Low-flow Intake Technical Analysis

Prepared for

California Department of Water Resources, Bay-Delta Office, Fishery Improvements Section

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Acronyms and Abbreviations

µm	micron
Bay	San Francisco Bay Estuary
BDAT	Bay Delta and Tributaries Project
BDCP	Bay Delta Conservation Plan
CCF	Clifton Court Forebay
CDEC	California Data Exchange Center
CHTR	collection, handling, transport, and release
CMP	Common Model Package
CPT	cone penetrometer test
CSDP	Cross Section Development Program
CVP	Central Valley Project
Delta	Sacramento–San Joaquin Delta
DFG	California Department of Fish and Game
DSLS	Delta Smelt Larval Survey
DWR	California Department of Water Resources
EC	electroconductivity
ESA	Endangered Species Act
fps	foot *or* feet per second
IEP	Interagency Ecological Program
ITP	incidental take permit
LFI	Low-flow Intake
MWT	Mid-water Trawl
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCAP	Operations Criteria and Plan
POD	Pelagic Organism Decline

PTM	Particle Tracking Model
Reclamation	Bureau of Reclamation
RMA	Resource Management Associates
RPA	Reasonable and Prudent Alternative
SDFPF	Skinner Delta Fish Protective Facility
SKT	Spring Kodiak Trawl
SWP	State Water Project
TFCF	Tracy Fish Collection Facility
TFFIP	Tracy Fish Facility Improvement Program
TFTF	Tracy Fish Test Facility
TNS	tow-net surveys
USACE	U.S. Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey

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Preface

California Department of Water Resources
Low-flow Intake Technical Analysis

Prepared by
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December 2009

This report describes conceptual alternatives for a low-flow screened intake to Clifton Court Forebay (Forebay). These concepts were developed to address periods when State Water Project (SWP) diversions are constrained to protect delta smelt and other species of concern. As a result, the alternatives are limited to a maximum diversion capacity of 2,000 cubic-feet per second (cfs). While this document is intended to provide DWR initial direction regarding location, composition, and arrangement of fish protective diversion facilities, the concepts and locations contained in this proposal are for illustration purposes only and require additional discussion and analysis.

Additional information required to conduct a feasibility-level study of these conceptual alternatives is described in Section 7 of the report. In addition, the conceptual-level construction cost estimates contained in this report are intended for relative comparison of the construction costs for the proposed concepts and should not be compared to any other options not included in this document. Refined estimates of costs may include, but need not be limited to, the costs of planning, design, environmental impact analysis, permits, mitigation, and land acquisition.

This initial assessment is simply one piece of information for analyzing the feasibility and effectiveness of a low-flow screened intake to the Forebay. Any future assessment efforts will have to consider the following items in addition to the SWP operational restrictions contained in the biological opinions of the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) governing the SWP and Central Valley Project Operations.

- The fate of screened fish including their potential for entrainment at other Delta diversions such as the CVP Jones Pumping facility and local agricultural diversions and losses to predation in the natural channels
- The likelihood that any concept would result in the increase in abundance of targeted fish populations
- The degree of improvement in SWP water supply reliability from any concept
- The potential of any concept to reduce predation in the Forebay and the population benefits to at-risk fish species of such reductions

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SECTION 1

Introduction

The California Department of Water Resources (DWR) is engaged in a number of processes, including the Bay Delta Conservation Plan (BDCP) and Delta Vision, intended to identify water conveyance facility modifications in the Sacramento–San Joaquin Delta (Delta) that would improve water supply reliability and reduce adverse impacts on Delta aquatic resources.

In recent years, several fish species inhabiting the Delta have been listed for protection under the California or federal Endangered Species Acts (ESA) and are featured in the Interagency Ecological Program's (IEP) Pelagic Organism Decline (POD) work plan. The direct and indirect effects of water project operations have been identified as one of several factors contributing to changes in Delta environmental conditions. During roughly this same period, State Water Project (SWP) and Central Valley Project (CVP) operations have been increasingly constrained by regulatory requirements and court-mandated operational changes that have reduced water supplies and water supply reliability.

In response to these changes, DWR, other state and federal resource agencies, environmental organizations, and a variety of other stakeholders are exploring possible near-term and long-term changes to facility operation and configuration that could improve water supply reliability and operational flexibility. One such project feature being considered is a new Low-flow Intake (LFI) to move water either through or around Clifton Court Forebay (CCF) to the Harvey O. Banks Pumping Plant.

Although previous efforts have considered varied diversion capacities up to the full capacity of the Banks Pumping Plant, the objective of this LFI Technical Analysis is to address the period when diversions into the SWP are limited to protect delta smelt and other sensitive species, such as during the Vernalis Adaptive Management Program. For this Technical Analysis, the maximum diversion capacity of the proposed screened LFI has been limited to 2,000 cfs in order to provide reliability by considering the unit capacities at the Banks Pumping Plant (two units rated at 375 cfs, four units rated at 1,067 cfs, and five units rated at 1,130 cfs). Also, during subsequent efforts to refine the recommended alternatives, hydraulic analyses will need to be completed similar to those performed for the 1996 Interim South Delta Program Draft EIS/EIR, which indicated that hydraulic restrictions in Italian Slough may limit conveyance from 2,000 to 3,000 cfs.

To help prepare information on the design and operations of the LFI, DWR has requested a technical analysis as part of Task Order No. CH-19 to CH2M HILL, under Standard Agreement No. 4600004591 (April 21, 2008). The initial product of this task order was the *Fish Passage Criteria and Guidance Report* (November 2008), and this *Low-flow Intake Technical*

Analysis supplements that document to support another DWR effort led by Zaffar Eusuff of the Bay-Delta Office, Fishery Improvements Section, to plan and design an LFI fish passage facility. These key consultants conducted the LFI technical analysis:

- Dennis Dorratcague, MWH Americas, Inc.
- Bob Gatton, CH2M HILL
- Tim Hamaker, CH2M HILL

This *Low-flow Intake Technical Analysis* includes the following requested information:

- A review of available recently documented studies and initiatives on numerous fish screen concepts at CCF
- A compilation of existing technical information concerning hydraulic, geotechnical, bathymetric, and water quality issues
- A summary of biological factor investigations regarding the existing fish life history and monitoring information, considerations necessary to design and operate any fish screens to meet regulatory criteria, and evaluation of potential locations in terms of predation and screening effectiveness
- Analyses and recommendations of alternatives to meet LFI objectives at several potential diversion sites around CCF, including alternatives that bypass CCF
- Conceptual-level construction cost estimates for the LFI alternatives
- Identification of additional data needs necessary to further develop the recommended alternatives in greater detail

The overall objective of this report is to identify potential alternatives to move forward into a more detailed feasibility study.

SECTION 2

Review of Previous CCF Screening Efforts

DWR provided a collection of electronic files related to previous CCF screening studies and initiatives. In general, the files included conceptual schematics of screen alternatives, cost estimates, project schedules, fish loss modeling results, memoranda, and meeting presentations and materials. The information most relevant to this LFI Technical Analysis is listed in Table 2-1. The index column provides a reference number for information cited elsewhere in this document. A complete list of the documents provided by DWR is presented in Appendix A.

TABLE 2-1
Previous CCF Fish Screen and Intake Planning Efforts Data
Low-flow Intake Technical Analysis

Index	Title	Preparer and Date	Brief Description
1	CCF Short-Circuit Alternative	Preparer and date unknown	CCF diagrams (3 pp): 1. CCF short-circuit alternative. 2. Positive barrier fish screen with LH pumps no salvaging. 3. Proposed intake site.
2	Second Stage Construction Plan	Preparer and date unknown	Plan diagram, second stage construction (4 pp).
3	South Delta Facilities Alternatives	Preparer and date unknown	13 South Delta facilities alternative diagrams with notes (13 pp).
4	South Delta Facilities Alternatives-Wide Range Draft	Preparer and date unknown	South Delta facilities for 17 alternatives (objectives, elements, special operations, assets, liabilities, costs, biological benefits, assumptions, risks, potential fatal flaws). Good summary of alternatives descriptions and biological benefits and risks (30 pp).
5	South Delta Fish Facilities State Water Project Alternative Configurations	Preparer unknown, 10/2002	South Delta Fish Facilities SWP Alternative Configurations presentation (50 pp).
6	South Delta Fish Facilities Alternatives	Preparer and date unknown	Presentation slides for two alternatives. Gunderboom alternative (5 pp).
7	South Delta Fish Facilities Implementation Strategy	Preparer unknown, 1/13/2003	South Delta Fish Facilities Implementation Strategy presentation (focus on TFTF) (9 pp).
8	Airphotos of CCF Alternatives	Preparer and date unknown	Aerial photos with Northeast and Northwest Intake alignments (3 pp).
9	Alternatives Development: Practicability of New Screened Intake Locations	Preparer and date unknown	Chapter discussion of multiple screened intake alternative locations and configurations (5 pp).

TABLE 2-1
Previous CCF Fish Screen and Intake Planning Efforts Data
Low-flow Intake Technical Analysis

Index	Title	Preparer and Date	Brief Description
10	Office Memo: CCF Fish Facility Planning and Design Nov 2000	DWR ESO, 11/2/2000	SWP Environmental Services Offices memo to DWR Office of Planning on Clifton Court Forebay fish facility planning and design that initiates and focuses the planning and design of the Clifton Court Forebay Fish Facility within DWR, at the interagency level, and with the State Water Contractors (13 pp).
11	Fish Screening and Fish Passage Analysis of the CALFED Bay-Delta Program Phase II Delta Conveyance Alternatives.	Darryl Hayes and Dan Odenweller, 7/28/1997	Fish Screening and Fish Passage Analysis Committee Status report, which provides recommendations on CALFED fish facilities planning. Contains a schematic of CCF (29 pp).
12	CCFIT Draft Meeting Notes	DWR, 10/10/2001	10/10/2001 meeting minutes (discussed project alternatives document, numerical/physical modeling direction, operating criteria progress, design status) (5 pp). 1/2001 proposed CCF Intake presentation (34 pp).
13	Draft CCF NW Intake Study For Preliminary Operating Criteria	DWR DOE, 9/7/2001	CCF NW Intake Study for Preliminary Operating Criteria (2001). Determines preliminary design parameters and operations criteria and assumption for the new intake at CCF (6 pp).
14	Italian Slough Conceptual Schematics	Preparer and date unknown	Schematic for new intake on Italian Slough. Five-bay inline layout for 13,300-cfs plan (9 pp).

SECTION 3

Existing Technical Information

This summary of existing technical information near the LFI study area included past data-collection efforts for geotechnical characteristics, bathymetry, hydrodynamics, and water quality data near CCF. In the appendixes, the data collected are summarized in spreadsheet form, and specific information helpful to laying out possible fish screen alternatives is presented. This information is used to site intake structures and screens and to determine their approximate size.

3.1 Geotechnical Data

Geotechnical information in areas near CCF is needed to determine the geotechnical characteristics at potential screened intake sites and to estimate the quantity of groundwater expected during construction dewatering.

Published in 1974, the DWR Bulletin 200 series describes the planning, design, construction, and operations of SWP facilities, including CCF. Bulletin 200, Volume 3, "Storage Facilities," was obtained from Gordon Enas, DWR Division of Engineering. Chapter 8 of Volume 3 includes an overview of the geologic conditions along with design and construction highlights for CCF and associated control structures and channels. The 18-page chapter includes a geology and seismicity characterization. Design highlights of the dam, intake channel, and piping and drainage systems are included. Construction activities described include dewatering and drainage, reservoir clearing, excavation, handling of borrow materials, embankment construction, and control structure construction.

