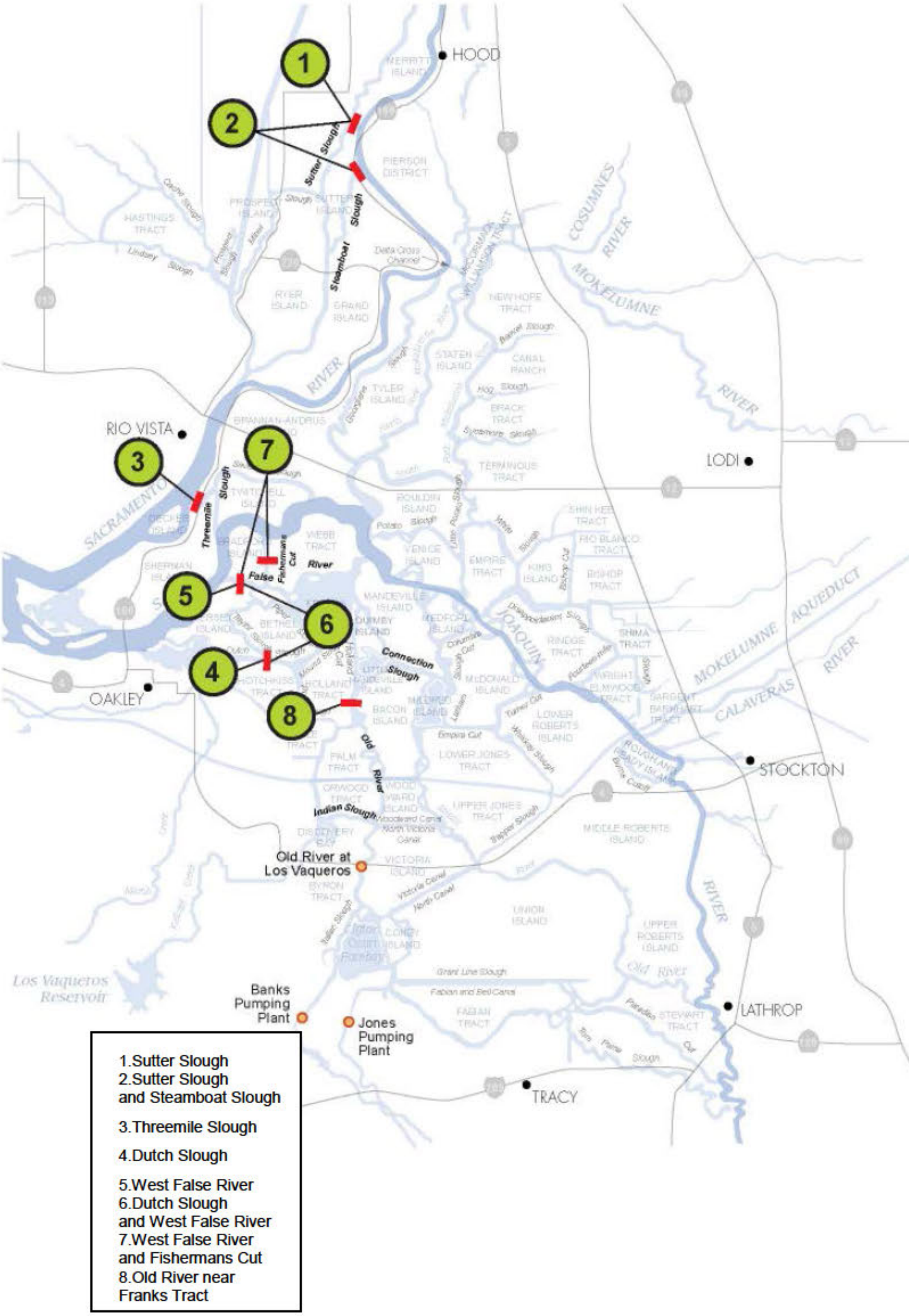

Figure 4-1a Location of Phase 1 Alternatives 1 through 8

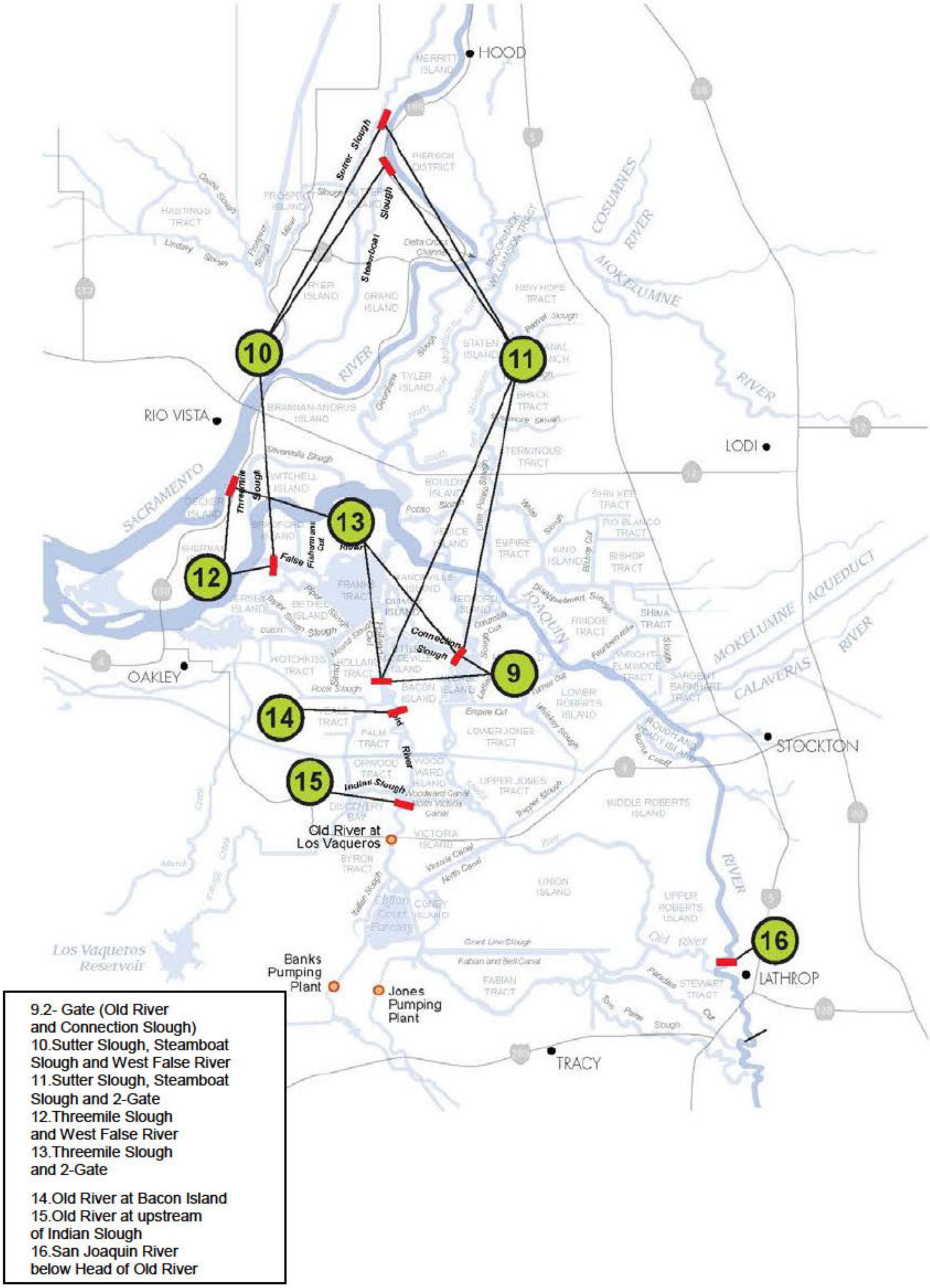

Figure 4-1b Location of Phase 1 Alternatives 9 through 16

1. Sutter Slough
2. Sutter Slough and Steamboat Slough
3. Threemile Slough
4. Dutch Slough
5. West False River
6. Dutch Slough and West False River
7. West False River and Fishermans Cut
8. Old River near Franks Tract
9. 2- Gate (Old River and Connection Slough)
10. Sutter Slough, Steamboat Slough and West False River
11. Sutter Slough, Steamboat Slough and 2-Gate
12. Threemile Slough and West False River
13. Threemile Slough and 2-Gate
14. Old River at Bacon Island
15. Old River at upstream of Indian Slough
16. San Joaquin River below Head of Old River

The effectiveness of the alternatives was measured in terms of percentage reduction in EC at SWP and CVP pumps from base condition (no project). The analysis was conducted for the July through November period using 2001 and 2002 hydrology (dry years). DWR's Delta Simulation Model 2 (DSM2) was used for the modeling analysis. Table 4.1 summarizes the results of the model studies.

The results show that several alternatives provide promising reductions in EC at SWP and CVP pumps. Alternatives that did not provide more than a 5% reduction in EC were not considered for Phase 2 analysis. If a combination of barriers did not result in more than a 5% reduction in EC as compared to a single barrier, that alternative was also not carried forward to Phase 2. For example, Alternative 7, consisting of barriers in West False River and Fishermans Cut, did not result in more than 5% reduction in EC when compared to Alternative 5, with only a barrier in West False River. Therefore, Alternative 7 was not carried forward to Phase 2 analysis.

Table 4.1: July-November Average Electrical Conductivity (EC) Reduction for Phase 1 Alternatives

Alternative Number	Description	Banks Pumping Plant (SWP) 2001	Banks Pumping Plant (SWP) 2002	Jones Pumping Plant (CVP) 2001	Jones Pumping Plant (CVP) 2002	Alternatives Carried to Phase 2
1	Sutter Slough	9%	14%	8%	12%	Yes
2	Sutter Slough and Steamboat Slough	17%	26%	15%	24%	Yes
3	Threemile Slough	10%	20%	9%	18%	Yes
4	Dutch Slough	0%	1%	0%	1%	Eliminated
5	West False River	12%	11%	12%	10%	Yes
6	Dutch Slough and West False River	15%	14%	14%	13%	Eliminated
7	West False River and Fishermans Cut	13%	12%	12%	11%	Eliminated
8	Old River near Franks Tract	5%	3%	4%	2%	Eliminated
9	2-Gate (Old River and Connection Slough)	13%	10%	11%	9%	Yes
10	Sutter Slough, Steamboat Slough and West False River	28%	35%	25%	32%	Yes
11	Sutter Slough, Steamboat Slough and 2-Gate	30%	37%	26%	32%	Yes
12	Threemile Slough and West False River	20%	28%	19%	26%	Yes
13	Threemile Slough and 2-Gate	19%	26%	17%	23%	Yes
14	Old River at Bacon Island	4%	2%	3%	2%	Eliminated
15	Old River at upstream of Indian Slough	0%	-13%	0%	-8%	Eliminated
16	San Joaquin River below Head of Old River	5%	3%	4%	2%	Eliminated
Base (no project) EC (us/cm)		451	478	464	483	
Average Sacramento Flow (cfs)		12,080	14,200	12,080	14,200	
Average Export (cfs)		3,070	4,392	3,943	4,140	

Note: (-) Negative indicates increasing salinity

4.2 Phase 2 – Analysis of Alternatives

The following alternatives were considered and grouped for a more detailed analysis in Phase 2:

Group 1

1. Sutter Slough
2. Sutter Slough and Steamboat Slough
3. Threemile Slough

Group 2

4. West False River
5. 2-Gate (Old River and Connection Slough)

Group 3

6. Sutter Slough, Steamboat Slough and West False River
7. Sutter Slough, Steamboat Slough and 2-Gate
8. Threemile Slough and West False River
9. Threemile Slough and 2-Gate

Figure 4-2 shows the location of these barrier alternatives. These alternatives are categorized into three groups based on how they achieve salinity reduction in the central and south Delta.

The alternatives in Group 1 would reduce salinity intrusion in the central and south Delta by increasing net outward flows in San Joaquin River.

The alternatives in Group 2 would reduce salinity intrusion by forcing higher salinity water to travel a longer path to reach the south Delta export facilities. This would increase mixing and dilution of salt water before it reaches the pumps.

Group 3 consists of a combination of Group 1 and Group 2 alternatives. Combining alternatives can potentially provide the most salinity reduction at the south Delta export facilities.

The Phase 2 alternatives were modeled and analyzed using DSM2 for the July through November period of the recent three years (2007 to 2009) drought. This period is noticeably different from prior dry years (2001 and 2002) due to pumping curtailments required as a result of an interim court order issued by Judge Wanger on December 14, 2007, for the purpose of protecting Delta smelt. Actual hydrology for years 2007 and 2008 along with actual pumping were used in the modeling runs. For year 2009, predicted hydrology and pumping were used in the modeling runs. The SWP water allocation estimated in the beginning of March 2009 was used in this study. The SWP water allocation was based on historical hydrology at 90 percent exceedance level, meaning that in the past 50 plus years on record, only one in 10 was drier. The allocations are calculated using DWR's Delta Coordinated Operations (DCO) Model. The DCO model takes into account the Delta requirements to comply with ESA, Water Quality Control Plan, (D-164) and other court decisions.