The Tracy Fish Test Facility Geologic Design Data Report (Reclamation, 2003) was obtained from Alan Stroppini, design branch chief of the Mid-Pacific Regional Office of the federal Bureau of Reclamation (Reclamation). The report is a proposal for the Tracy Fish Test Facility (TFTF), which was being designed for the purpose of evaluating experimental fish screen components in the south Delta. The 30-page report focuses on the proposed TFTF location, which was immediately north of the Tracy Fish Facility at the intake of the Delta-Mendota Canal, near the southeast corner of CCF. The report summarizes data from a 2000–2002 field investigation and previous investigations in 1945, 1952, 1998, and 1999. A regional geology section covers the site geology and includes descriptions of the seven major soils in the area. The report ends with a 6-page description of geotechnical concerns and conclusions. Geologic cross-sections and plan maps, cone penetrometer test (CPT) logs, and laboratory soils data from the proposed TFTF location were collected from the report. Technical memorandums of hydrogeological investigations, which determined the quantity and quality of groundwater to be expected during construction dewatering, were also collected.

The Pile Driving Test Report (Reclamation, 2001) for the TFTF was also obtained from Alan Stroppini at Reclamation. The report documents results from penetration tests at the TFTF to test the driving of sheet piles through the upper sand unit as a method of groundwater cutoff. The sheet-pile-driving tests served several purposes:

- Evaluated the drivability of sheet-pile sections, which may be similar to those used in full-scale pile driving
- Evaluated the integrity of sheet-pile interlocks after driving through the upper sand unit, if possible
- Estimated full-scale pile-driving production rates
- Evaluated different pile-driving methods (such as vibratory versus impact)
- Evaluated representative sizes of pile-driving hammers
- Provided contractors with pile-driving information at the proposed project site
- Evaluated on- and off-site sound and vibration levels resulting from pile-driving operations

The report's attachments include geologic logs of the drill hole and notes on the vibratory and impact pile driving.

Table 3-1 lists the key contacts identified during the geotechnical data collection effort for the LFI technical analysis.

TABLE 3-1
List of Key Contacts for Geotechnical Data Resources
Low-flow Intake Technical Analysis

Name	Agency	Role	Phone Number
Alan Stroppini	Reclamation	Branch Chief, Mid-Pacific Regional Office	(916) 978-5376
Gordon Enas	DWR	Division of Engineering	(916) 653-7589

3.2 Bathymetric Data

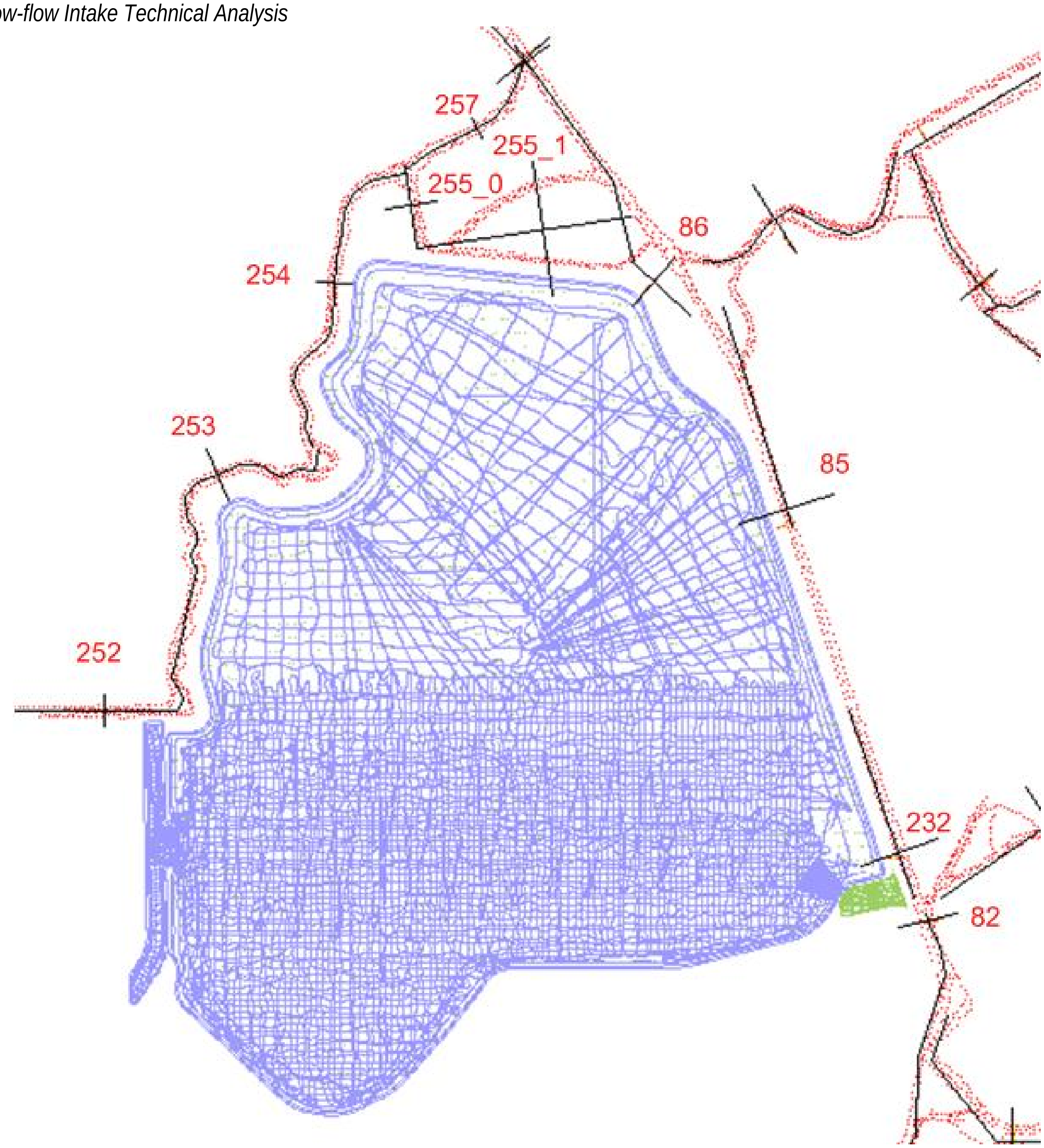
Bathymetry cross-section data in channels adjacent to potential intake sites are necessary to facilitate sizing of the intake fish screens. Bathymetry cross-section data were collected from two sources:

- DWR's Cross Section Development Program (CSDP) developed by Brad Tom
- DWR's South Delta Scour Monitoring Program from Shawn Mayr

The CSDP is a software program that uses 3-D bathymetry data to draw approximate cross-sections for use by the DSM2-Hydro model. The CSDP software and bathymetry data are available for download at http://modeling.water.ca.gov/delta/models/dsm2/tools/csdp/index.html. Bathymetry data adjacent to the CCF was collected by the National Oceanic and Atmospheric Administration (NOAA) in 1934 and by DWR in 1990, 1991, and 1992. Bathymetry data in CCF was collected by DWR in 1999 and 2005.

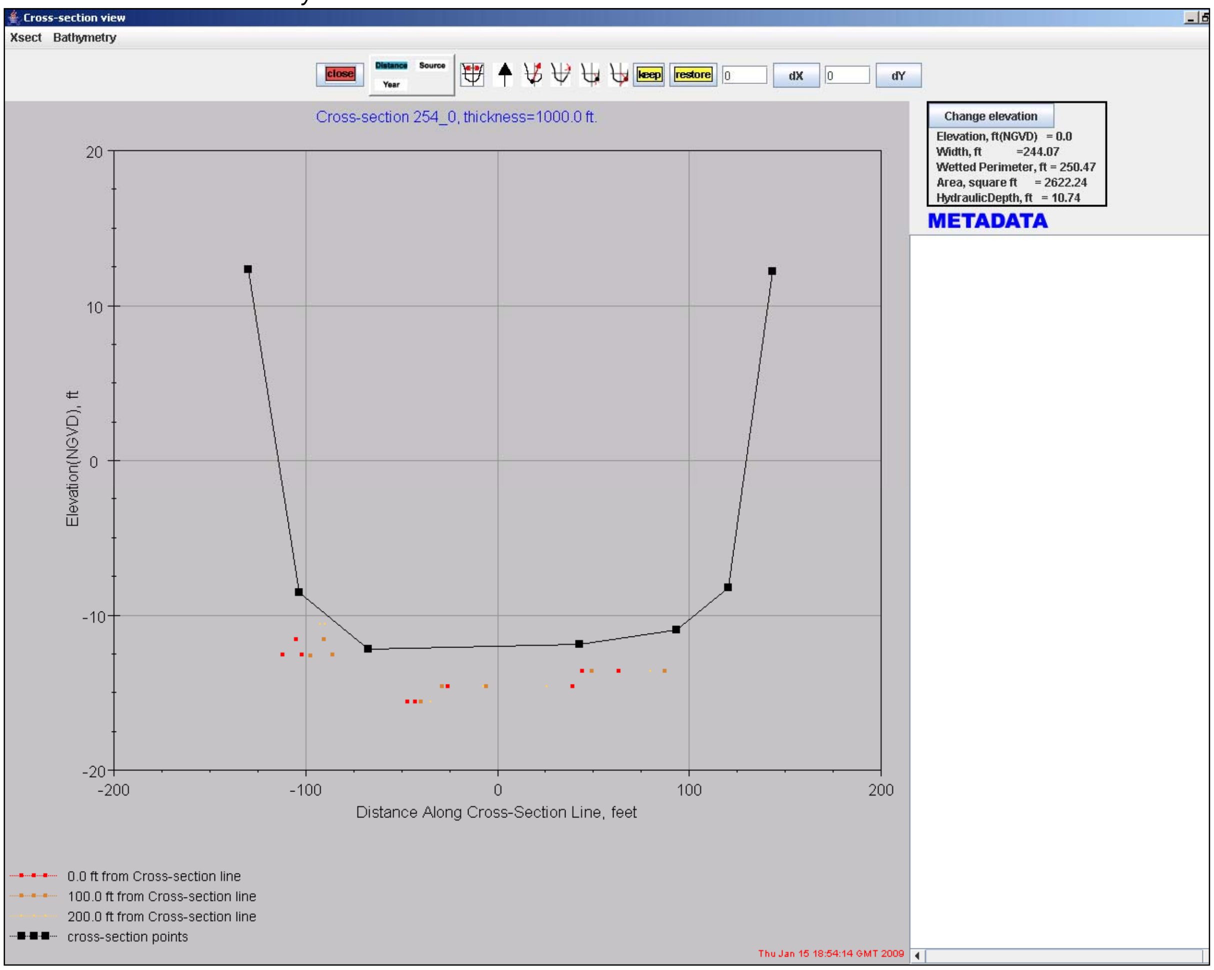
Brad Tom provided a network file that displays bathymetric cross-section information for areas around the CCF (Figure 3-1). The black lines perpendicular to the channels denote locations where bathymetric cross-sections have been drawn. Cross-section numbers for each cross-section adjacent to the CCF are shown in red. As an example, the data output for cross-section 254 is shown in Figure 3-2.