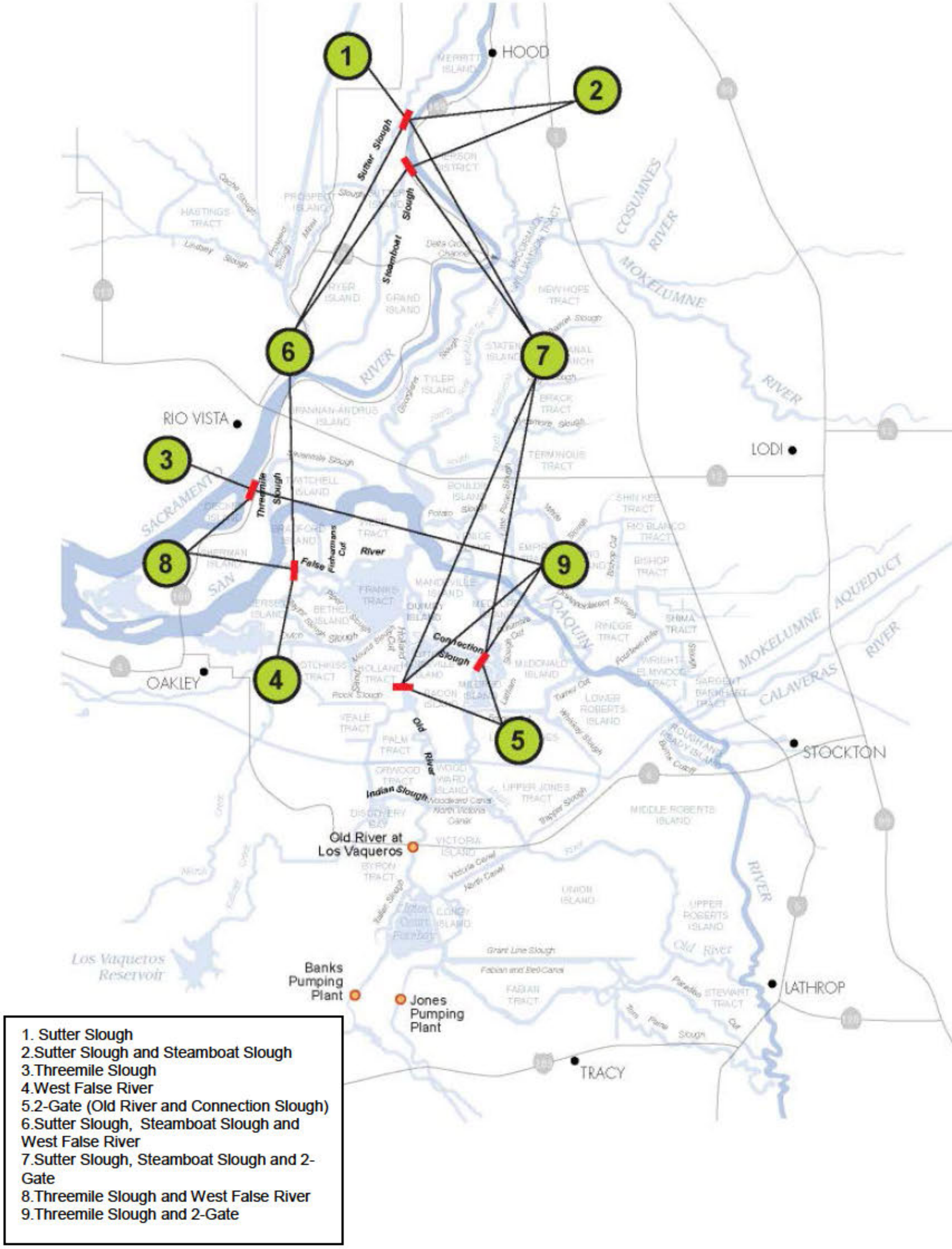

Figure 4-2 Location of Phase 2 Alternatives

The EC results of the modeling simulations for 2007 to 2009 period were evaluated and compared at six key locations (Figure 4-3) in the Delta. The key locations are: SWP, CVP, CCWD OR, Victoria Canal (VIC), Sacramento River at Emmaton (EMM), and San Joaquin River at Jersey Point (JER). Tables 4.2a and 4.2b present the average EC reductions of the alternatives for July through November period. Following are the key observations:

- The reduction in EC at exports varies with flows in the Sacramento River and combined SWP and CVP exports.
- During year 2007, Group 1 alternatives provide higher EC reductions at exports than Group 2 alternatives. In 2007, the five month (July-November) average Sacramento River flows was on the order of 14,000 cfs. The combined exports during the same period were on the order of 9000 cfs.
- During year 2008, both Group 1 and 2 alternatives performed equally well. In 2008, the five month (July-November) average of flows in Sacramento River was on the order of 10,000 cfs. The combined exports during the same period were on the order of 5000 cfs.
- For the forecasted hydrology of year 2009, Group 2 alternatives provide higher EC reductions than Group 1 alternatives. The predicted Sacramento River flows for year 2009 for the five month (July-November) average is on the order of 7000 cfs, and the combined exports are on the order of 2000 cfs. When low flows in the Sacramento River are combined with low exports, the Group 2 alternatives seem to perform better. It should be noted that the predictions for year 2009 hydrology has a greater level of uncertainty. If hydrology for 2009 turns out to be noticeably different from what was assumed, then the conclusions would be different.
- EC reductions for Group 3 alternatives, which include Group 1 and Group 2 alternatives in combination, are additive.

- Sutter Slough and the Sutter Slough and Steamboat Slough alternatives result in increases in EC at Emmaton. This is due to reduction in Sacramento River flows at Emmaton.
- 2-Gate alternative results in increases in EC at Jersey Point and Emmaton. This is due to increases in more sea water mixing concentrated near the confluence of Sacramento and San Joaquin rivers.

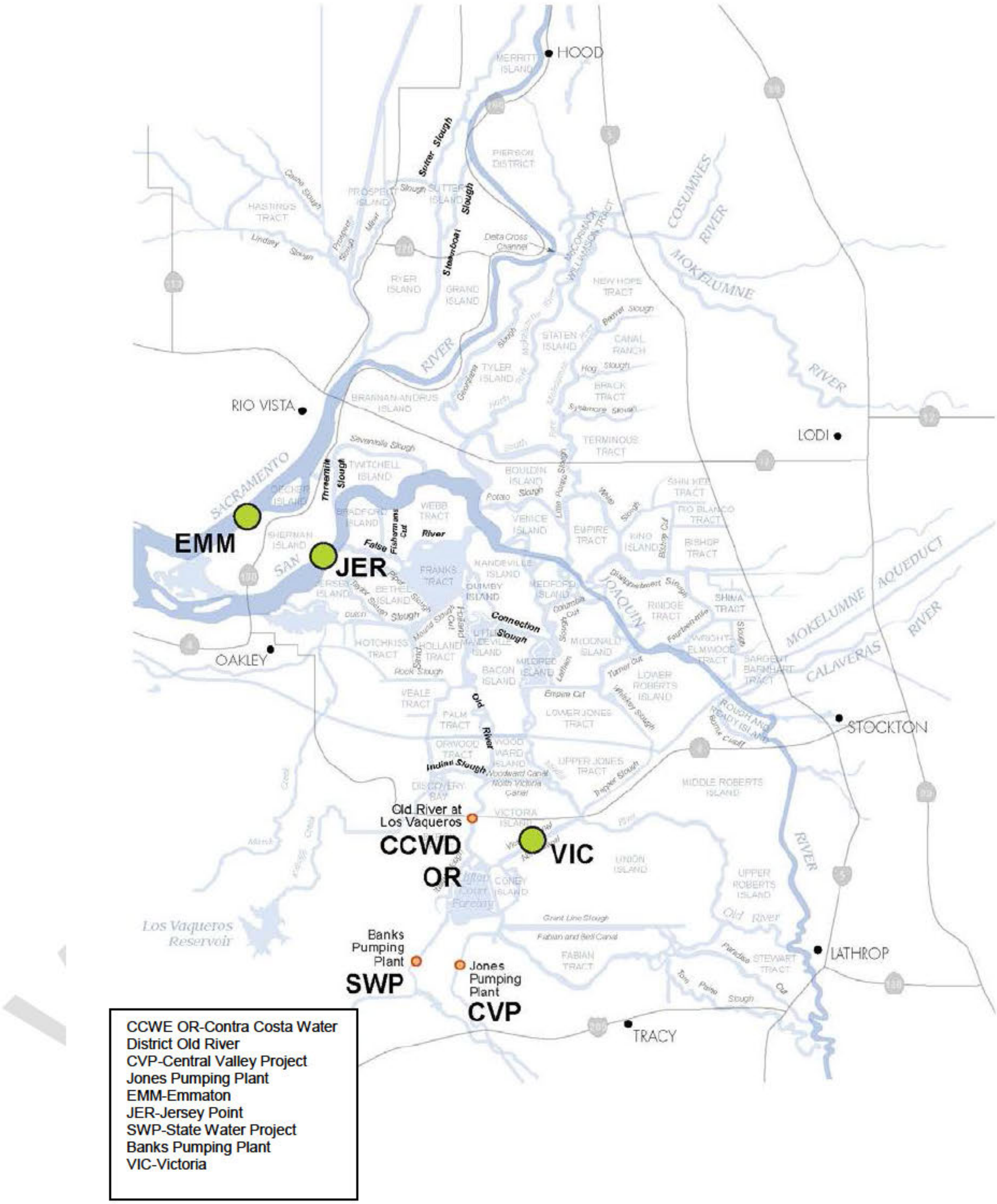

Figure 4-3 Electrical Conductivity (EC) Output Locations

Table 4.2a: Average Electrical Conductivity (EC) Reduction for Phase 2 Alternatives

Alt #	Description	Banks Pumping Plant (SWP)			Jones Pumping Plant (CVP)			Old River at Los Vaqueros		
		2007	2008	2009	2007	2008	2009	2007	2008	2009
1	Sutter Slough	15%	7%	3%	13%	6%	2%	16%	8%	4%
2	Sutter Slough and Steamboat Slough	28%	13%	7%	25%	11%	5%	30%	15%	9%
3	Threemile Slough	26%	6%	2%	23%	5%	2%	29%	8%	3%
4	West False River	11%	12%	20%	10%	10%	13%	15%	17%	31%
5	2-Gate (Old River and Connection Slough)	10%	12%	20%	8%	8%	11%	20%	19%	34%
6	Sutter Slough, Steamboat Slough and West False River	37%	23%	28%	33%	20%	19%	43%	30%	41%
7	Sutter Slough, Steamboat Slough and 2-Gate	39%	25%	29%	32%	18%	17%	45%	32%	45%
8	Threemile Slough and West False River	33%	16%	21%	29%	13%	14%	39%	22%	32%
9	Threemile Slough and 2-Gate	32%	16%	22%	27%	10%	12%	39%	22%	36%
Base (no project) EC (us/cm)		461	386	670	477	420	685	515	408	704
Average Sacramento Flow (cfs)		14,456	10,272	7,556	14,456	10,272	7,556	14,456	10,272	7,556
Average Export Flow (cfs)		4,887	1,496	758	4,146	3,513	1,155	114	130	224

Table 4.2b: July-November Average EC Reduction for Phase 2 Alternatives

Alt #	Description	San Joaquin River at Jersey Pt			Sacramento River at Emmaton			Victoria Canal		
		2007	2008	2009	2007	2008	2009	2007	2008	2009
1	Sutter Slough	11%	9%	1%	-5%	-4%	-4%	13%	7%	5%
2	Sutter Slough and Steamboat Slough	26%	18%	1%	-12%	-11%	-11%	24%	12%	12%
3	Threemile Slough	41%	20%	1%	8%	3%	1%	18%	3%	3%
4	West False River	7%	6%	5%	7%	8%	6%	1%	5%	19%
5	2-Gate (Old River and Connection Slough)	-7%	-5%	-5%	-5%	-4%	-4%	-14%	-1%	16%
6	Sutter Slough, Steamboat Slough and West False River	31%	24%	6%	-3%	-2%	-4%	25%	15%	30%
7	Sutter Slough, Steamboat Slough and 2-Gate	21%	14%	-4%	-18%	-16%	-15%	24%	16%	31%
8	Threemile Slough and West False River	43%	25%	6%	16%	11%	7%	19%	8%	20%
9	Threemile Slough and 2-Gate	38%	17%	-4%	4%	-2%	-2%	15%	4%	19%
Base (no project) EC (us/cm)		1,687	1,210	2,107	1,425	1,584	3,402	353	320	552
Average Sacramento flow (cfs)		14,456	10,272	7,556	14,456	10,272	7,556	14,456	10,272	7,556

Note: (-) Negative indicates increasing salinity

5 CONCEPTUAL LAYOUT OF DROUGHT EMERGENCY BARRIERS

The nine alternatives identified in Section 4 comprise only six alternative sites. These six sites or locations serve as the basis for developing barrier layout requirements. This section presents the general characteristics for these sites and the conceptual layout for both rock and barge mounted barriers.

5.1 Types of Barriers

The locations of the proposed barriers as identified by model studies are shown in Figure 5-1. For conceptual-level layouts, two different types of temporary barriers were considered for this project: (1) rock barrier and (2) barge mounted operable barrier. Table 5.1 provides a summary of river characteristics at the proposed sites for the temporary barriers.

Table 5.1: River Cross-Section Characteristics at Proposed Barrier Sites

Proposed Sites	Location	River Channel Invert Elevation*	River Width at EL 7.0'*	River Cross-Sectional Area at EL. 7.0'*
		ft	ft	sq.ft
Sutter Slough	Sutter Island (West) & Grand Island (East)	-16	176	2,842
Steamboat Slough	Merritt Island (North) & Sutter Island (South)	-14	213	2,975
Threemile Slough	Brannan Island (North) & Sherman Island (South)	-26	620	17,004
West False River	Bradford Island (North) & Jersey Island (South)	-32	853	25,286
Connection Slough	Mandeville Island (North) & Bacon Island (South)	-30	370	9,401
Old River	Holland Tract (West) & Bacon Island (East)	-28	713	15,917

* North American Vertical Datum of 1988 (NAVD88(ft))

Rock Barriers

Rock barriers have been used in the South Delta Temporary Barriers program for many years. The same type of approach could be applied to the drought emergency barriers project. Because of the operational requirements of the Threemile Slough alternative, a rock barrier was not considered for this location.

The rock barriers require minimal foundation preparation and they have a simple design. Compared to operable gates, the construction time for rock barriers is short and they are inexpensive to build. At the end of the season, the embankment material could be removed using conventional construction equipment. Despite their simplicity in design and low construction costs, the rock barriers have some disadvantages. Since the rock barriers lack gates, they do not provide operational flexibility as well as passage to migratory fish and boats. Special fish passage devices may be needed to allow passage to migratory fish. Boat passage can be provided by constructing boat ramps on both the upstream and downstream sides of the barrier and having an onsite boat trailer.

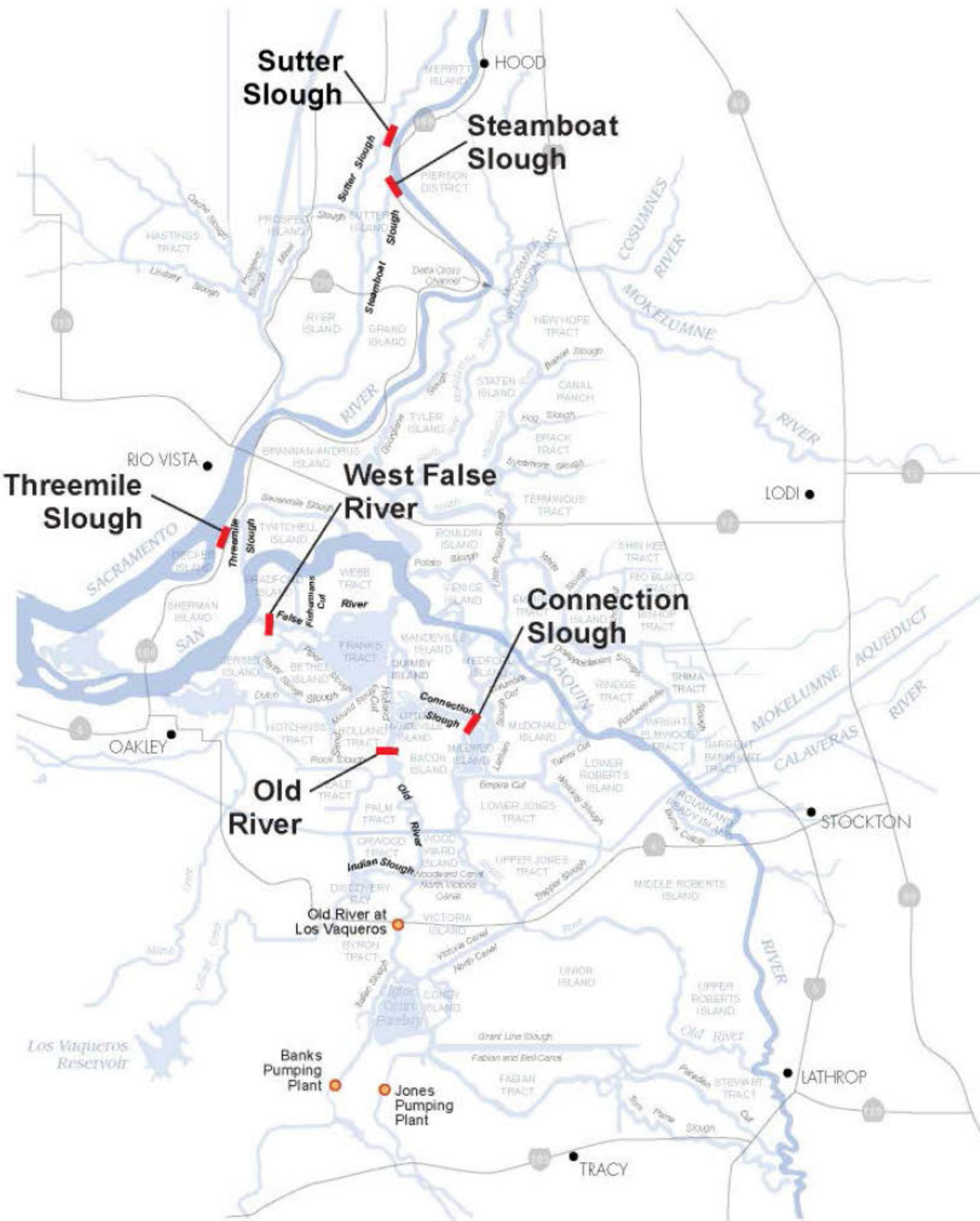

Figure 5-1 Location of Proposed Barriers

The rock barrier will consist of an in-channel rock embankment such that the flow of water could be stopped or minimized. The embankment material will consist of approximately 24 inch diameter rocks. The embankment crest is taken to elevation 7 feet (NAVD 88). In order to allow passage of heavy equipment during the construction and removal of rock materials from the embankment, the crest of the embankment will be about 20 feet wide. The barrier is not expected to completely stop the flow of water through it, thus eliminating the need of any cutoff walls within the embankment core and in the foundation. Figures 5-2 through 5-6 illustrate conceptual layouts of rock barriers for each of the proposed sites (except Threemile Slough).