FIGURE 3-1
Cross-section Development Program Network (Source: DWR)
Low-flow Intake Technical Analysis



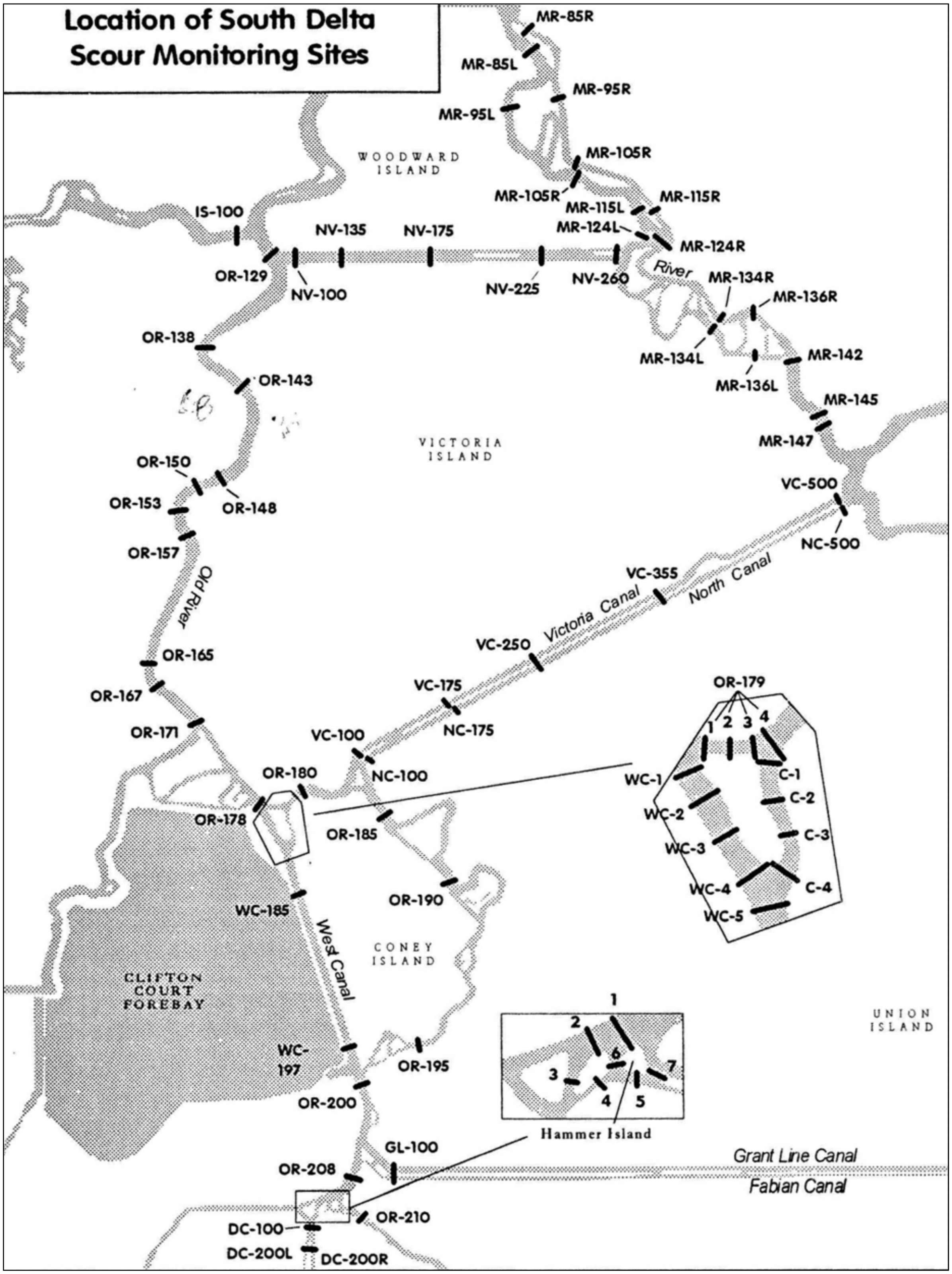
In Figure 3-2, the cross-section data show measured bathymetric data and cross-section points. The year collected and source of the bathymetric data can also be displayed. The cross-section points were drawn by DWR staff during development of the CSDP. The program uses the cross-section points to estimate the channel's width, wetted perimeter, area, and hydraulic depth for any user-specified elevation. All cross-sections adjacent to CCF are provided in Appendix B. Tom noted that the CSDP may not contain some of the most accurate and recent bathymetric data; rather than taking bathymetry measurements at fixed sites along the channels (which provides the most accurate bathymetric results), much of the data for the CSDP were collected by driving a boat in a zigzag trajectory and extracting the measured data points in proximity to each DSM2 node.

FIGURE 3-2
Output for Cross-section 254 in Italian Slough (Source: DWR)
Low-flow Intake Technical Analysis



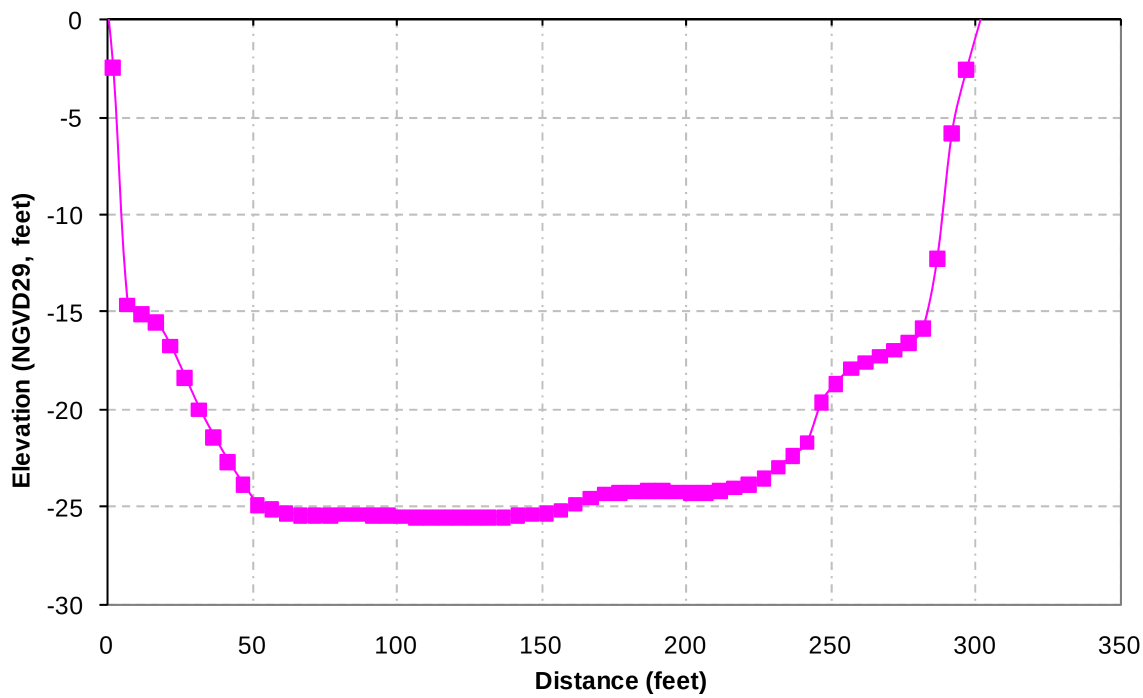
The most accurate and recent bathymetric data near the CCF, predominantly from the South Delta Scour Monitoring Program, was provided by Shawn Mayr at DWR's Resources Assessment Branch. Under this program, DWR's Central District monitors the cross-sections of many fixed sites in the north and south Delta to help establish the natural variations in channel bathymetry under existing conditions. Sites in the south Delta near the CCF intake gates have been monitored since 1969, and the number of south Delta locations monitored since then has increased to 74 sites. John Ho, engineer at the DWR Resources Assessment Branch, provided a 1998 Central District Memorandum Report of the South Delta Scour Monitoring Program from 1993 through 1997, which summarizes monitoring activities and provides bathymetry cross-section data from scour monitoring surveys from 1993 through 1997. South Delta scour monitoring sites are shown in Figure 3-3.

FIGURE 3-3
Locations of South Delta Scour Monitoring Sites (Source: DWR)
Low-flow Intake Technical Analysis



The DWR Resources Assessment Branch provided detailed bathymetric data collected in April and October of 2002 for each scour monitoring site shown in Figure 3-3. An October 2002 bathymetric cross-section at scour monitoring site WC-1 is provided in Figure 3-4 for illustrative purposes.

FIGURE 3-4
October 2002 Bathymetry Cross-Section at WC-1 (Source: South Delta Scour Monitoring Program)
Low-flow Intake Technical Analysis



USGS resources for relevant bathymetry include Jon Burau and Cathy Ruhl, who were contacted, but had no additional bathymetric data. Both Burau and Ruhl are involved in bathymetric- and hydrodynamics-related work in CCF.

Table 3-2 lists key contacts identified during the bathymetry data collection effort for the LFI technical analysis.

TABLE 3-2
List of Key Contacts for Bathymetry Data Resources
Low-flow Intake Technical Analysis

Name	Agency	Role	Phone Number
Brad Tom	DWR	Developer of CSDP. Water Resources Engineer, Suisun Marsh Planning Section	(916) 376-9763
Shawn Mayr	DWR	Department of Planning and Local Assistance, Resources Assessment Branch	(916) 376-9664
Cathy Ruhl	USGS	Bathymetric- and hydrodynamics-related work in CCF	(916) 278-3129
Jon Burau	USGS	Bathymetric- and hydrodynamics-related work in CCF	(916) 278-3127

3.3 Delta Hydrodynamic Data

Stage, flow, and velocity data in Delta channels near CCF are needed to facilitate sizing of screened intake designs. In the following discussions, measured historical data and simulated hydrodynamic data are presented separately.

3.3.1 Measured Data

Tara Smith, DWR Delta Modeling Section Chief, recommended the following sources for measured stage, flow, and velocity data near the CCF:

- California Data Exchange Center (CDEC), http://cdec.water.ca.gov
- Bay Delta and Tributaries Project (BDAT), http://bdat.ca.gov/
- IEP Hec-DSS Time-Series Databases, http://iep.water.ca.gov/cgi-bin/dss/map_pick.pl?area=sdelta
- Dayflow, http://iep.water.ca.gov/dayflow/index.html

In addition to this publicly available information, the DWR Resources Assessment Branch provided velocity and flow data from two DWR gauges: West Canal near Clifton Court Intake, and Old River near Clifton Court Intake. Table 3-3 identifies the historical stage, flow, and velocity data collected from all of these data sources.

All stage data is available in the NGVD29 datum. Shawn Mayr also recommended Tim Nelson of DWR as a possible resource for additional stage data not listed in Table 3-3.

For all data sources, a portion of the most recent data available was collected during March through June. Although data can be extracted for any duration in the historical data record, data is presented for these months to represent the annual period when diversions into CCF could be restricted to protect delta smelt or other sensitive species. Stage, flow, and velocity data from 2005 for several Delta locations is provided in Appendix C. Stage, flow, and velocity data is also shown for April 28, 2005 to highlight hourly variations in the data set.

TABLE 3-3
Measured Stage, Velocity, and Flow Data
Low-flow Intake Technical Analysis

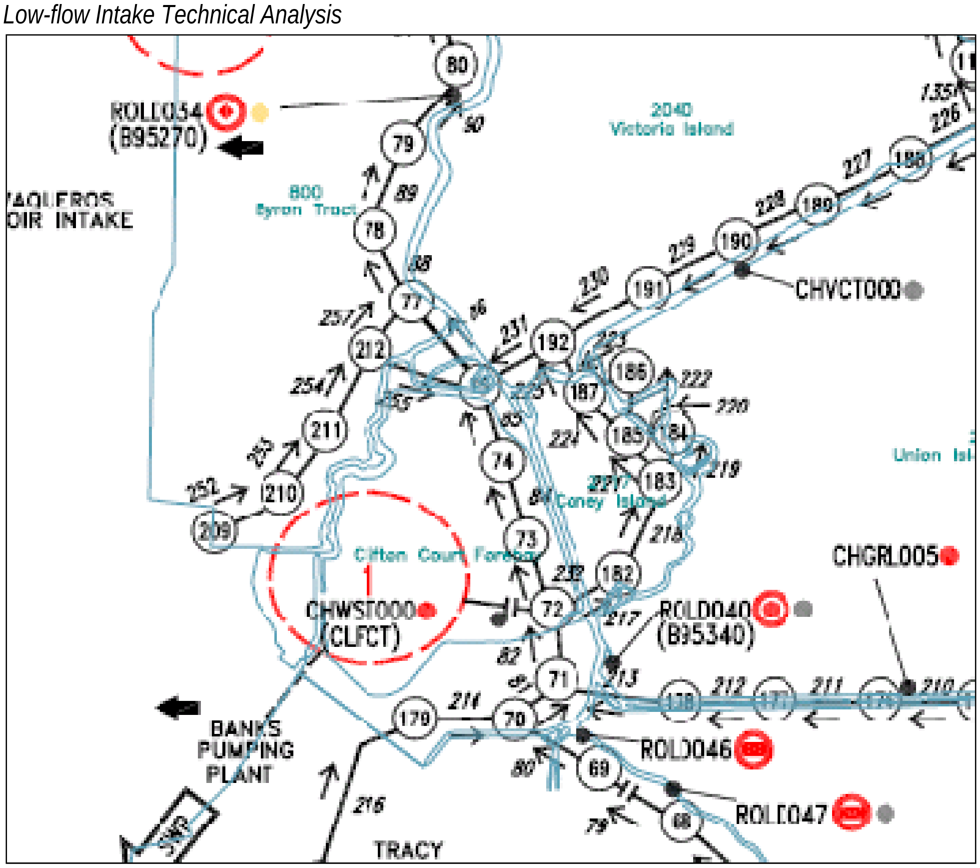
Data Type	Location	Historical Data Record	Time Step	Data Source	Agency
Flow	Old River at Clifton Court Ferry (ROLD040)	4/1/1997 to 5/25/1998	10 minutes	IEP	USGS
	Old River near Clifton Court Intake (100 yards downstream of intake)	3/26/2005 to 12/31/2008	15 minutes	DWR	DWR
	Old River near Delta Mendota Canal (SE Barrier) (ROLD047)	4/1/1998 to 12/31/2002	15 minutes	IEP	USGS
	Victoria Canal (CHVCT000)	4/1/1997 to 6/29/1998	10 minutes	IEP	USGS
	West Canal near Clifton Court Intake	3/26/2005 to 12/31/2008	15 minutes	DWR	DWR
Index water velocity	Old River at Forebay Intake	3/30/2005 to 6/13/2005	15 minutes	BDAT	USGS
	Old River at Hwy 4 Bridge	6/25/1999 to 4/30/2006	15 minutes	BDAT	USGS
Mean velocity	Old River near Clifton Court Intake (100 yards downstream of intake)	3/26/2005 to 12/31/2008	15 minutes	DWR	DWR
	West Canal near Clifton Court Intake	3/26/2005 to 12/31/2008	15 minutes	DWR	DWR
Mean water velocity	Old River at Forebay Intake	3/30/2005 to 6/13/2005	15 minutes	BDAT	USGS
	Old River at Hwy 4 Bridge	6/25/1999 to 4/30/2006	15 minutes	BDAT	USGS
	Victoria Tract at Union Island	2/23/2005 to 1/8/2006	15 minutes	BDAT	USGS
	West Canal at Forebay Intake	3/16/2005 to 7/3/2005	15 minutes	BDAT	USGS
Stage	Clifton Court Forebay Radial Gates (downstream) (CHWST000)	9/1/2000 to 8/31/2008	1 hour	IEP	DWR
	Clifton Court Forebay Radial Gates (upstream) (CHWST000)	9/1/2000 to 8/31/2008	1 hour	IEP	DWR
	Italian Slough Near Headwater near Byron	12/14/2004 to Present	15 minutes	CDEC	USGS
	Old River at Clifton Court Ferry (ROLD040)	9/1/1982 to 1/31/2003	15 minutes	IEP	DWR
	Old River near Delta Mendota Canal (NW Barrier) (ROLD046)	9/1/1991 to 1/31/2003	15 minutes	IEP	DWR

3.3.2 Simulated Data

Simulated Delta hydrodynamic data can be obtained from DSM2 simulation results. DSM2 is a one-dimensional mathematical model for dynamic simulation of tidal hydraulics, water quality, and particle tracking in a network of riverine or estuarine channels. DSM2 can calculate stages, flows, velocities, transport of individual particles, and mass transport processes for conservative and non-conservative constituents. The Common Model Package (CMP), a component of the Common Assumptions effort led by DWR, Reclamation, and the California Bay-Delta Authority, is a modeling framework that provides consistent assumptions about facilities, operations, management, and regulations. The Common Assumptions FTP site contains DSM2 model runs of existing and future conditions to facilitate evaluation of with- and without-project conditions for potential projects.

Two DSM2 simulation runs were obtained from the Common Assumptions FTP site to provide hydrodynamic data for locations near CCF. The first simulation was a 1990–2006 historical flows simulation with 15-minute and daily time steps. This simulation used historical flow data at Vernalis and other Delta locations as inputs. The second was a 2005 existing conditions simulation with a 15-minute time step, which simulates a 2005 level of development. The 15-minute, rather than daily, time step is desirable to capture the tidal variation of flow and stage data throughout a typical day. While DSM2 historical simulation results are available for the entire 1990–2006 record, stage and flow results from April 2005 are provided in Appendix C. Figure 3-5 shows a portion of the DSM2 grid near the CCF.

FIGURE 3-5
DSM2 Grid near CCF
Low-flow Intake Technical Analysis



Hydrodynamic data available from the 1990–2006 historical flow simulation in locations near CCF are summarized in Table 3-4.

TABLE 3-4
DSM2 Simulated Stage and Flow Data
Low-flow Intake Technical Analysis

Location	DSM Output Name	Data Type	Time Step
CCF Radial Gates	CHWST000	Stage	15 minutes
Grant Line Canal	CHGRL005	Flow, stage	15 minutes
Old River at Clifton Court Ferry	ROLD040	Flow, stage	15 minutes
Old River at Tracy	ROLD046	Flow, stage	15 minutes
Old River near Byron	ROLD034	Flow, stage	15 minutes
Old River near Delta-Mendota Canal	ROLD047	Flow, stage	15 minutes
Victoria Canal	CHVCT000	Flow, stage	15 minutes

Resource Management Associates' (RMA) finite element model of the San Francisco Bay and Delta was identified as another source of simulated hydrodynamic data. The *Flooded Islands Pre-Feasibility Study: RMA Delta Model Calibration Report* (RMA, 2005) was obtained from the RMA Web site. The report describes the calibration process of the RMA model to predict flow, stage, and electrical conductivity (EC) in the Delta. Model results are compared with measured results at Delta monitoring stations. John DeGeorge at RMA was identified as the primary contact to obtain the modeling results from the RMA model.

Table 3-5 lists key contacts identified during the hydrodynamic data collection effort for the LFI technical analysis.

TABLE 3-5
List of Key Contacts for Hydrodynamics Data Resources
Low-flow Intake Technical Analysis

Name	Affiliation	Role	Phone Number
Tara Smith	DWR	Bay-Delta Office, Modeling Support Branch	(916) 653-9885
Tim Nelson	DWR	Stage, velocity, and flow data	(916) 376-9764
John DeGeorge	RMA	Finite element model of the San Francisco Bay and Delta	(707) 864-2950 x200
Cathy Ruhl	USGS	Bathymetric- and hydrodynamics-related work in CCF	(916) 278-3129
Jon Burau	USGS	Bathymetric- and hydrodynamics-related work in CCF	(916) 278-3127

3.4 Water Quality Data

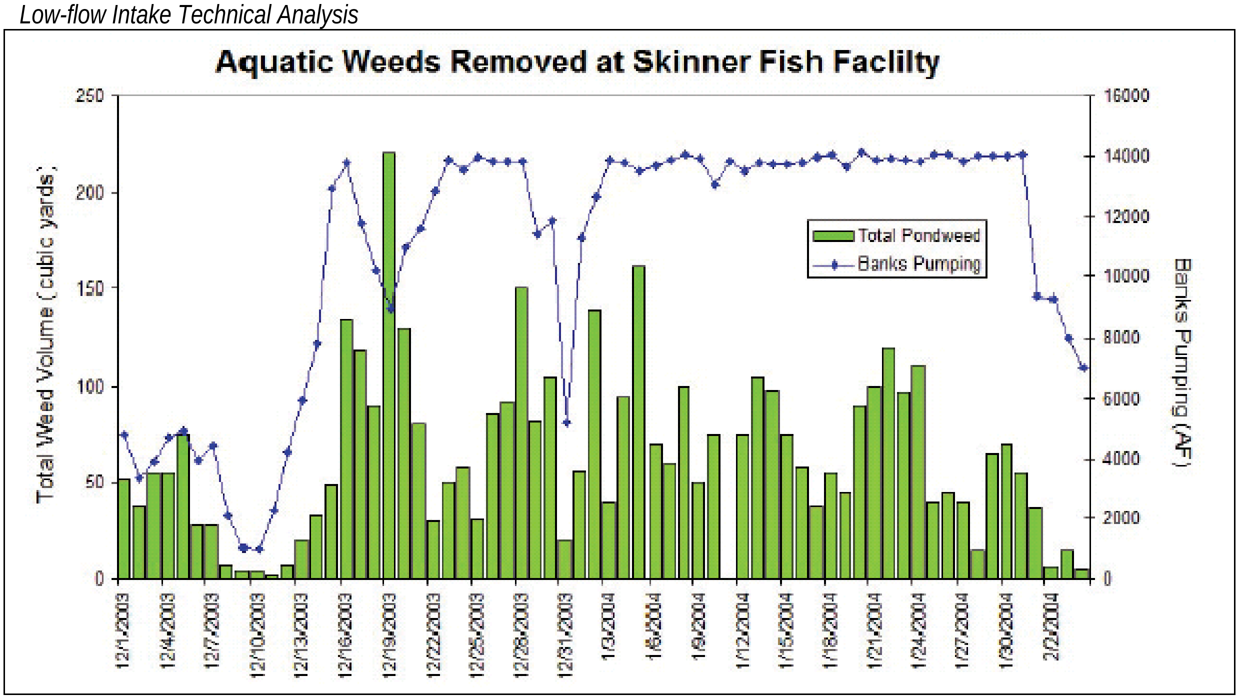
Invasive aquatic plants and Delta salinity are two water quality issues relevant to an LFI facility conveying flows into or near CCF. Invasive aquatic plants accumulate on trash racks of fish screens and obstruct pumping facilities. Salinity is an important water quality parameter that determines CCF operations. Turbidity is also an important water quality parameter because of its impacts on delta smelt habitat.

3.4.1 Invasive Aquatic Plants

Egeria densa and water hyacinth are two aquatic pests prevalent in the CCF area and throughout the Delta. These nonnative aquatic plants form dense floating mats of vegetation that obstruct navigation channels, marinas, irrigation systems, and water intake structures.

Egeria densa mats accumulate on the trash racks at the South Delta Fish Protection Facility (SDFPF) and compromise the ability to pump from the Banks Pumping Plant. It is estimated that between December 2003 and January 2004, pumping plant operation was reduced temporarily by an estimated 60,000 acre-feet because of aquatic weeds (Jarnagin and Smith, 2004). Figure 3-6 shows the amount of aquatic weeds removed at the SDFPF.