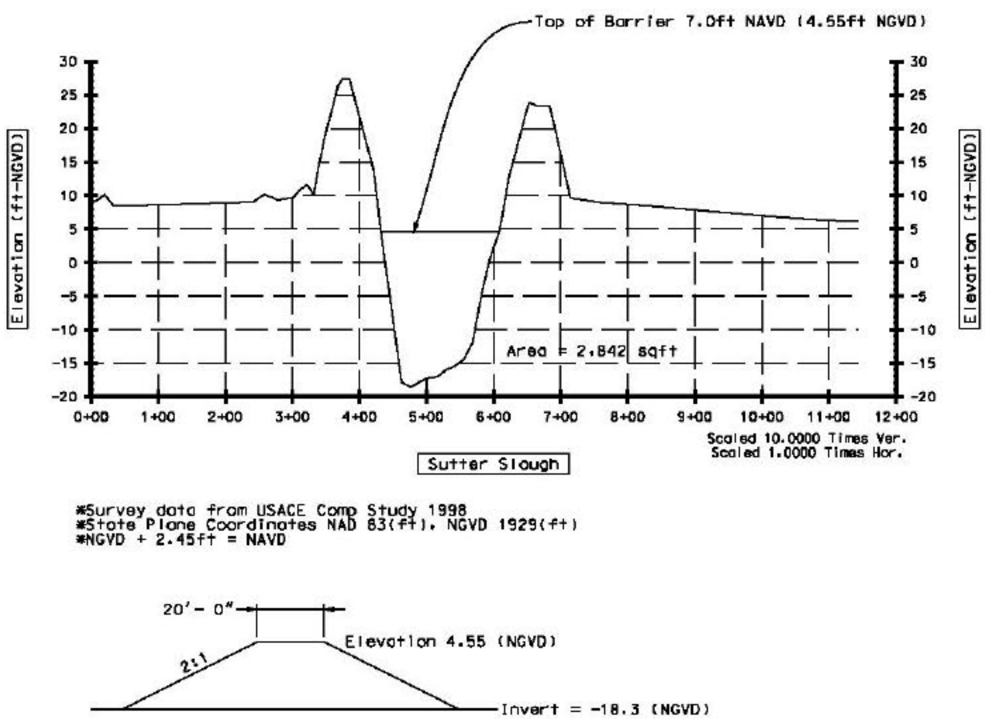

Figure 5-2 Sectional Views of Rock Barrier at Sutter Slough

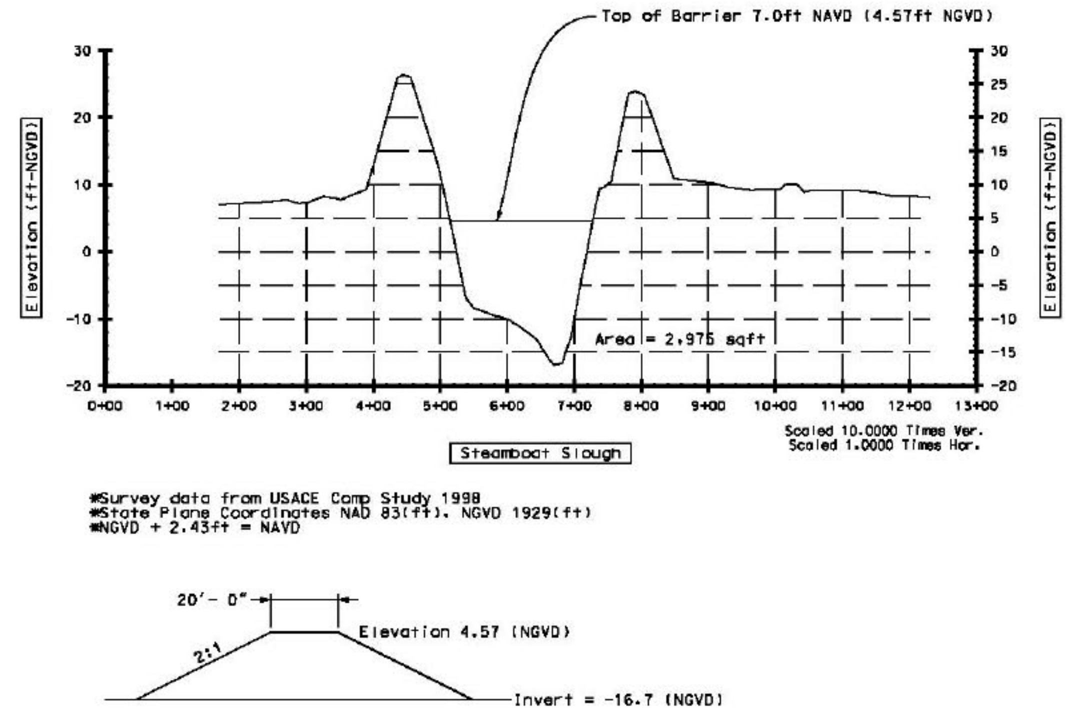

Figure 5-3 Sectional Views of Rock Barrier at Steamboat Slough

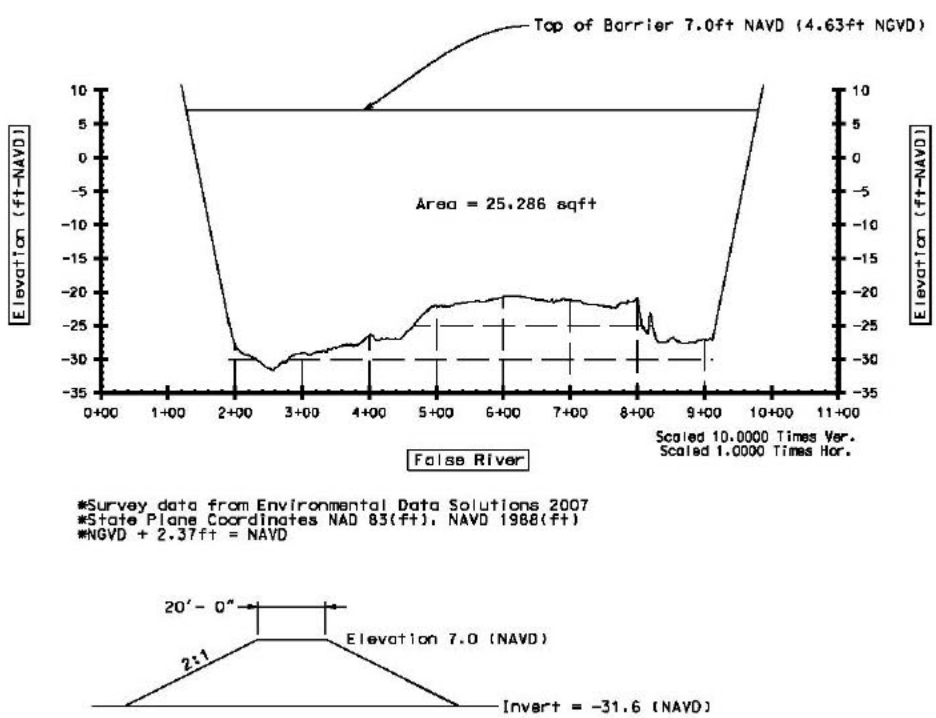

Figure 5-4 Sectional Views of Rock Barrier at West False River

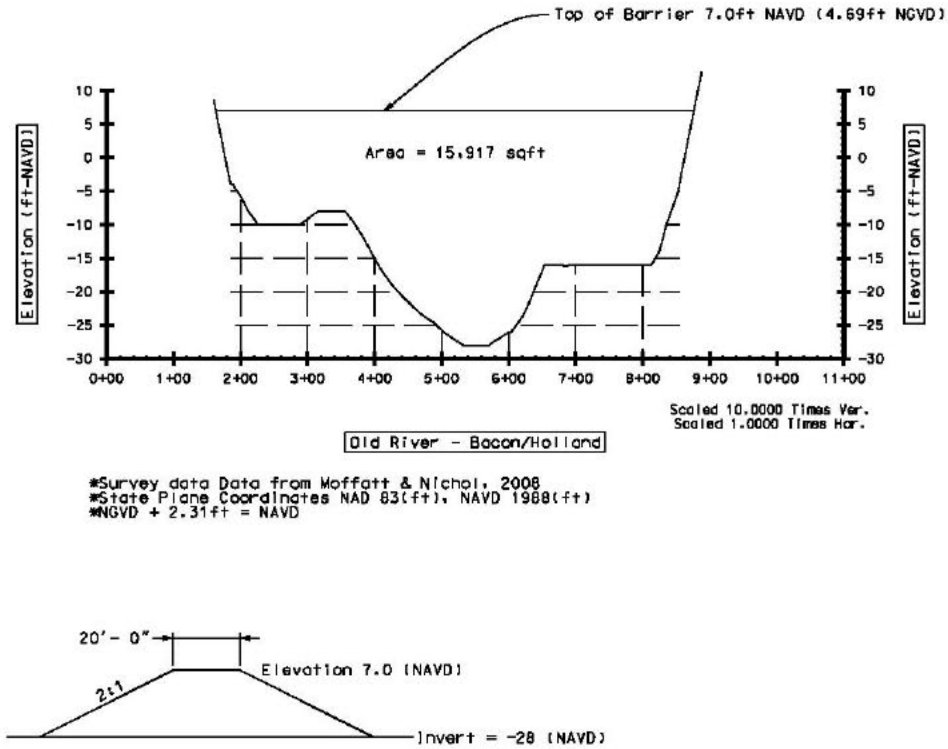

Figure 5-5 Sectional Views of Rock Barrier at Old River

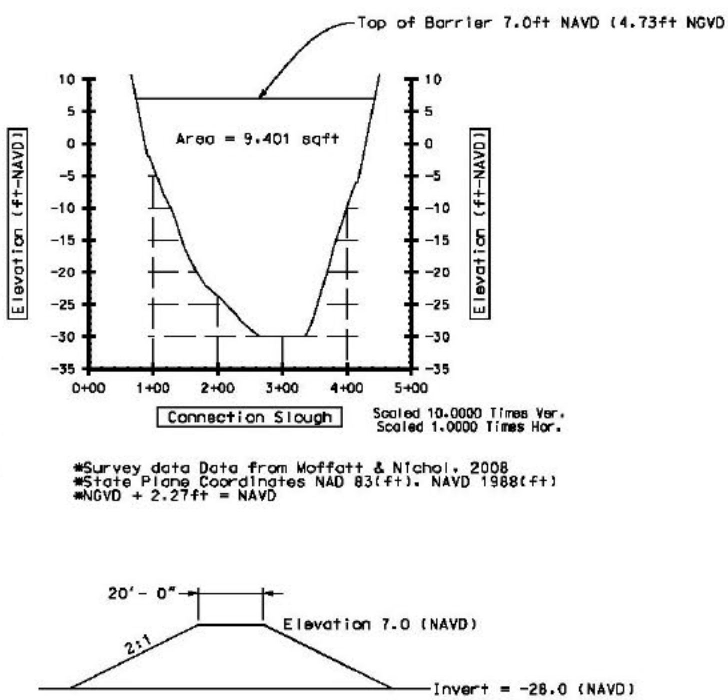

Figure 5-6 Sectional Views of Rock Barrier at Connection Slough

Barge Mounted Operable Barrier

The barge mounted operable barriers are currently being proposed for the 2-Gate Project. Similar operable barriers could be used at any of the proposed emergency barrier locations. The barge mounted operable barriers can be installed and removed in a short period of time. After the end of the season, the barrier can be removed and stored for future use.

The construction of the operable barrier involves installation of butterfly gates on top of a commercially available cargo barge. The converted barge could be floated to the site and ballasted at the prepared site on the river bottom. Prior to the installation of the barge-mounted gate system, the channel bottom would need to be dredged to remove unstable material, and a gravel sub-base foundation would need to be installed to provide uniform foundation. After the installation of the barge, rock embankment will be placed in the remaining portions of the river channel. The gates can be operated to manage flows to reduce sea water intrusion. The gates would provide a navigational opening to accommodate normal commercial and large public vessel traffic typical in Delta. Boat ramps could be installed both upstream and downstream of the barrier to allow boat passage when the gates are closed. Figures 5.7 and 5.8 illustrate conceptual layouts of barge mounted operable barrier in closed and open position, respectively. Depending upon the width of the river channel and length of the barge, two barges might be needed to regulate flows.

Compared to a rock barrier, the barge mounted gates are expensive and need some foundation preparation. Depending upon the hydrodynamic forces associated with head differences across the gate when it is operational, piles might be needed to support the barge from sliding or overturning. This could increase the construction cost and may require additional permits to be secured for the installation of the barge.

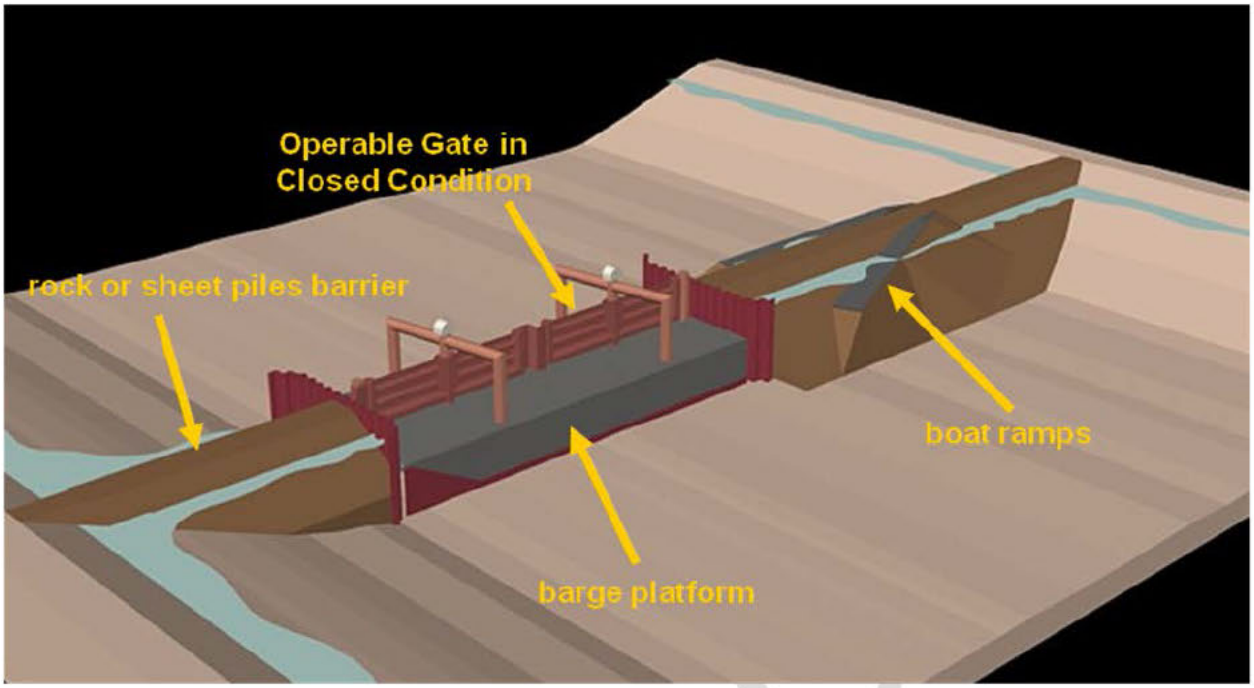

Figure 5-7 Barge Mounted Operable Barrier – Closed Condition

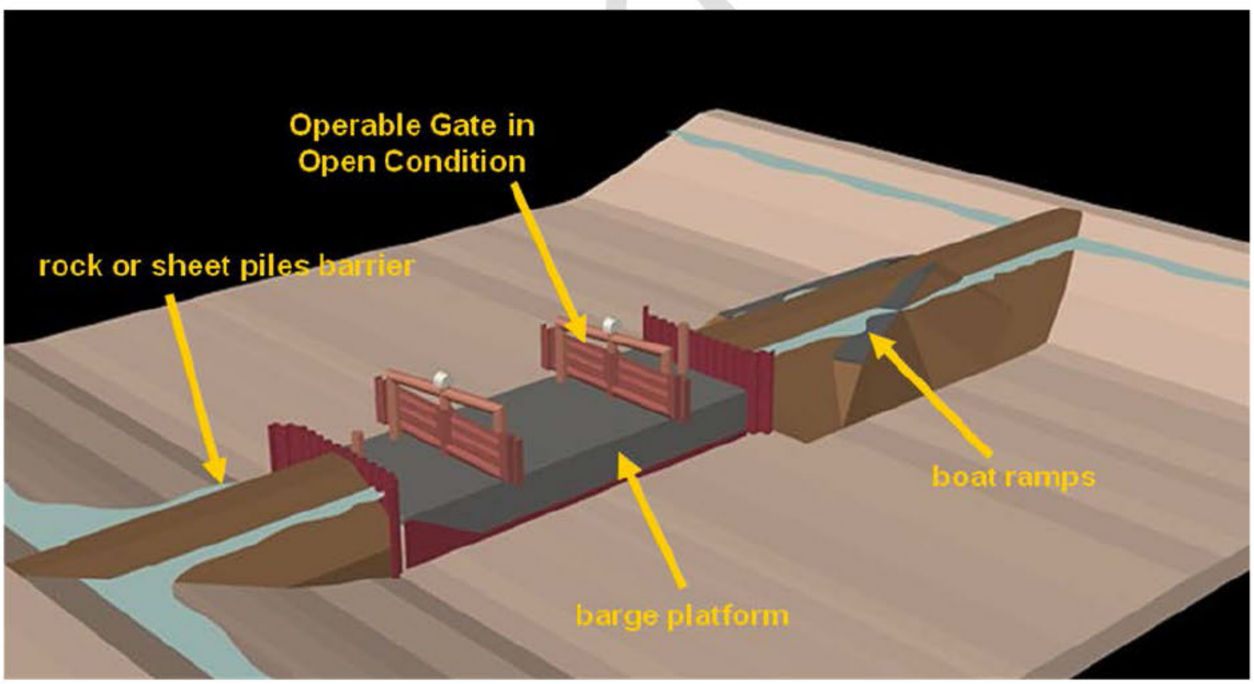

Figure 5-8 Barge Mounted Operable Barrier – Open Condition

Table 5.2 provides a summary of the major project parameters for barge mounted gates at all proposed locations. For all alternatives in this conceptual level study, the elevation of the top of the gates was set to 6.5 feet. The number and size of barges vary depending upon the depth and width of channel. With the exception of the Threemile Slough and West False River sites, the remaining sites would need only one barge per site.

Table 5.2 Barge mounted gate project parameters

No	Parameters*	Barge Placement Site					
		Sutter Slough	Steamboat Slough	Threemile Slough	West False River	Old River	Connection Slough
1	Minimum channel bed elevation **	-15.5	-14	-30	-25	-22	-22
2	Total width of channel	220	220	600	900	875	437
3	Length of temporary rockfill	110	120	200	400	635	197
4	Thickness of bedding rock	7	7	7	7	5	7
5	Number of barges (#)	1	1	2	2	1	1
6	Length of barge	110	100	200	250	240	240
7	Width of barge	40	40	50	50	65	65
8	Thickness of barge deck	7	7	12	12	12	12
9	Barge sill elevation **	-6	-4	-13	-13	-13	-13
10	Top of gate **	6.5	6.5	6.5	6.5	6.5	6.5
11	Height of gate **	12.5	10.5	19.5	19.5	19.5	19.5
12	Bottom of barge **	-13	-11	-25	-25	-25	-25

*All values in feet except as noted
**North American Vertical Datum NAVD(88)

5.2 Alternative Barrier Project Costs

Conceptual level cost estimates for each alternative barrier location and barrier type are presented in Table 5.3.