FIGURE 3-6
Aquatic Weed Removal at SDFPF from December 2003 to February 2004
Low-flow Intake Technical Analysis



Source: Jeffrey Janik, DWR

Egeria densa and water hyacinth reproduce through the spread of plant fragments that drift downstream, infesting new areas. When water hyacinth or *Egeria densa* extend into faster-flowing channels, or when higher flows occur, plants are torn away from their mats and moved by currents and wind until they encounter obstructions such as fish screens, marinas, irrigation pumps, or backwater areas.

Table 3-6 provides the estimated *Egeria densa* surface acreage at sites near CCF according to the Department of Boating and Waterways (DBW, 2006). DBW is the lead agency for controlling *Egeria densa* and water hyacinth in the Delta and Suisun Marsh.

TABLE 3-6
Estimated *Egeria densa* Surface Acreage
Low-flow Intake Technical Analysis

Site Name	Site Description	Estimated Total Water Acres	Estimated *Egeria densa* Acres in 2000	Percentage *Egeria densa* Acres in 2000
Old River Del's	Portion of Old River south of Clifton Court Forebay near Del's Boat harbor	116.19	67	58%
Coney Island	Island on the east side of Clifton Court Forebay	1,049.02	116	11%
Victoria Canal	Canal northeast of Clifton Court Forebay running from Coney Island to Union Point	194.65	57	29%
Grant Line Canal	Canal southeast of Clifton Court Forebay from Old River to Doughty Cut	276.71	13	5%

3.4.2 Turbidity

Turbidity is an important water quality parameter because laboratory studies have shown that delta smelt require turbidity for successful feeding. Clearer water may also increase the vulnerability of some fish species to predation by other fishes. Turbidity data at locations near CCF were collected from CDEC and the BDAT (Table 3-7).

TABLE 3-7
Measured Turbidity Data
Low-flow Intake Technical Analysis

Location	Historical Data Record	Time Step	Data Source	Agency
Clifton Court	3/10/1988 to Present	1 hour	CDEC	DWR
Grant Line Canal	7/5/2007 to Present	15 minutes	CDEC	USGS
Old River at Clifton Court Ferry	710/1990 to 7/20/1994	Semiweekly, semimonthly	BDAT	DWR
Old River at CCF Intake	7/25/1989 to 7/20/1994	Semiweekly, semimonthly	BDAT	DWR
Old River at Delta Mendota Canal	7/25/1989 to 7/20/1994	Semiweekly, semimonthly	BDAT	DWR
Victoria Canal near Byron	7/5/2007 to Present	15 minutes	CDEC	USGS

3.4.3 Salinity

Salinity is an important water quality parameter in managing daily Banks Pumping Plant operations. Salinity near CCF can vary due to the impact of tidal action, project reservoir releases, Delta export levels, and operation of the Delta Cross Channel gates. The IEP HEC-DSS Timeseries Database and CDEC provide historical EC timeseries data near CCF, as shown in Table 3-8.

TABLE 3-8
Historical EC Data
Low-flow Intake Technical Analysis

Location	Historical Data Record	Time Step	Data Source	Agency
CCF (CLC)	1/1/1987 to present	1 hour	CDEC	DWR
CCF Radial Gates	1/1/1997 to present	Daily	IEP	DWR
Old River near Delta Mendota Canal (southeast of barrier)	10/1/1992 to 1/31/2003	15 minutes	IEP	DWR
Old River near Delta Mendota Canal (northwest of barrier)	10/1/1992 to 1/31/2003	15 minutes	IEP	DWR
Victoria Canal near Byron	7/1/2008 to present	Daily	CDEC	USGS

The 2005 existing conditions DSM2 simulation results also provide daily EC estimates for the following locations.

- CCF
- Old River near Byron
- Old River at Clifton Court Ferry
- Victoria Canal

3.5 Clifton Court Forebay

CCF is a shallow reservoir at the head of the California Aqueduct. It was formed by constructing a low, zoned earthfill dam inside the levees of Clifton Court Tract. The forebay has the following key features:

- Maximum operating storage is 28,653 acre-feet.
- Maximum operating surface area is 2,109 acres.
- Maximum operating elevation is 5 feet.
- Crest elevation of the dam is 14 feet.

A gated control structure regulates flow into CCF. The structure consists of five radial gates housed in a reinforced-concrete gate bay structure and has the following key features:

- Each gate is 20 feet wide by 25.5 feet high.
- The design flow is 10,300 cfs.
- Design velocity is 2 fps.

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SECTION 4

Biological Factors

The purpose of this section is to investigate and document the biological factors affecting the design of an LFI near CCF that would allow maximum screened flows of 2,000 cfs to be pumped by the Banks Pumping Plant during times when sensitive species are in the area, and to evaluate potential sites for the facility relative to species distribution and movement. The following discussion summarizes the existing fish temporal distribution and life history, monitoring information, and predation information, and reviews the considerations necessary to design and operate an LFI to meet regulatory criteria and requirements.

4.1 Life History and Distribution of Fishes in the LFI Project Area

The approximate temporal distribution of several species of concern in the south Delta is summarized in Table 4-1. Generally, adult delta and longfin smelt and Sacramento splittail would be expected in the LFI project area during the winter through spring, and the early life stages (embryos, larvae, and juveniles) of these species would be expected during the spring and early summer months. Juvenile Chinook salmon and steelhead would generally be expected during periods with cooler water temperature from winter to early summer (Moyle, 2002) (DFG, 2009).

TABLE 4-1
Approximate Life Stage Periodicity of Fishes of Concern in the General Vicinity of Project
Low-flow Intake Technical Analysis

Species	Life Stages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Delta smelt	Adult	■	■	■	■	■	■						■
	Embryo/ larvae <20 mm		■	■	■	■	■						
	Larvae/juvenile >20 mm			■	■	■	■	■					
Longfin smelt	Adult	■	■	■	■	■							■
	Embryo/larvae <20 mm	■	■	■	■	■	■						
	Larvae/juvenile >20 mm		■	■	■	■	■	■					
Chinook salmon	Juvenile	■	■	■	■	■	■					■	■
Steelhead	Juvenile	■	■	■	■	■							■
Sacramento splittail	Adult	■	■	■	■	■	■	■					■
	Embryo/larvae		■	■	■	■	■	■					
	Juvenile			■	■	■	■	■	■				

Delta and longfin smelt are pelagic species found in greatest abundance within the water column and usually not in association with shorelines (except during their embryonic and larval stages). Sacramento splittail are less associated with the open water column; adult and juvenile life stages forage and rear in association with the bottom. Juvenile salmonids, (Chinook salmon and steelhead) would be expected to be found throughout the water column, along the shoreline, the bottom, and in open water.

Embryos of delta smelt are demersal (associated with the bottom) and adhesive, attaching to substrates in main channels having current. Newly hatched larvae are semibuoyant, allowing this life stage to remain near the bottom until the swim bladder and fins develop several weeks after hatching. The earliest larval and juvenile life stages of delta smelt have poor swimming ability and tend to move passively with currents and tides. After developing a swim bladder at approximately 16 to 18 mm total length (TL), larvae become more buoyant and move into the water column. Adult delta smelt are also poor swimmers (less than 1.0 fps) and tend to select portions of the water column with low velocities, where they swim in short bursts followed by a glide. Adults also move up and down within the water column in a diel pattern to follow plankton (prey) movements. Delta smelt primarily spawn at night and usually during new or full moon periods corresponding to low tides.

Other species in the project area include recreationally important striped bass and American shad, and several important forage species, including threadfin shad and many other native and introduced species. Similar to the smelts, larval and early juvenile life stages of species including striped bass, threadfin shad, and American shad prefer pelagic habitats and move somewhat passively within the water column. This life history trait makes these species and life stages vulnerable to being swept into south Delta diversion facilities.

4.2 Fish Monitoring in the Project Area

Several recent long-term fish-monitoring programs have been conducted or are now in progress in the San Francisco Bay Estuary (Bay) and the Delta. These programs provide temporal and spatial fish abundance and biological information for a large number of fish species in these geographic areas. The California Department of Fish and Game (DFG), as a member of the IEP, participates in at least five fish-monitoring survey projects in the Bay-Delta.[1] Of these monitoring programs the following are focused on delta smelt:

- 20-mm survey
- Delta Smelt Larval Survey (DSLS)
- Spring Kodiak Trawl (SKT)

DFG also collects fish-monitoring data from these sources:

- The fall Mid-water Trawl (MWT)
- Tow-net surveys (TNS)

[1] Specific information is available at http://www.delta.dfg.ca.gov/IEP/.

Fish salvage and loss information at the SDFPF and from the federal Tracy Fish Collection Facility (TFCF) are collected and managed by DFG's Fish Facilities Monitoring Project. All of these fish-monitoring projects are conducted by DFG's Bay-Delta (East) Region in Stockton.

The United States Fish and Wildlife Service's (USFWS) Stockton Fish and Wildlife Office also participates in the IEP Delta Juvenile Fish Monitoring Program by conducting beach seining and trawling surveys throughout the lower Sacramento and San Joaquin rivers, the Delta, and the Bay. These surveys focus on collecting data on abundance and distribution and life history information for juvenile salmonids, green sturgeon, and other fish species.

4.2.1 Monitoring Data Relevant to the LFI Project

Of the programs identified, the following are most useful in assessing the temporal and spatial presence and abundance near potential LFI sites.

20-mm Survey

The major source of fish temporal and spatial distribution data is from IEP's 20-mm survey. This ongoing survey (beginning in 1995) monitors delta smelt (and other species) post-larval and juvenile timing, distribution, and relative abundance throughout their spring range in the Bay-Delta region. Data are collected from a core of 41 (maximum 55) collecting stations starting in the early spring (March or April).[2]

These surveys are conducted at 2-week intervals through midsummer (July or August). The survey data is used to help estimate larval delta smelt losses and the magnitude of larval and juvenile entrainment at the SWP and CVP. The fish are collected using a conical plankton net with a mesh size of 1,600 microns (µm). Because of their life-history characteristics, delta smelt in the central and south Delta areas are vulnerable to be entrained into the SWP and CVP pumps, especially in the spring and early summer months.

This survey gets its name from the size (20 mm) at which delta smelt are retained and readily identifiable at the SDFPF and TFCF facilities. Data from the 20-mm surveys is reported as mean number of fish per volume of water sampled (standardized to 10,000 m^3). Despite these extensive sampling efforts, fish larvae less than 20 mm are not effectively sampled.

DSLS

This survey began in 2005 and was primarily focused on determining the timing, distribution, and abundance of delta smelt larvae in the mid-winter (January and February) period. Other species, when captured, were also identified and data was tabulated. These surveys were conducted at 19 to 49 stations every 2 weeks and continued through the early summer (June and July) or until catch efficiency decreased or delta smelt were not in danger of being entrained at the SWP and CVP.[3] Fish larvae and zooplankton were collected using four conical nets (two fore and two aft) with a mesh size of 505 µm. As with the 20-mm surveys, data were reported as a mean number of fish per volume of water samples

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[2] Data is available at ftp://ftp.delta.dfg.ca.gov/.

[3] Data is available at ftp://ftp.delta.dfg.ca.gov/.

(standardized to 10,000 m^3). Eleven surveys were conducted from January through July, 2005; five surveys were conducted from January through March, 2006; and one survey was conducted in April 2007. No DSLS surveys have been conducted since then.

SKT Survey

The SKT survey is conducted to monitor and provide timing, distribution, and abundance information on pre-spawning and spawning-aged delta smelt. These ongoing surveys began in 2002. Forty locations in the upper Bay and Delta are sampled every other week beginning in early January through late spring or until delta smelt are no longer spawning.[4] Adult spawning-sized delta smelt are targeted using a standard Kodiak trawl with mesh size from 2 inches down to 0.25 inch. Data is reported as mean number of fish per volume of water samples (standardized to 10,000 m^3).

Monitoring Stations Providing Most Relevant Data Sets

The 20-mm surveys and the DSLS at the following two stations have the most relevant data set that may be useful in evaluating the abundance, temporal, and geographical characteristics of young life stages of fish near CCF:

- Station 915 (western arm of Old River at the railroad bridge north of CCF)
- Station 918 (Old River northwest of Coney Island and adjacent to CCF)

Additionally, a one-time (1999) supplemental 20-mm survey was conducted at three stations in Old River southeast of CCF near the CVP intake channel:

- Station 997
- Station 998
- Station 999

Approximate locations of these sampling survey stations are identified in Figure 4-1.

[4] Data is available at ftp://ftp.delta.dfg.ca.gov/.

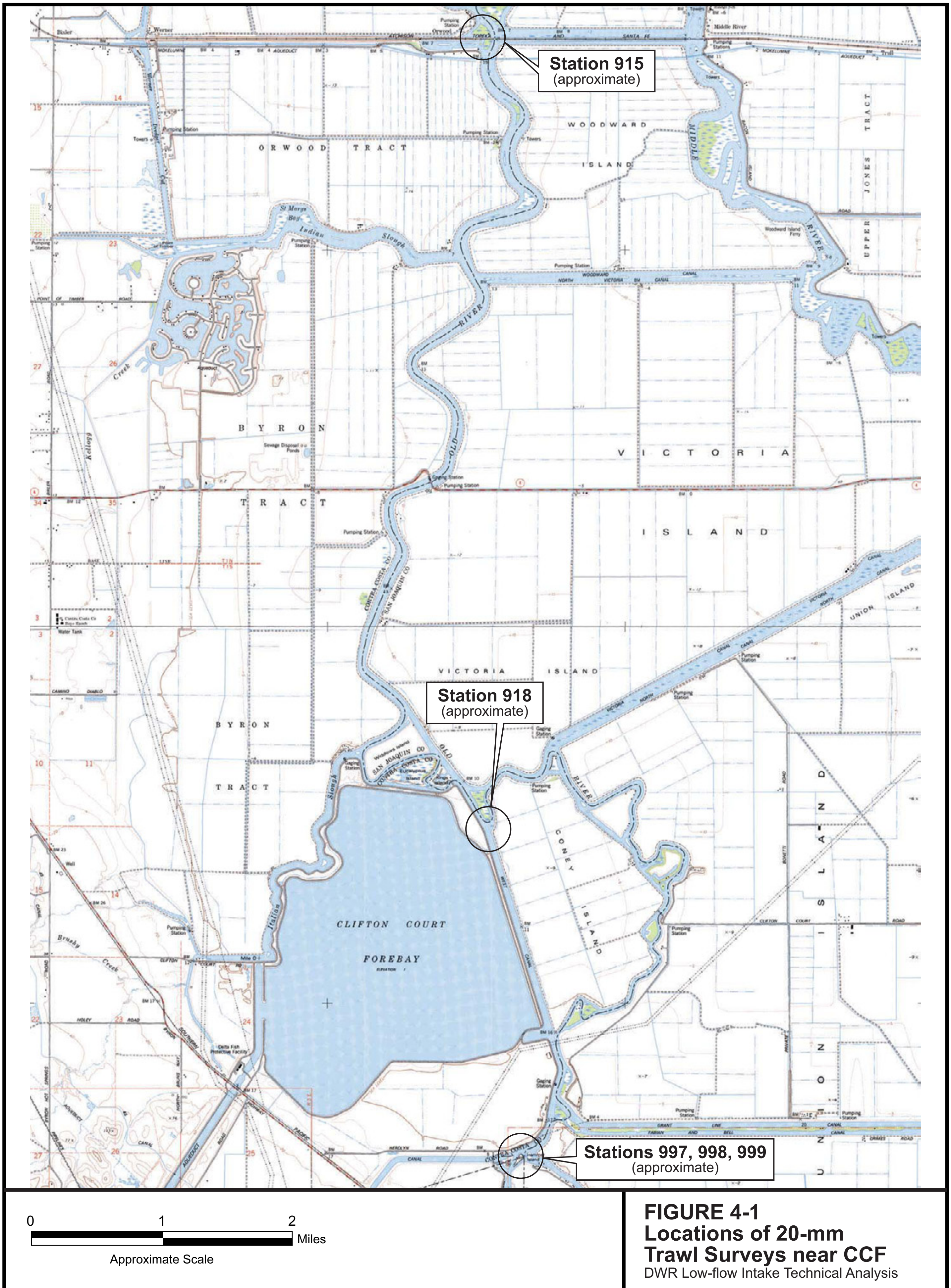

FIGURE 4-1
Locations of 20-mm Trawl Surveys near CCF
DWR Low-flow Intake Technical Analysis

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State and Federal Fish Facilities

Since the SDFPF became operational in the 1960s, a large amount of fish monitoring data has been collected there. DFG's Fish Facilities Unit, in cooperation with DWR, began salvaging fish at the SDFPF in 1968. The salvaged fish are trucked daily and released at several sites in the western Delta. Salvage is conducted 24 hours a day, seven days a week at regular intervals. Entrained fish sampling at the SDFPF and the TFCF is the source for DFG's daily salvage and loss estimates for monitoring incidental take of listed fish species.

This operation maintains one of the largest historical databases on Delta species available and has been used to assess the effects of new facilities and programs, proposed water project operations, and proposed CALFED alternatives. Salvage data is available on the Bay-Delta FTP server at ftp://ftp.delta.dfg.ca.gov/salvage/. The most recent 3-year summary of fish-collection data for the TFCF can be found at http://www.usbr.gov/pmts/tech_services/tracy_research//glossary/fish-genus-species.html.

The federal TFCF, and more recently the Tracy Fish Facility Improvement Program (TFFIP) initiated in 1989, have collected a large fish-monitoring database and have published research activities in the south Delta. The published TFFIP research reports for investigations conducted since 1989 can be accessed at http://www.usbr.gov/pmts/tech_services/tracy_research//tracyreports/index.html.

4.2.2 Evaluation of the Most Relevant Monitoring Data

Delta Smelt Database

The most relevant fish data collected at the sampling locations nearest to the CCF were obtained and summarized from the master delta smelt database.[5] These data were compiled from the ongoing 20-mm and DSLS surveys. The database includes monitoring data for the four fish species currently being investigated by the IEP's POD work teams. These POD fish species compose the largest biomass of larval and juvenile pelagic fish in the south Delta:

- Delta smelt
- Longfin smelt
- Striped bass
- Threadfin shad

Because of these species' vulnerability to entrainment, impingement, and salvage, the following analysis was focused on larval and juvenile lifestages of the POD species collected at Old River survey stations 915 and 918. The monitoring data from these two survey stations is summarized Table 4-2. This table represents 14 years of data collected over a variety of south Delta diversion patterns, water year types, and environmental conditions that affect the fish evaluated. Data from an additional survey (June 1999) at three locations near the TFCF facilities in Old River (Stations 997, 998, and 999) is also summarized with data for the same period from Stations 915 and 918 in Table 4-2. Except for 2000 and 2001, the total numbers of individual POD fishes captured at sampling stations 915 and 918 were less than 400 at each location (Figure 4-2). During the months (January through July) in which data was collected there is little difference between the total numbers of larvae and

[5] Available at ftp://.delta.dfg.ca.gov/.

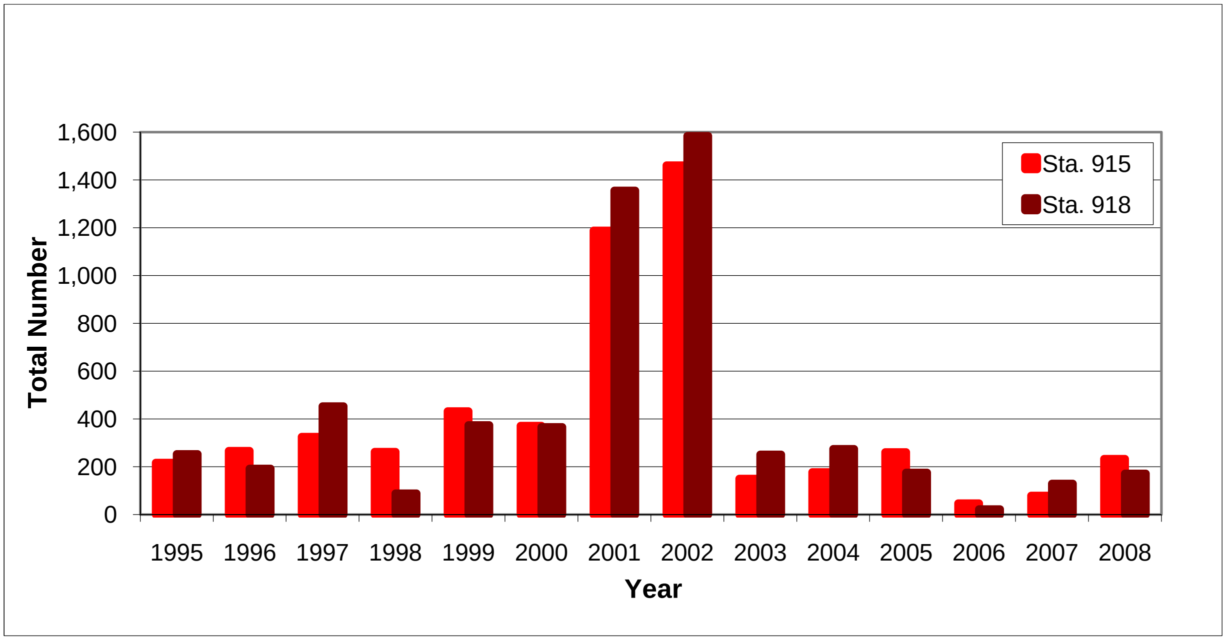
TABLE 4-2
Summary of the Total Number of POD Fish for Stations 915 and 918 from 1995 through 2008
Low-flow Intake Technical Analysis

Station*	Species Common Name	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Species Sub-total, All Years
915	Delta smelt	0	2	12	1	20	23	6	21	2	1	0	0	0	1	89
	Longfin smelt	0	0	4	0	0	2	15	50	2	1	18	0	0	2	94
	Striped bass	181	80	168	75	340	321	498	199	104	124	62	2	69	223	2,446
	Threadfin shad	35	184	141	186	72	25	669	1,191	42	51	181	45	10	7	2,839
	Annual subtotal	*216*	*266*	*325*	*262*	*432*	*371*	*1,188*	*1,461*	*150*	*177*	*261*	*47*	*79*	*233*	*5,468*
918	Delta smelt	0	2	1	0	13	27	7	17	4	4	2	0	0	0	77
	Longfin smelt	0	67	5	0	0	2	9	51	7	0	25	0	0	4	170
	Striped bass	216	77	247	31	253	300	231	158	54	127	17	5	103	147	1,966
	Threadfin shad	34	46	200	55	108	37	1,108	1,358	186	143	130	10	26	20	3,461
	Annual subtotal	*250*	*192*	*453*	*68*	*374*	*366*	*1,355*	*1,584*	*251*	*274*	*174*	*15*	*129*	*171*	*5,674*

Source: Delta Smelt Database, ftp://.delta.dfg.ca.gov/
* For station location, see Figure 4-1.

and juveniles for the selected fish species collected (Table 4-2). For example, the total number of larvae and juvenile POD fishes collected in the same calendar year was greater at Station 915 than Station 918 in 7 out of 14 years. Conversely, in 7 out of the 14 surveyed years, Station 918 had greater total numbers of larval and juvenile fish annually compared to Station 915. This data suggests that, at least for these two geographic locations in the south Delta, overall larval POD fish abundance and distribution is relatively similar (Table 4-2 and Figure 4-2).