The conceptual level cost estimates include allowances for design, construction management, mobilization/demobilization, site preparation, and navigation aids. An additional allowance is included for more in-depth geotechnical investigation for barge alternatives. The estimate also includes 30% contingencies to account for unknowns at this level of study.

The cost estimates for rock barriers were based on the total volume of the rock needed for construction of the embankment.

The estimates of quantities for the barge mounted gates were based on quantities developed in the 2-Gate Project.

Table 5.3: Cost Summary for Rock Barriers and Barge Mounted Operable Barriers

Proposed Sites	Rock Barriers	Barge Mounted Operable Barriers
Sutter Slough	$ 2,800,000	$ 6,000,000
Steamboat Slough	$ 2,800,000	$ 5,400,000
Threemile Slough	--	$ 19,600,000
West False River	$ 16,900,000	$ 23,900,000
Connection Slough	$ 7,100,000	$ 10,400,000
Old River	$ 10,500,000	$ 12,900,000

While Table 5.3 shows the costs at each separate barrier location, Table 5.4 details the costs associated with the Phase 2 alternatives. The alternatives include single barriers as well as multiple barriers within an alternative. Each alternative details both construction methods, the rock barriers and the barge mounted operable barrier.

Table 5.4: Cost Summary for Phase 2 Alternatives

Alt #	Description	Cost of Rock Barriers	Cost of Barge Mounted Operable Barriers
1	Sutter Slough	$2,800,000	$6,000,000
2	Sutter Slough and Steamboat Slough	$5,600,000	$11,400,000
3	Threemile Slough	--	$19,600,000
4	West False River	$16,900,000	$23,900,000
5	2-Gate (Old River and Connection Slough)	$17,600,000	$23,300,000
6	Sutter Slough, Steamboat Slough and West False River	$22,500,000	$35,300,000
7	Sutter Slough, Steamboat Slough and 2-Gate	$23,200,000	$34,700,000
8	Threemile Slough and West False River	-	$43,500,000
9	Threemile Slough and 2-Gate	-	$42,900,000

6 SCREENING OF ALTERNATIVES

The nine alternatives identified in Section 4 were evaluated in a screening analysis comparing the potential alternative water quality benefit (as a reduction in salinity) versus the alternative estimated cost. A relationship between the benefit and cost was calculated and expressed as a benefit-cost index or BCI. The basis of the calculation and the comparison of the respective alternative BCIs is presented below.

Determination of Cost Benefit Index

The Benefit-Cost Index (BCI) is a unit-less value for each project alternative that provides a means of allowing comparative analysis of each alternative, based on the evaluation parameters of benefit and cost.

Based on the results of hydrodynamic modeling, a table of salinity reduction benefits (benefits), expressed as percent change relative to baseline conditions, was prepared for the modeling period (July-November of year 2007 through 2009). These benefits were determined at the three export locations, SWP, CVP and CCWD OR.

For each export location, the benefits were then summarized to give a numerically averaged benefit value for each project alternative. Because significant differences exist in the volume of water diverted at each export location, it was necessary to adjust the benefits calculation by applying a weighting factor based on the relative difference between export volumes at the three locations. This weighting factor was applied to each calculated diversion flow for each year in the 2007 through 2009 period to provide a weighted percent reduction or benefit value. To determine the BCI, the values were scaled to a number near one (1). The calculation included: multiplying the weighted percent reduction (benefits) by 100; dividing the estimated costs (see Table 5.4) by one million (10^6); and then dividing the weighted benefit value by the estimated cost (in $mil). The resulting BCI provides a relative measure of an alternative's cost effectiveness in achieving salinity reduction benefits. A higher BCI represents a more cost-effective alternative.

The results of the analysis are presented in Table 6.1. A more detailed table of the results presenting the intermediate calculated values which support the data presented in Table 6.1 is located in Appendix C.

Table 6.1: Benefit/Cost Index for Phase 2 Alternatives

Alt #	Description	Units	Banks Pumping Plant (CVP)	Jones Pumping Plant (CVP)	Old River at Los Vaqueros	Total benefit/ cost index
1	**Sutter Slough**					
	Rock barrier	Cost ($,000,000's)	2.80	2.80	2.80	
		Benefit / cost index	1.32	1.32	0.10	2.74
	Operable gate	Cost ($,000,000's)	6.00	6.00	6.00	
		Benefit / cost index	0.62	0.62	0.05	1.28
2	**Sutter Slough and Steamboat Slough**					
	Rock barrier	Cost ($,000,000's)	5.60	5.60	5.60	
		Benefit / cost index	1.26	1.28	0.10	2.65
	Operable gate	Cost ($,000,000's)	11.40	11.40	11.40	
		Benefit / cost index	0.62	0.63	0.05	1.30
3	**Threemile Slough**					
	Rock barrier	Cost ($,000,000's)	-	-	-	
		Benefit / cost index	-	-	-	
	Operable gate	Cost ($,000,000's)	19.60	19.60	19.60	
		Benefit / cost index	0.28	0.25	0.01	0.55
4	**West False River**					
	Rock barrier	Cost ($,000,000's)	16.90	16.90	16.90	
		Benefit / cost index	0.32	0.36	0.08	0.76
	Operable gate	Cost ($,000,000's)	23.90	23.90	23.90	
		Benefit / cost index	0.23	0.26	0.05	0.54

Alt #	Description	Units	Banks Pumping Plant (CVP)	Jones Pumping Plant (CVP	Old River at Los Vaqueros	Total benefit/ cost index
5	**2-Gate (Old River and Connection Slough)**					
	Rock barrier	Cost ($,000,000's)	17.60	17.60	17.60	
		Benefit / cost index	0.30	0.28	0.08	0.67
	Operable gate	Cost ($,000,000's)	23.30	23.30	23.30	
		Benefit / cost index	0.23	0.22	0.06	0.50
6	**Sutter Slough, Steamboat Slough and West False River**					
		Cost ($,000,000's)	22.50	22.50	22.50	
	Rock barrier	Benefit / cost index	0.54	0.58	0.08	1.20
	Operable gate	Cost ($,000,000's)	35.30	35.30	35.30	
		Benefit / cost index	0.34	0.37	0.05	0.76
7	**Sutter Slough, Steamboat Slough and 2-Gate**					
	Rock barrier	Cost ($,000,000's)	23.20	23.20	23.20	
		Benefit / cost index	0.55	0.52	0.09	1.16
	Operable gate	Cost ($,000,000's)	34.70	34.70	34.70	
		Benefit / cost index	0.37	0.35	0.06	0.77
8	**Threemile Slough and West False River**					
	Rock barrier	Cost ($,000,000's)	-	-	-	
		Benefit / cost index	-	-	-	
	Operable gate	Cost ($,000,000's)	43.50	43.50	43.50	
		Benefit / cost index	0.23	0.23	0.03	0.49
9	**Threemile Slough and 2-Gate**					
	Rock barrier	Cost ($,000,000's)	-	-	-	
		Benefit / cost index	-	-	-	
	Operable gate	Cost ($,000,000's)	42.90	42.90	42.90	
		Benefit / cost index	0.23	0.20	0.04	0.47

Based on the analysis a rock barrier in Sutter Slough or rock barriers in Sutter Slough and Steamboat Slough provide the greatest BCI.

7 FINDINGS AND CONCLUSIONS

The following key observations are made in this analysis.

1. The nine alternatives identified in Phase 2 of this study have potential to reduce salinity at exports during drought periods.
2. The performance (reduction in EC at exports) of alternatives varies with flows in the Sacramento River and exports.
3. The EC reductions up to 40% can be achieved at exports by installing barriers in Delta during drought periods.
4. Based on this study, a rock barrier in Sutter Slough or rock barriers in Sutter Slough and Steamboat Slough seem to be provide the highest benefit cost ratio.

Although the Sutter Slough and Sutter Slough/ Steamboat Slough alternatives provide higher BCIs it is not the only evaluation parameter and criteria that should be used to select a preferred or recommended alternative. At this conceptual-planning level no refinement of the benefit analysis has been done to consider and evaluate other impacts (or benefits). These other impacts or benefits include the environment, fishery resources, navigation, recreation, socio-economic, transportation, air quality, agricultural, as well as others. The purpose of this document is to serve as a basis for further evaluation and analysis of potential temporary emergency barriers. A further analysis will be necessary to consider all potential impacts (or benefits) and identify a recommended or preferred alternative(s).

A flow and water quality monitoring plan might also need to be implemented to monitor the performance of the installed barrier and operate the CVP and SWP facilities.

Appendix C contains a discussion on monitoring needs for each of the proposed alternatives.

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Department of Water Resources (1978) – "The 1976-1977 California Drought, A Review", pgs. 26 – 36.

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APPENDIX A

APPENDIX A -BARRIERS INSTALLED IN 1976/77

Appendix A presents a summary of the use of barriers in the Delta by DWR during 1976 and 1977 to address drought impacts on water quality. The summary information in this appendix was obtained from DWR records including "The 1976-1977 California Drought, A Review (DWR, 1978), Bulletin 132-78, "Management of the California State Water Project" (DWR, 1978), and Bulletin 132-78, Appendix E, "Management of the California State Water Project" (DWR, 1981).

1976 Barriers

Several rock barriers were installed at Delta locations during 1976/77 to help mitigate for drought conditions (See Table 1). Barriers were installed at two different locations during 1976. One barrier was constructed at Sutter Slough from September to December to help meet water quality criteria, to conserve water during the drought, and enable increased SWP pumping. DWR estimated that the barrier and increased pumping conserved 60 TAF. The barrier had little effect on salinity upstream of Rio Vista. Low tide levels immediately downstream of the closure were lowered by up to 1.6 feet, but irrigation was not impacted. The barrier was breached when EC at Emmaton began to approach the maximum limit.

Another barrier was built at the head of Old River to protect fishery resources in the Delta. This barrier should not be considered as specifically drought related, as it was installed annually at the request of the Department of Fish and Game. This barrier is installed pursuant to the Four Party Interim Fish Protection Agreement between the Department of Water Resources, Department of Fish and Game, U.S. Bureau of Reclamation, and the U.S. Fish and Wildlife Service. The barrier increased the flow in the San Joaquin River by reducing the flow into Old River. This increased flow raised dissolved oxygen levels in the San Joaquin River which benefits the upstream migration of salmon.

Figure 13.
DROUGHT MITIGATIVE FACILITIES CONSTRUCTED BY DWR
SACRAMENTO - SAN JOAQUIN DELTA 1976 and 1977

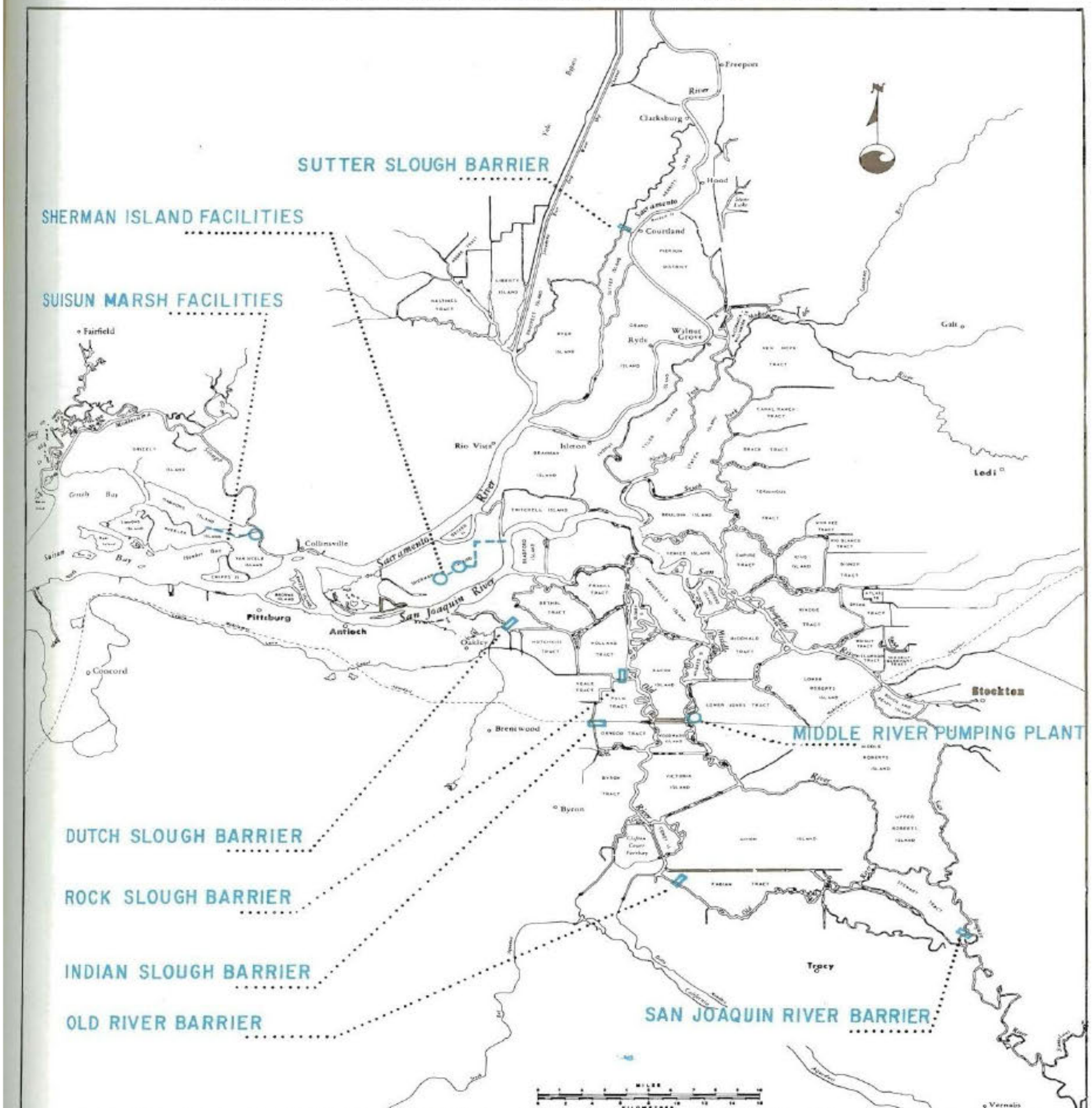

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Figure A-1
Taken from "The 1976-1977 California Drought, A Review"

1977 Barriers

As drought conditions continued, barriers were installed at six different locations in the Delta in 1977. In addition, control facilities were built at another two locations, Suisun March and Sherman Island. The Suisun Marsh Facilities provided duck club owners with lower salinity water through existing culverts and controlled levee breaches. This lower salinity water was needed to produce waterfowl vegetation. The Sherman Island facilities altered the existing irrigation system to provide better quality water for farming purposes.

South Delta Facilities

Two barriers were constructed in the South Delta, one in Old River east of Clifton Court and one in the San Joaquin River near Mossdale. (The fish barrier at Old River will be explained below under 'Old River Closure'.) Another barrier planned on Middle River was canceled due to interference with construction work at the Tracy Road Bridge. The Old River barrier east of Clifton Court contained flap gates which allowed eastward flow at high tide and increased water circulation and quality in Old River. The San Joaquin River barrier raised the water level, particularly at low tide, and allowed water users south of Paradise Cut to pump at a constant rate regardless of the tidal stage. The total cost of about $443,000 was funded by the Federal Drought Emergency Act. These costs included engineering, construction, removal, and surveillance of the barriers.

Rock Slough Quality Control Facilities

Two rock barriers were constructed at Rock and Indian Sloughs (Werner Cut) as well as a temporary pumping plant on Middle River to reduce chloride levels at the Contra Costa Canal Intake. The barriers acted to limit inflow of Old River water (typically high in chlorides) to the Canal Intake. The Rock Slough barrier allowed for emergency east-west flow but generally prevented channel inflow. The Indian Slough barrier permitted only northward flow which contains some Middle River water via Santa Fe Cut and the Woodward- Victoria North Canal. This water tends to have lower salinity than does Old River further downstream. The temporary pumping plant at Middle River served to further reduce chloride levels in the pool. The pumping plant operated during the time period of June 10, 1977, to January 15, 1978. The plant lifted better quality water into East Bay Municipal Utilities District's Mokelumne Aqueduct Number 1, to flow to the intake pool just north of the Indian Slough Barrier.

The barriers and pumping plant were funded by the Federal Drought Emergency Act and the California Water Fund at a cost of about $2.5 million. The combination of barriers and pumping plant were considered a success as chloride levels in the Contra Costa Canal Intake Pool were significantly lower than in Old River. The salinity of Contra Costa Canal was also lowered by an average of about 28 percent.

West Delta Facilities

Three barriers were proposed to be constructed in the West Delta area, at Dutch Slough, Fishermans Cut, and False River. However, only the Dutch Slough barrier with siphon and flap gates was actually constructed. This barrier allowed westward flow at ebb tide and restricted eastward flow with the intention of moving higher salinity water away from Dutch and Sandmound Sloughs into False River and the San Joaquin River. The barriers at Fishermans Cut and False River were not needed due to heavy rains in January of 1978. The barrier at Dutch Slough cost around $533,000 and was funded by the Federal Drought Emergency Act.

Old River Closure

As in 1976, a barrier was installed at the head of Old River for fishery purposes. The barrier was installed at the request of the Department of Fish and Game to protect the fall upstream migration of salmon.

1976-77 Drought Mitigation Barriers	
Sutter Slough Barrier	Sept 1, 1976 – Dec 3, 1976
Rock Slough Barrier	June 10, 1997* – March 16, 1978*
Indian Slough Barrier	June 10, 1997* – March 16, 1978*
Dutch Slough Barrier	Sept 20, 1977* – Jan 13, 1978
Old River Barrier	July 20, 1977 – Jan 15, 1978*
San Joaquin River at Mossdale Barrier	July 20, 1977 – Jan 15, 1978*
Old River at Head Barrier	Nov 1, 1976 – Nov 23, 1976 Oct 28, 1977 – Dec 2, 1977

*Estimated dates

APPENDIX B

APPENDIX B - BARRIERS CONSIDERED IN RECENT STUDIES

Appendix B presents a summary of several recent Delta barrier projects in the planning phase being considered by DWR. The projects include the Franks Tract project which is a CALFED programmatic action under the Ecosystem Restoration Program, and the 2-Gate project which has been proposed by several State water contractors (CCWD and MWD) for possible implementation by DWR. The planning information from each of these projects has provided the basis for evaluating barrier alternatives as presented in this report.

Franks Tract Project

The Franks Tract Project was initiated by the CALFED Record of Decision (August, 2000). The Franks Tract Project was one of 600 programmatic Ecosystem Restoration Program (ERP) actions. The California Department of Water Resources (DWR) and U.S. Department of the Interior, Bureau of Reclamation (Reclamation) conducted numerous studies to evaluate the feasibility of modifying the hydrodynamic conditions near Franks Tract to improve Delta water quality and enhance fish protection. These studies (DWR 2005a, 2005b, 2005c, 2005d, 2005e, 2006a, 2007; Reclamation 2007, 2008; Shrestha, pers. comm., 2007) indicated that modifying the hydrodynamic conditions near Franks Tract may reduce salinity in the Delta and protect fish resources. DWR and Reclamation are jointly preparing an Environmental Impact Statement/Environmental Impact Report (EIS/EIR) for this project.

Several alternatives were considered as part of the Franks Tract Project. After detailed evaluation of those alternatives, the following three alternatives are being carried forward in the EIS/EIR.

Alternative #1: Operable Gate in Threemile Slough

Alternative #2: Operable Gate in West False River

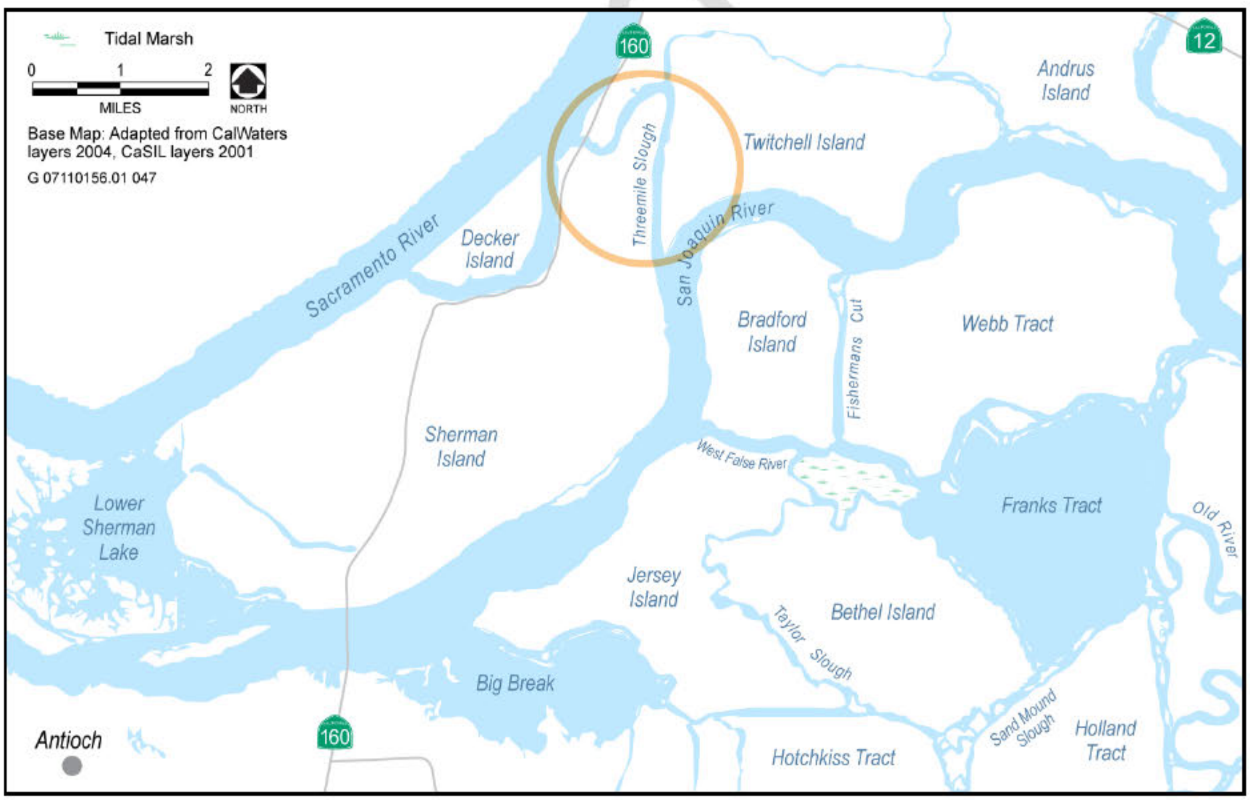
Alternative #3: Operable Gate in West False River and Threemile Slough

Below is a brief description of each of the project alternatives:

Threemile Slough Gate Alternative

Threemile Slough connects the Sacramento and San Joaquin Rivers in the west Delta approximately 8.5 miles (measured along the Sacramento River) upstream of their confluence near Collinsville. This alternative involves installing an operable gate in the Threemile Slough channel (See Figure B-1) to regulate flow between the Sacramento River and San Joaquin River.

A water quality modeling analysis (Reclamation 2008; DWR 2005e, 2006b) showed that by balancing net downstream flows in both the Sacramento and the San Joaquin rivers, there would be a reduction in sea water intrusion in the central and south Delta. This reduction is a result of increasing net outward flows in the western reaches of the San Joaquin River.



Source: Adapted by EDAW in 2008

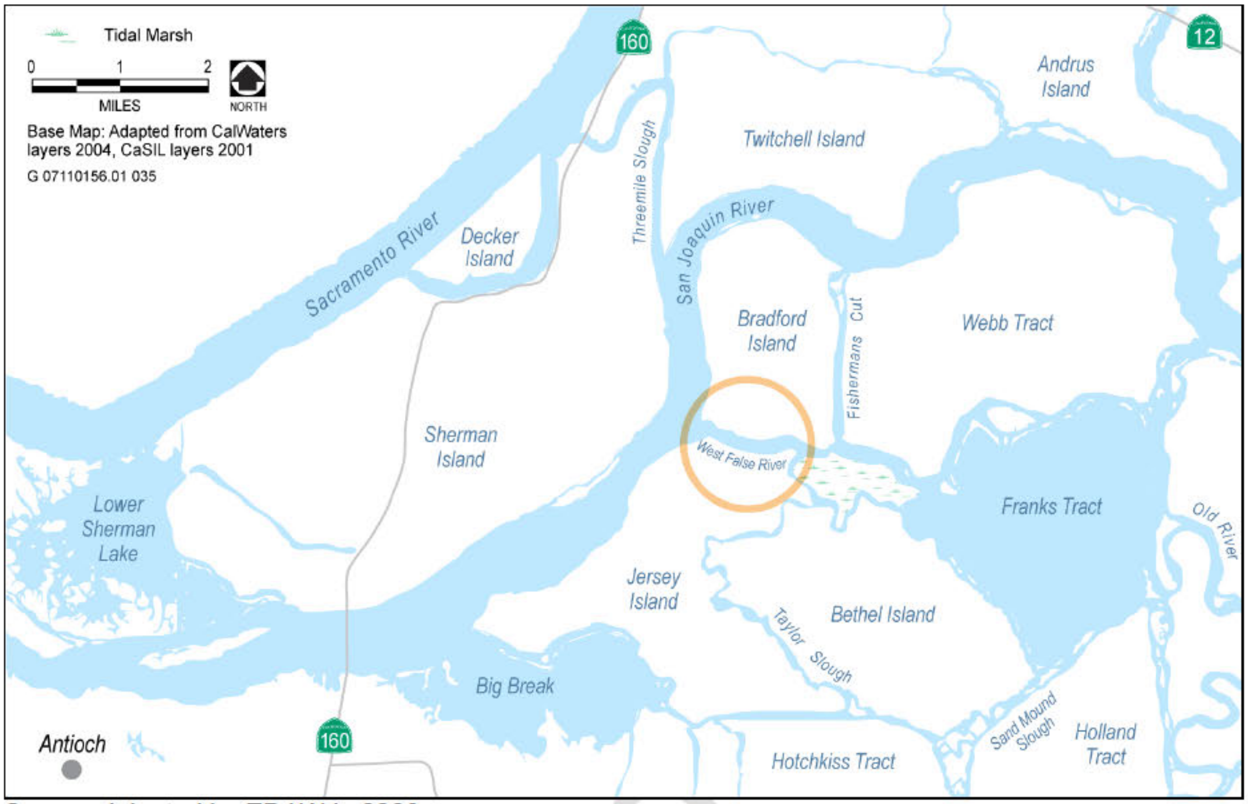
Figure B-1 Threemile Slough Gate Alternative