FIGURE 4-2
Summary of the Total Number of Larval and Juvenile POD Fishes Collected from 20-mm Surveys, 1995 to 2008
Low-flow Intake Technical Analysis



During the 20-mm surveys conducted in June 1999, three additional sampling locations near the CVP intake (southeast of CCF) in Old River were sampled concurrently with Stations 915 and 918 (Table 4-3). From this one-time supplemental survey, the data suggests that at two of the locations in the Old River near the CVP intake (Stations 997 and 998), greater larval and juvenile fish abundance occurred during the sampling period compared to sampling stations farther north (downstream) and adjacent to the CCF in Old River (Stations 915 and 918, respectively) (Figure 4-3). For the other sampling station associated with the CVP intake (Station 999), the numbers collected were similar to those at the other Old River stations collected that month (Figure 4-3). The database did not reveal the reason for the much larger number of POD fishes collected at Stations 997 and 998 relative to Stations 915, 918, and 999.

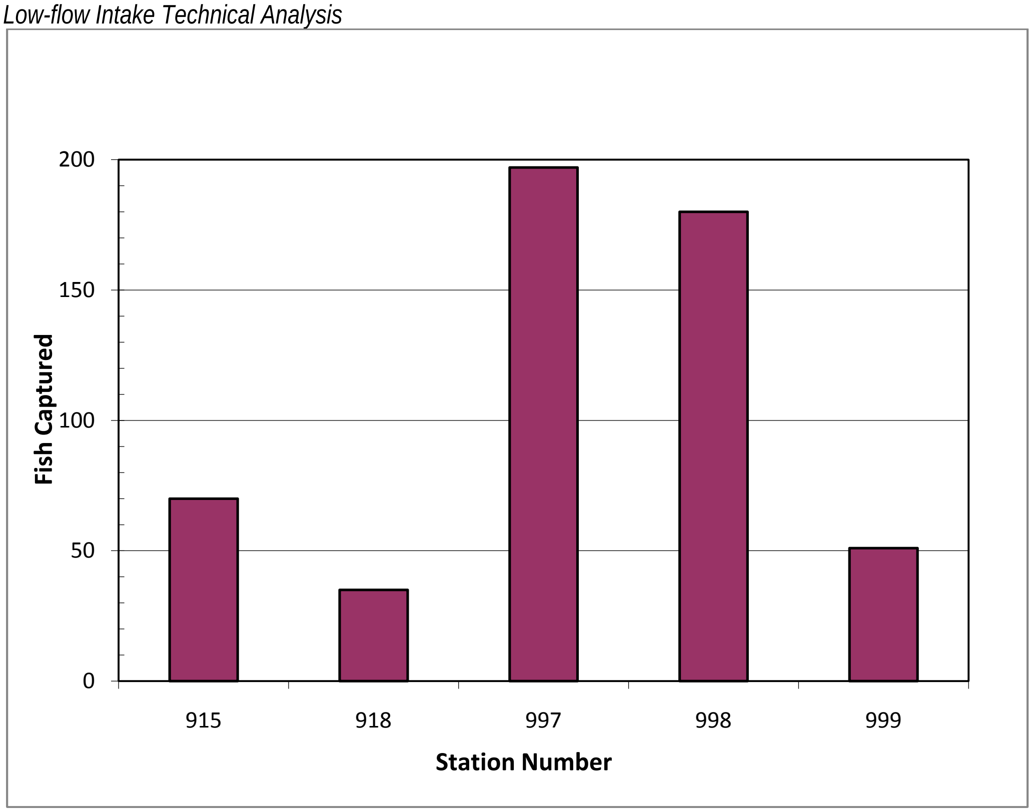
TABLE 4-3
Summary of the Total Number of POD Fish for Simultaneous Collections at Stations 915, 918, 997, 998, and 999, June 1999
Low-flow Intake Technical Analysis

	Station*					
Species	**915**	**918**	**997**	**998**	**999**	**All**
Delta smelt	0	0	2	0	0	2
Longfin smelt	0	0	0	0	0	0
Striped bass	32	17	180	160	20	409
Threadfin shad	38	18	15	20	31	122
Station subtotal	*70*	*35*	*197*	*180*	*51*	

Source: Delta Smelt Database, ftp://.delta.dfg.ca.gov/

* For station location, see Figure 4-1.

FIGURE 4-3
Total POD Fish Captured During 20-mm Surveys, June 2-7, 1999
Low-flow Intake Technical Analysis

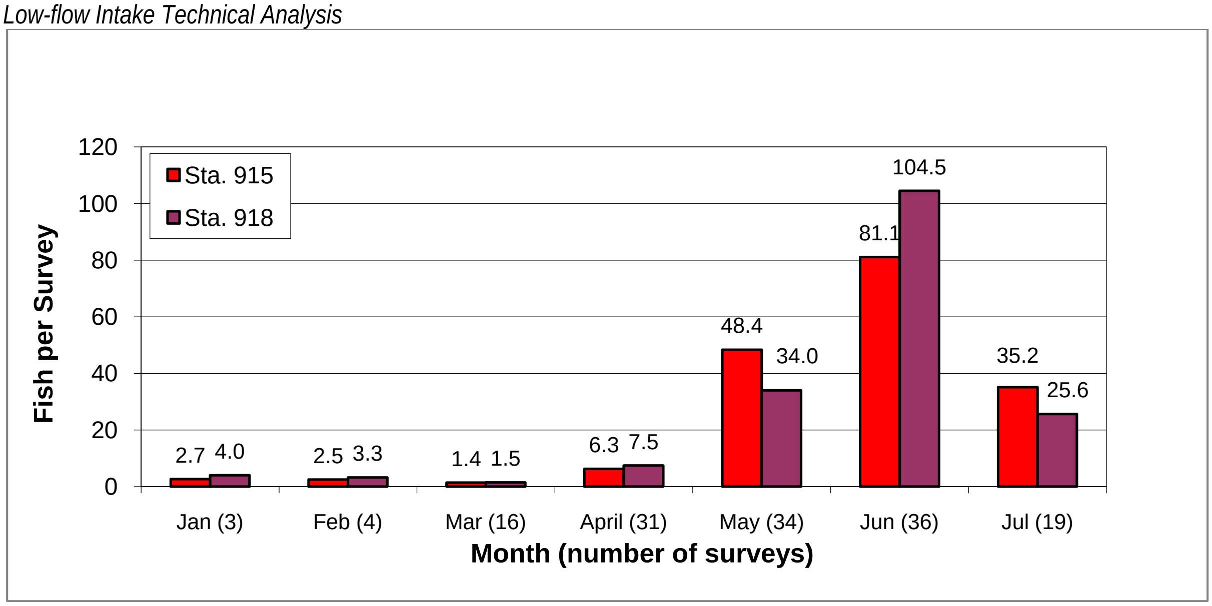


SKT Surveys

The following information was obtained and assessed for its relevance to the LFI. From these surveys, only one station (915) in the south Delta was sampled over the period 2002 through 2008, during which very few fish species of special concern were captured. A total of 31 individual fish representing delta smelt, Chinook salmon, steelhead, and threadfin shad were captured in the SKTs at Station 915 in the Old River downstream (north) of CCF during those 7 years. As there are no stations at or near CCF to compare these data with, no further analysis of the SKT data was attempted.

To further examine the seasonal abundance of larval and juvenile POD species collected during the 20-mm surveys near CCF, the average number of larvae and juveniles collected by month at each of the two Old River survey stations during the 1995 to 2008 sampling period were summarized and compared. The majority of the small young POD fishes were captured in May through July, with a peak in June at both stations (Figure 4-4). Before May, average numbers of larval and juvenile fish collected from both stations are small. From 1995 through 2008, the average number of larval and juvenile POD fishes collected at Station 915 (downstream of CCF) is approximately 40 percent greater than that for Station 918 (adjacent to CCF). However, in June the average number of larval and juvenile POD fishes collected at Station 918 is approximately 25 percent greater than at Station 915. This pattern may reflect the temporal distributions of those POD species as affected by exports from the SWP and CVP projects following the spawning of those larvae and juveniles during the previous December-through-March period.

FIGURE 4-4
Average Number of POD Fish Captured per 20-mm Survey at Stations 915 and 918 by Month, 1995–2008
Low-flow Intake Technical Analysis



4.2.3 Summary of Fish Life-history Characteristics and the Monitoring Data Evaluated

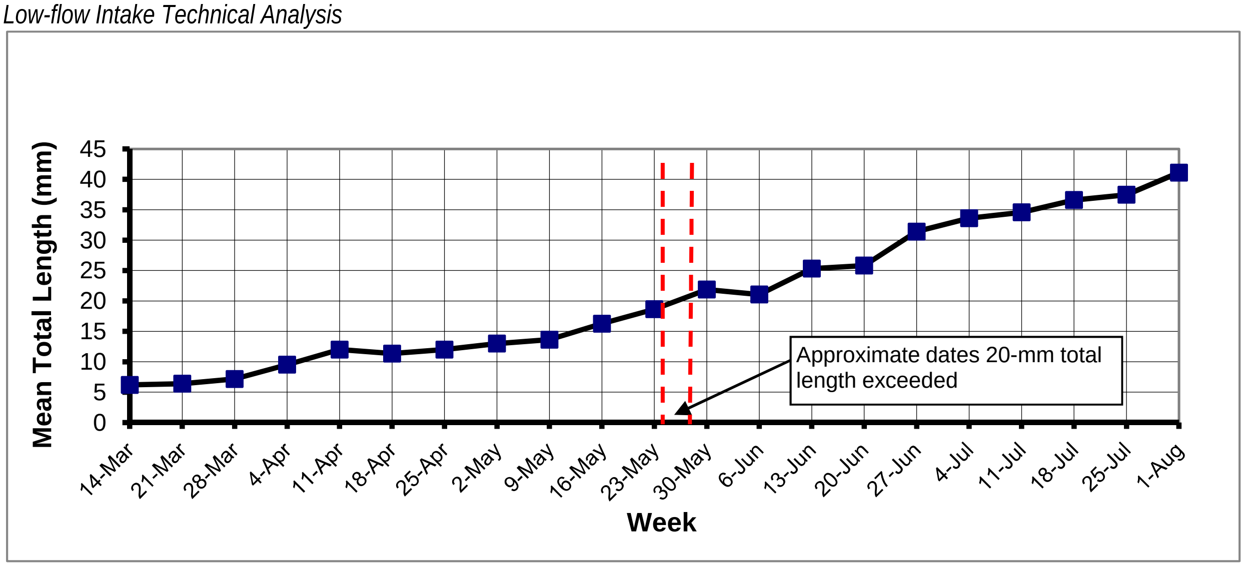
The life histories of the species of most concern (POD species) are such that during December through July, adults of several of these species and the early life stages of all of them would likely be vulnerable to entrainment at any new diversion near CCF.

As shown in Figure 4-4, the period from April through July would be most problematic for entrainment or impingement of larvae and early juvenile life stages at any screen (Moyle, 2002). From data collected in the IEP program's 20-mm surveys, the mean total lengths (TL) of Delta Smelt during that period are summarized and shown in Figure 4-5. Based on data collected for all Bay-Delta stations sampled during 1995 through 2008, on average, delta smelt would be expected to reach 20-mm TL or greater in late May (Figure 4-5) (DFG, 2009). Before late May, embryos and larvae of this species may not be as vulnerable to entrainment or impingement at a fish screen because at that stage of development, they remain close to the bottom of the water column until they develop their swim bladders, which occurs at approximately 16 to 18 mm in length (Moyle, 2002).