Fisheries modeling studies for the Threemile Slough Gate Alternative indicate that the gate could be operated in two different ways to provide distinct beneficial influences on conditions for early life stages of sensitive fish species in the west and central Delta. Operating the gate closed on the flood tide substantially increases movement of particles (representing early life stages of sensitive fish species) down the lowermost reach of the Sacramento River to areas in the west Delta, where favorable rearing habitat exists. Operating the gate closed on a portion of the ebb tide substantially increases movement of particles in the lowermost reach of the San Joaquin River to areas in the west Delta, where favorable rearing habitat exists. Furthermore, this substantially reduces movement of associated particles to the central and south Delta, where there are increased vulnerabilities to fish predation and in-Delta and export losses through fish entrainment and impingement.

This alternative could potentially provide a high level of operational flexibility for the CVP and SWP, based on its ability to operate during different tidal regimes and provide water quality and fish benefits.

West False River Alternative

West False River is a major waterway connecting the lower San Joaquin River with Franks Tract. When closed completely or partially, the West False River Gate Alternative (See Figure B-2) would reduce the intrusion of higher salinity water from the west Delta into Franks Tract via West False River. The higher salinity water would be forced to travel a longer distance up the San Joaquin River north of Bradford Island and Webb Tract before entering Franks Tract from the north and being subsequently drawn south toward the CVP and SWP export facilities via Old River. This alternative would also prevent saltwater from entering Franks Tract and becoming trapped and mixed in Franks Tract (Reclamation 2008). The modeling (Reclamation 2008; DWR 2005e, 2006b) results showed that the alternative would reduce salinity at CVP and SWP pumps, as well as other Delta locations.



Source: Adapted by EDAW in 2008

Figure B-2 West False River Gate Alternative

Analysis indicates that a gate in West False River could provide moderate benefits to fish resources. Delta and longfin smelt present in the west and central Delta could benefit from gate operations that decrease tidal flows into Frank Tract where there is higher vulnerability to predation and decrease fish losses from entrainment, impingement, and predation at the water export facilities in the south Delta.

This alternative could potentially provide a high level of operational flexibility for the CVP and SWP, based on its ability to operate during different tidal regimes and meet water quality and fish objectives.

West False River and Threemile Slough Gates Alternative

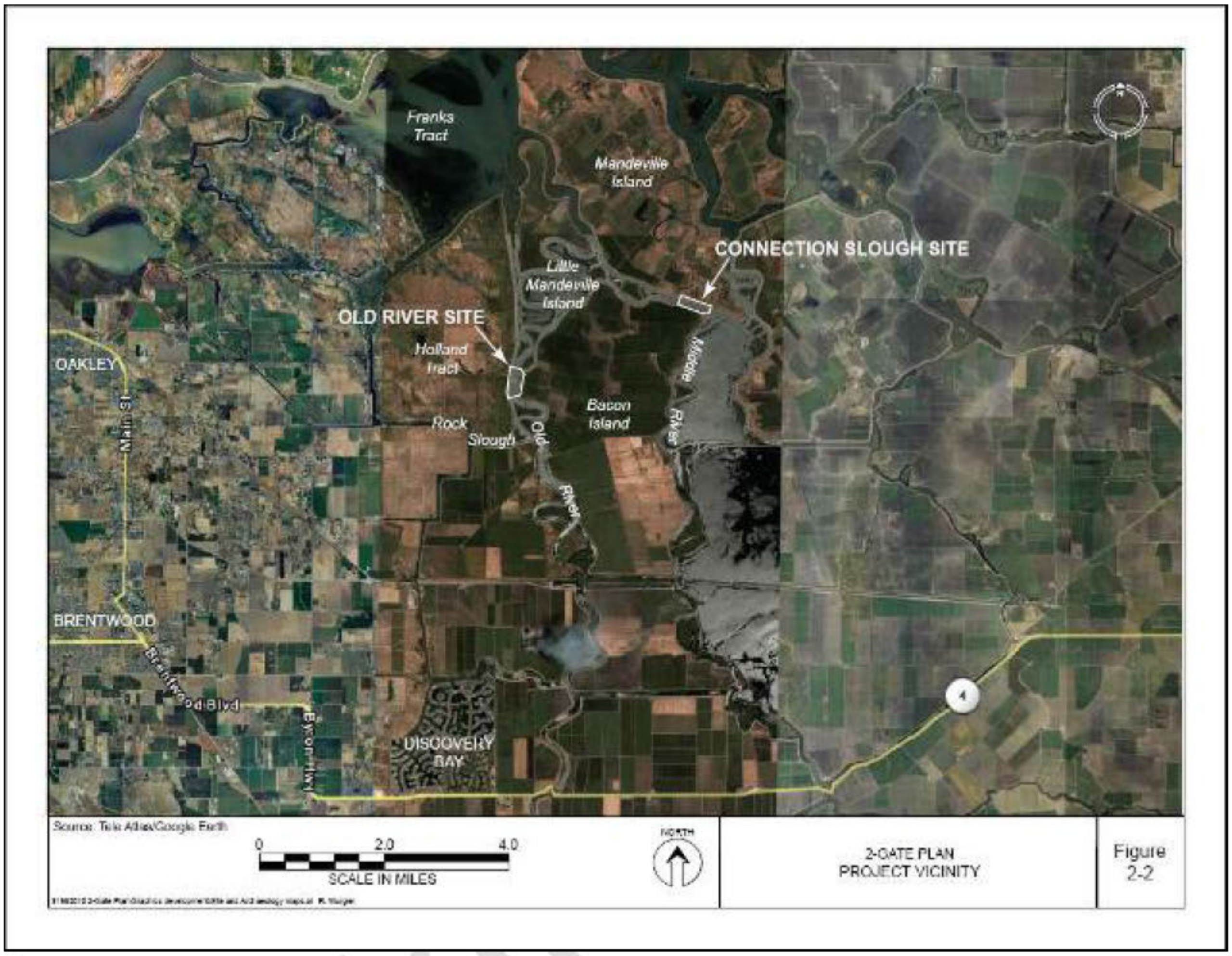
This alternative involves installing flow control gates on both Threemile Slough and West False River to expand the benefits provided by a gate on only one of the channels. It is a combination of alternatives described above. This alternative would be designed to divert flow from the Sacramento River to the San Joaquin River in order to create a balanced net outflow toward the west Delta in both the Sacramento and San Joaquin Rivers and create a physical barrier to salinity intrusion into Franks Tract. The operation of the gates in West False River and Threemile Slough could have fish benefits similar to those found for the two alternatives separately. These gates could operate in coordination or independently of one another, depending on the specific tidal, fish, and water quality conditions present.

Gates on both channels could provide additional benefits and flexibility beyond those provided by installing a gate on only one of the two channels. The combined effects of these gates on reducing the number of fish that move into the central and south Delta (where potential survival would be decreased) would potentially provide a high level of improvement for fish species of concern. Two operable gates would provide more operational flexibility for the CVP and SWP than one gate.

2-Gate Project (Operable Gates in Old River and Connection Slough)

The 2-Gate project proposes to install and operate removable gates in two key channels in the central Delta (Old River and Connection Slough) in order to control flows and thereby help reduce entrainment of delta smelt and other sensitive aquatic species at the State Water Project (SWP) and Central Valley Project (CVP) export pumps.

The Old River and Connection Slough sites are located in the central Delta, approximately 13 and 16 miles northwest of Stockton, and 4.8 and 6.8 miles north and northwest of Discovery Bay, respectively. As shown on Figure B-3, the Old River site is located on Old River between Holland Tract and Bacon Island, about 3 miles south of Franks Tract and about 1 mile north of the confluence of Old River and Rock Slough. As shown on Figure B-3, the Connection Slough site is located about 3.5 miles southeast of Franks Tract between Mandeville Island and Bacon Island and between Middle River and Little Mandeville Island.



Source: Adapted from 2-Gate Fish Protection Demonstration Project MND/EA, October 2008 (CCWD, MWD)

Figure B-3 2-Gate Project Barrier Locations

The 2-Gate Project is a demonstration conservation project that is intended to improve Delta water management activities for the benefit of delta smelt and other listed species. The 2-Gate Project provides a means of controlling flows in portions of the Old and Middle River branches of the San Joaquin River (via Connection Slough) in order to help reduce the entrainment of fish from the western and central Delta at the export pumps. Modeling results indicate that under certain hydrologic conditions the gates would be effective at reducing entrainment of delta smelt, plankton, and other weak swimming fish from the western and central Delta by the export pumps in the southern

Delta. This would enhance delta smelt populations in the western and central Delta while allowing for the export of water to meet critical water needs.

The gates in Connection Slough and Old River will be operational during December through June to reduce fish entrainment at the export pumps.

APPENDIX C

APPENDIX C - SUPPORT DOCUMENTATION:

C.1 – BENEFIT-TO-COST DOCUMENTATION

C.2 – MONITORING DOCUMENTATION

Appendix C: Detailed Benefit/Cost Index for Phase 2 Alternatives

Alt #	Description	Units	Banks Pumping Plant (SWP)				Jones Pumping Plant (CVP)				Old River at Los Vaqueros				Benefit/cost index
			2007	2008	2009	Avg	2007	2008	2009	Avg	2007	2008	2009	Avg	
	Total Export	Flow (cfs)	4,887	1,496	758	2380	4,146	3,513	1,155	2938	114	130	224	156	
	Export % per pump	%	53.4	29.1	35.5	39.3	45.3	68.4	54.0	55.9	1.2	2.5	10.5	4.8	
1	**Sutter Slough**	Percent Reduction	15%	7%	3%	8%	13%	6%	2%	7%	16%	8%	4%	9%	
		Weighted %	8.0%	2.0%	1.1%	3.7%	5.9%	4.1%	1.1%	3.7%	0.2%	0.2%	0.4%	0.3%	
		Benefit (% *100)	8.01	2.04	1.06	3.71	5.89	4.10	1.08	3.69	0.20	0.20	0.42	0.27	
	Rock barrier	Cost ($,000,000's)	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	
		Benefit / cost index	2.86	0.73	0.38	1.32	2.10	1.46	0.39	1.32	0.07	0.07	0.15	0.10	2.74
	Operable gate	Cost ($,000,000's)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
		Benefit / cost index	1.34	0.34	0.18	0.62	0.98	0.68	0.18	0.62	0.03	0.03	0.07	0.05	1.28
2	**Sutter Slough and Steamboat Slough**	Percent Reduction	28%	13%	7%	16%	25%	11%	5%	14%	30%	15%	9%	18%	
		Weighted %	15.0%	3.8%	2.5%	7.1%	11.3%	7.5%	2.7%	7.2%	0.4%	0.4%	0.9%	0.6%	
		Benefit (% *100)	14.96	3.78	2.48	7.08	11.33	7.52	2.70	7.18	0.37	0.38	0.94	0.57	
	Rock barrier	Cost ($,000,000's)	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	
		Benefit / cost index	2.67	0.68	0.44	1.26	2.02	1.34	0.48	1.28	0.07	0.07	0.17	0.10	2.65
	Operable gate	Cost ($,000,000's)	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	
		Benefit / cost index	1.31	0.33	0.22	0.62	0.99	0.66	0.24	0.63	0.03	0.03	0.08	0.05	1.30
3	**Threemile Slough**	Percent Reduction	26%	6%	2%	11%	23%	5%	2%	10%	29%	8%	3%	13%	
		Weighted %	13.9%	1.7%	0.7%	5.4%	10.4%	3.4%	1.1%	5.0%	0.4%	0.2%	0.3%	0.3%	
		Benefit (% *100)	13.89	1.75	0.71	5.45	10.43	3.42	1.08	4.97	0.36	0.20	0.31	0.29	
	Rock barrier	Cost ($,000,000's)	-	-	-	-	-	-	-	-	-	-	-	-	
		Benefit / cost index	-	-	-	-	-	-	-	-	-	-	-	-	
	Operable gate	Cost ($,000,000's)	19.60	19.60	19.60	19.60	19.60	19.60	19.60	19.60	19.60	19.60	19.60	19.60	
		Benefit / cost index	0.71	0.09	0.04	0.28	0.53	0.17	0.06	0.25	0.02	0.01	0.02	0.01	0.55
4	**West False River**	Percent Reduction	11%	12%	20%	14%	10%	10%	13%	11%	15%	17%	31%	21%	
		Weighted %	5.9%	3.5%	7.1%	5.5%	4.5%	6.8%	7.0%	6.1%	0.2%	0.4%	3.2%	1.3%	
		Benefit (% *100)	5.88	3.49	7.09	5.49	4.53	6.84	7.03	6.13	0.19	0.43	3.25	1.29	
	Rock barrier	Cost ($,000,000's)	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	
		Benefit / cost index	0.35	0.21	0.42	0.32	0.27	0.40	0.42	0.36	0.01	0.03	0.19	0.08	0.76
	Operable gate	Cost ($,000,000's)	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	
		Benefit / cost index	0.25	0.15	0.30	0.23	0.19	0.29	0.29	0.26	0.01	0.02	0.14	0.05	0.54
5	**2-Gate (Old River and Connection Slough)**	Percent Reduction	10%	12%	20%	14%	8%	8%	11%	9%	20%	19%	34%	24%	
		Weighted %	5.3%	3.5%	7.1%	5.3%	3.6%	5.5%	5.9%	5.0%	0.2%	0.5%	3.6%	1.4%	

		Benefit (% *100)	5.34	3.49	7.09	5.31	3.63	5.47	5.95	5.01	0.25	0.48	3.56	1.43		
	Rock barrier	Cost ($,000,000's)	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60		
		Benefit / cost index	0.30	0.20	0.40	0.30	0.21	0.31	0.34	0.28	0.01	0.03	0.20	0.08	0.67	
	Operable gate	Cost ($,000,000's)	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30		
		Benefit / cost index	0.23	0.15	0.30	0.23	0.16	0.23	0.26	0.22	0.01	0.02	0.15	0.06	0.50	
6	**Sutter Slough, Steamboat Slough and West False River**	Percent Reduction	37%	23%	28%	29%	33%	20%	19%	24%	43%	30%	41%	38%		
		Weighted %	19.8%	6.7%	9.9%	12.1%	15.0%	13.7%	10.3%	13.0%	0.5%	0.8%	4.3%	1.9%		
		Benefit (% *100)	19.77	6.70	9.93	12.13	14.96	13.67	10.27	12.97	0.54	0.76	4.30	1.86		
	Rock barrier	Cost ($,000,000's)	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50		
		Benefit / cost index	0.88	0.30	0.44	0.54	0.66	0.61	0.46	0.58	0.02	0.03	0.19	0.08	1.20	
	Operable gate	Cost ($,000,000's)	35.30	35.30	35.30	35.30	35.30	35.30	35.30	35.30	35.30	35.30	35.30	35.30		
		Benefit / cost index	0.56	0.19	0.28	0.34	0.42	0.39	0.29	0.37	0.02	0.02	0.12	0.05	0.76	
7	**Sutter Slough, Steamboat Slough and 2-Gate**	Percent Reduction	39%	25%	29%	31%	32%	18%	17%	22%	45%	32%	45%	41%		
		Weighted %	20.8%	7.3%	10.3%	12.8%	14.5%	12.3%	9.2%	12.0%	0.6%	0.8%	4.7%	2.0%		
		Benefit (% *100)	20.84	7.28	10.29	12.80	14.50	12.30	9.19	12.00	0.56	0.81	4.72	2.03		
	Rock barrier	Cost ($,000,000's)	23.20	23.20	23.20	23.20	23.20	23.20	23.20	23.20	23.20	23.20	23.20	23.20		
		Benefit / cost index	0.90	0.31	0.44	0.55	0.63	0.53	0.40	0.52	0.02	0.03	0.20	0.09	1.16	
	Operable gate	Cost ($,000,000's)	34.70	34.70	34.70	34.70	34.70	34.70	34.70	34.70	34.70	34.70	34.70	34.70		
		Benefit / cost index	0.60	0.21	0.30	0.37	0.42	0.35	0.26	0.35	0.02	0.02	0.14	0.06	0.77	
8	**Threemile Slough and West False River**	Percent Reduction	33%	16%	21%	23%	29%	13%	14%	19%	39%	22%	32%	31%		
		Weighted %	17.6%	4.7%	7.4%	9.9%	13.1%	8.9%	7.6%	9.9%	0.5%	0.6%	3.4%	1.5%		
		Benefit (% *100)	17.63	4.66	7.45	9.91	13.14	8.89	7.57	9.87	0.49	0.56	3.35	1.47		
	Rock barrier	Cost ($,000,000's)	-	-	-	-	-	-	-	-	-	-	-	-		
		Benefit / cost index	-	-	-	-	-	-	-	-	-	-	-	-		
	Operable gate	Cost ($,000,000's)	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50		
		Benefit / cost index	0.41	0.11	0.17	0.23	0.30	0.20	0.17	0.23	0.01	0.01	0.08	0.03	0.49	
9	**Threemile Slough and 2-Gate**	Percent Reduction	32%	16%	22%	23%	27%	10%	12%	16%	39%	22%	36%	32%		
		Weighted %	17.1%	4.7%	7.8%	9.9%	12.2%	6.8%	6.5%	8.5%	0.5%	0.6%	3.8%	1.6%		
		Benefit (% *100)	17.10	4.66	7.80	9.85	12.24	6.84	6.49	8.52	0.49	0.56	3.77	1.61		
	Rock barrier	Cost ($,000,000's)	-	-	-	-	-	-	-	-	-	-	-	-		
		Benefit / cost index	-	-	-	-	-	-	-	-	-	-	-	-		
	Operable gate	Cost ($,000,000's)	42.90	42.90	42.90	42.90	42.90	42.90	42.90	42.90	42.90	42.90	42.90	42.90		
		Benefit / cost index	0.40	0.11	0.18	0.23	0.29	0.16	0.15	0.20	0.01	0.01	0.09	0.04	0.47	

Delta Barrier Alternatives for Drought
Monitoring Needs to Support Alternatives
Central District
17 March 2009

Below is a suggested water monitoring plan for the six alternatives being considered to address potential impacts of the drought on Delta flow and water quality. A well planned monitoring program can help establish a Delta operational scheme to maximize the efficiency of the implemented alternative. A common monitoring recommendation for each alternative is to augment the existing flow, EC and temperature station at the Middle River at Middle River site at the southeast corner of Bacon Island with turbidity. This may help define impacts of flooded Mildred Island on Middle River water quality and assist in delta smelt migration studies.

Alternative 1 – Install gate next to Hwy 160 Bridge at Three Mile Slough

This alternative will prevent or reduce Sacramento River water from taking the short cut through Three Mile Slough to flow directly into the San Joaquin River and Franks Tract area. Instead Sacramento River flow will be forced around the west end of Sherman Island and drawn towards the central and south Delta through the sloughs that feed into Franks Tract. There are three main channels that provide flows from the west end of Sherman Island to Franks Tract: False River, Dutch Slough and Fishermans Cut.

A USGS flow station and a DWR water quality station already exists in False River sharing a common pile. Parameters being monitored are: flow, velocity, temperature, EC and turbidity. Similar stations for both Dutch Slough and Fishermans Cut should be established to measure the same parameters as False River. These three stations will most likely experience increased flows and velocities when the Three Mile Slough barrier is closed which may result in scour and water quality changes that can impact channel capacity, levee stability and aquatic habitat in the central and south Delta.

Alternative 2 – Install gate in the west end of False River

False River appears to be the main channel providing flow into Franks Tract from the Three Mile Slough and Antioch area. If flow through this channel into Franks Tract and Old/Middle River area is reduced or stopped, flow in Dutch Slough and Fishermans Cut will most likely increase significantly to compensate.

New stations should be established in Dutch Slough and Fishermans Cut to monitor flow, EC, temperature and turbidity. The mouth of Dutch Slough is spatially closer to the San Francisco Bay than False River and if Dutch Slough flows are increased it can potentially introduce increased EC levels into the central Delta. Also increased flows through the Big Break flooded area immediately west of Dutch Slough can impact central Delta turbidity levels which may impact delta smelt migration patterns.

Alternative 3 – Install two gates, in Old River and Connection Slough

These two gates will control flow into Old and Middle Rivers from the Franks Tract area. When these gates are closed, flow from the Sherman Island area into Old and Middle Rivers will be dependent on Turner and Columbia Cuts and Middle River. Flows will most likely increase significantly in these three channels which will impact water quality in the central and south Delta. Also, flows through Old River at Head may also increase significantly when exports are occurring.

There are currently flow, temperature and EC monitoring stations in Turner Cut and Middle River between McDonald Tract and Mandeville Island. Both stations should be upgraded to monitor turbidity since these channels will be the most likely route turbid Sacramento River water will enter into the south Delta and possibly attract delta smelt. The Turner Cut station should also be modified to monitor dissolved oxygen and chlorophyll *a*. The San Joaquin River at the Stockton Port has always been identified with low DO levels which can be drawn into Turner Cut with the closure of the two gates. Chlorophyll *a* concentrations can be used as an indicator of algae biomass in water body. Algae can influence water quality by affecting pH, dissolved oxygen, turbidity, the color, taste and odor of water, and under certain conditions, some species can develop noxious blooms.

Alternative 4 – Barriers at Sutter and Steamboat Sloughs

Both of these barriers will prevent Sacramento River water from diverting into Steamboat Slough which will maximize flows past the Delta Cross Channel. Therefore, when the Delta Cross Channel is open, flows through the Cross Channel will be higher which will increase flows down the North and South Forks Mokelumne River and Little Potato and Little Connection Slough.

No additional monitoring is needed. Existing monitoring network is adequate except for an upgrade to the existing Middle River at Middle River station mentioned above.

Alternative 5 – Barriers at Sutter and Steamboat Sloughs and False River gate
Installation of the Sutter and Steamboat Sloughs barriers will force more Sacramento River water past the Delta Cross Channel. If the DXC is open, then more Sacramento River water will enter into Mokelumne River system and the Central Delta. The False

River gate will prevent higher saline water from the Sherman Island area to enter directly into the Franks Tract but force flow through the more circuitous Dutch Slough and Fishermans Cut routes. This will potentially decrease the amount of higher saline water from the Sherman Island area from entering through the Franks Tract area and increase through Delta flow to the south Delta.

Add flow, temperature, EC and turbidity stations in Dutch Slough and Fishermans Cut to document the change in flow and water quality when the False River gate is operated. Also add a flow, temperature, EC and turbidity station in Little Potato Slough between Terminous and the bifurcation with White Slough. This station will help define freshwater inflow from the Mokelumne River into the north Delta as well as the split of Mokelumne River flow around the east and west side of Bouldin Island. This station may also help delineate the migration of Sacramento River turbid water into the central Delta to assist in the delta smelt study.

<u>Alternative 6</u> – Barriers at Sutter and Steamboat Sloughs and gates at Old River and Connection Slough

Installation of the Sutter and Steamboat Sloughs barriers will force more Sacramento River water past the Delta Cross Channel. If the DXC is open, then more Sacramento River water will enter into the Mokelumne River system and the Central Delta. The Old River and Connection Slough gates will control flow into Old and Middle Rivers from the Franks Tract area. When these gates are closed, flow from the Sherman Island area into Old and Middle Rivers will be dependent on Turner and Columbia Cuts and Middle River. This will force Sherman Island area water up the San Joaquin River past where the Mokelumne River water enters into the San Joaquin River. At this point San Joaquin River water will be drawn into the Old/Middle Rivers channels through Turner and Columbia Cuts and Middle River.

Also add a flow, temperature, EC and turbidity station in Little Potato Slough between Terminous and the bifurcation with White Slough. This station will help define freshwater inflow from the Mokelumne River into the north Delta as well as the split of Mokelumne River flow around the east and west side of Bouldin Island. This station may also help delineate the migration of Sacramento River turbid water into the central Delta to assist in the delta smelt study. The existing Turner Cut station and the Middle River station between McDonald Tract and Mandeville Island should be upgraded to monitor turbidity since these channels will be the most likely route turbid Sacramento River water will enter into the south Delta and possibly attract delta smelt. The Turner Cut station should also be modified to monitor dissolved oxygen and chlorophyll *a*. The San Joaquin River at the Stockton Port has always been identified with low DO levels which can be drawn into Turner Cut and the south Delta with the closure of the two gates. Chlorophyll *a* concentrations can be used as an indicator of algae biomass in water body. Algae can influence water quality by affecting pH, dissolved oxygen, turbidity, the color, taste and odor of water, and under certain conditions, some species can develop noxious blooms.