In summary, examination of the somewhat limited set of larval and juvenile fish-survey data available from the monitoring station near CCF, it is unclear if an optimal location for the LFI project exists. The fish-monitoring data examined did not clearly identify large differences in geographic presence or seasonal abundance of young fishes that distinguishes data from those two monitoring locations. Consequently, the available data provides little guidance on LFI siting.

However, as previously noted, despite the somewhat robust sampling efforts conducted from 1995 to 2008, it is generally recognized that fish larvae approximately 20 mm and smaller are not effectively sampled by the current survey methodology (USFWS, 2008). Therefore, the monitoring survey data reviewed and evaluated may not adequately represent and characterize the overall abundance and geographical distribution of vulnerable fish larvae near CCF.

FIGURE 4-5
Delta Smelt Larva and Juvenile Mean Total Length, 1995–2008 (All Stations)
Low-flow Intake Technical Analysis



4.3 Fish Predation Considerations

Considerable information on the behavior, movement, and presence of predatory fish species inside CCF is available. In 2005, a CALFED technical workshop was held with presentations and discussions focused on issues related to predation on fish species of concern in and near the water export facilities in the south Delta.[6]

Predation occurs before fish are counted at the SWP and CVP fish salvage facilities, which complicates efforts to quantify total losses of entrained fish at the two facilities. For the SWP water intake system, the radial gates at the southeast corner of the CCF are opened periodically to allow water from Old River channels to enter CCF. This set up likely results in high predation losses inside CCF. Steelhead have been shown to exit CCF through the radial gates (Clark 2009), but it is unknown if other prey species are capable of the same feat. Recent tagging experiments with steelhead in CCF resulted in estimated predation losses exceeding 74 to 83 percent, and for Chinook salmon, from 63 to 99 percent (Clark, 2009). However, information about the specific rates of predation and the magnitude of population-level impacts for many species is lacking, especially for delta and longfin smelts. DFG and USFWS are conducting a pilot study to investigate delta smelt losses within CCF and at the SDFPF.

For the purposes of the applicable ESA incidental take permits (ITP) for the CVP and SWP, predators are assumed to remove up to 75 percent of the juvenile Chinook salmon entering the SWP facilities, and 15 percent of those entering the CVP facilities (Kimmerer and Brown, 2006). The SWP estimate is based on fish mark-recapture studies in the CCF. The 15 percent loss rate estimated for the CVP Tracy Fish Facility is based on predation investigation estimates, but not any specifically conducted at the CVP intake facility. This predation estimate is being used in salvage-estimate calculations until an actual predation loss estimate at the CVP facilities can be developed (Kimmerer and Brown, 2006). Predation rates for other species in CCF and at the CVP facilities are unknown.

Fish predators are known to hold in lower-velocity habitat areas where higher-velocity flows bring food toward them. For example, striped bass are known to congregate near the entrance to the CCF when the radial gates are open. Among the most important parameters for management consideration to minimize predation is the rate and duration of encounter between predators and prey. In contrast, the CVP export facility has no forebay, and water is taken directly from the adjacent Old River channel. In studies at the CVP facilities, predators' diets were composed primarily of shad, with bay goby making up a substantial proportion of the overall diets. Researchers also found that removing predators from the CVP fish separation and salvage system was inefficient, as the areas were repopulated with predators within days.

It is likely that predatory fishes (striped bass, white catfish, largemouth bass, and others) would be found throughout habitats in Old River, CCF, and adjacent waters. These predators would congregate when habitat and foraging conditions are suitable. Similar to the observations of predatory fish behavior within CCF, predatory fish within Old River or other potential LFI locations would seek to occupy somewhat lower-velocity habitats

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[6] Findings of this workshop are available at http://www.science.calwater.ca.gov/events/workshops/workshop_predation.html.

adjacent to higher velocity waters in which prey fish are being swept along or passing. From these habitats, predators would act to ambush passing prey fish. Conversely, predators would seek pockets of prey species that congregate in selected portions of the water column containing low-water velocities.

4.4 Fish Screen Design and Operating Considerations

It would be necessary to implement current fish screen design guidance and criteria as specified by National Marine Fisheries Service (NMFS), USFWS, and DFG for any fish screen considered and developed for this LFI project.[7] It would be necessary to use design criteria protective of the most sensitive species likely to be present in the project area (likely delta smelt). These are the major design and operation considerations relative to biological factors:

- Siting a diversion and its accompanying fish screen must consider channel hydraulic conditions at the screen and for any fish bypasses being considered.
- Operations must consider tidal stages, velocities, and frequencies; species diel cycles; water quality, debris, and sediment conditions; stream flow and stages in Old and Middle rivers; and channel geomorphology.
- Predation conditions must address potential for predation at fish bypasses or adjacent to screening facilities; fish behavior, including swimming performance; and life history characteristics of species expected to be found at the project site.

Careful considerations of all of these factors would increase effectiveness of any screen protection system for larval and juvenile life stages of fishes present in the south Delta.

Minimizing or eliminating habitats or conditions for predators congregating near screen facilities and at any fish bypass outlets (if part of the design) should receive special attention to the extent that it can be evaluated. Placement of any such bypass should be designed to widely disperse bypassed fish into an environment less suitable for predator concentration.

Any LFI facility should consider fish (and bird) predation management as an essential factor in design and siting. Facility design considerations for reducing or eliminating predation associated with the LFI, including bypass outfall placement and operations and LFI facility isolation from CCF, are mandatory given the overall need to greatly reduce predation rates at SWP export facilities. All of the following considerations would assist in minimizing or eliminating predation at the LFI facility:

- The physical location of the LFI (distance to any bypass outfall) and operational conditions, including multiple bypass outfalls coupled with random bypass discharges, should be considered for any LFI diversion facilities incorporating fish bypasses.
- The receiving water's geomorphic condition (channel width and depths, velocities, habitat type) must be considered when designing any fish bypass outfalls.

[7] A summary of the existing published criteria and guidelines is provided in found in the *Fish Passage Criteria and Guidance Report* prepared in November 2008 for DWR under this task order (Ott et al., 2008).

- Operational factors for fish bypasses should consider receiving water flow, tidal stage and velocity, and day/night condition which may assist in reducing or eliminating predation at bypass outlets.

One of the most difficult design and operation factors arises from the complex tidal and river flow characteristics near CCF exclusive of any diversion activity; flows occur in both directions—or not at all—depending on tidal conditions, river outflow, and many variable factors affecting both. In this regard, the LFI is unlike any previously built project outside the Delta. Consequently, sweeping velocities and exposure time criteria intended to help protect fish at other diversion facilities on rivers with unidirectional flow cannot be easily applied at any site being considered for the LFI. The Contra Costa Water District (CCWD) and the Banta Carbona diversions nearby on Old River operate under similar conditions and both required waivers (informal) from the regulating agencies to deviate from the criteria regarding sweeping velocities and exposure time.

USEPA, USFWS, NMFS, and DFG will ultimately determine the screen design criteria of any LFI alternative. Specific biological and hydraulic evaluations of each will be necessary, and it is likely that agency waivers will be necessary to operate certain alternatives presented in this technical analysis.

4.5 Conclusions

Based on the limited set of larval and juvenile fish-survey data available from the monitoring stations near CCF, it is unclear if an optimal location for the LFI project exists with regard to the life stages of the species targeted for protection by the LFI. The fish-monitoring data reviewed for this report did not clearly identify any large differences in geographic presence or seasonal abundance of young fishes.

In terms of predation, information is generally lacking, especially with regard to waters outside CCF and away from the state and federal fish salvage facilities. Predators are generally present throughout the waterbodies in the LFI project area, and will naturally congregate in areas where habitat and foraging conditions are suitable, such as lower-velocity habitats adjacent to higher velocity waters in which prey fish are being swept along or passing. Predators will also seek prey species congregating in selected portions of the water column containing low water velocities. Given the greatly variable hydrodynamics in the project area, this predator behavior alone does not indicate a favorable site. Additional evaluation is provided with the discussion of each alternative presented in Section 5.

Finally, any LFI alternative will likely require screen criteria waivers from the fisheries agencies to deviate from sweeping velocities and exposure time criteria, as was the case for the nearby CCWD and Banta Carbona diversion facilities.

SECTION 5

Intake Alternatives: Development and Analysis

This section presents the basis of development and a cursory level technical analysis of intake alternatives as allowed within the scope of this task. The discussion is presented in three parts:

- **Key Design Factors** outlines common factors that were considered for developing the alternative,
- **LFI Alternatives** presents potential LFI projects at seven sites along with their merits and demerits, and
- **Further Conveyance Considerations** documents issues to be considered in a detail study

5.1 Key Design Factors

These three key design factors help define any LFI alternative:

- Site location
- Screen technology (on-river or off-river)
- Conveyance of screened water to the Banks Pumping Plant

These design factors may seem like simple, logical factors to consider, but they can be combined in several configurations that can make the terminology confusing. Therefore, each key factor is described before the alternatives are presented in the context of site location, conveyance, and screen technology and fish protection.

Although previous efforts have considered varied diversion capacities up to the full capacity of the Banks Pumping Plant, the objective of this LFI Technical Analysis is to address the period when diversions into the SWP are limited to protect delta smelt and other sensitive species, such as during the Vernalis Adaptive Management Program. For this Technical Analysis, the maximum diversion capacity of the proposed screened LFI has been limited to 2,000 cfs in order to provide reliability by considering the unit capacities at the Banks Pumping Plant (two units rated at 375 cfs, four units rated at 1,067 cfs, and five units rated at 1,130 cfs). Also, during subsequent efforts to refine the recommended alternatives, hydraulic analyses will need to be completed similar to those performed for the 1996 Interim South Delta Program Draft EIS/EIR, which indicated that hydraulic restrictions in Italian Slough may limit conveyance from 2,000 to 3,000 cfs.

The challenge is to accomplish this objective *without fish salvage* as it has been historically practiced at the SWP and CVP. All previous studies of fish facilities at CCF have included fish salvage, which we define as *collection, handling, transportation, and release of salvaged fish*. This approach of avoiding the need to collect, concentrate, and handle fish is consistent with the current fishery agency objectives to 1) use the most biologically protective fish screen concepts, 2) provide a positive fish screen barrier, and 3) avoid creating areas where predators may congregate or where potential prey would have increased vulnerability to predation. For the LFI, only volitional fish bypass in the Old River/West Canal or simple pumped fish bypass similar to that employed at the Banta Carbona diversion are proposed. The LFI is proposed to operate primarily in the months of April through June. For the remaining months, it is assumed that the existing CCF Radial Gates would continue their current normal operation. If shown to be a benefit to fish, a LFI might also be operated in conjunction with the CCF radial gates during other times of the year.

5.1.1 Site Location

The LFI should be located close enough to the Old River/West Canal/other areas with desirable hydraulic characteristics to allow fish to be volitionally bypassed by tidal flow if no internal bypasses are provided. If a pumped bypass with no fish salvage is provided, the LFI should be reasonably near the Old River/West Canal to minimize the distance that the bypass outfall is away from the LFI diversion point, to reduce costs, and to increase fish survival. For example, the Banta Carbona bypass is 2,000 feet long. Having the LFI too far south on Italian Slough could negate potential bypass options because it is too far from the Old River/West Canal, which would increase cost and fish mortality due to unsuitable hydraulic condition.

Numerous full-flow (10,300 cfs) options near Old River/West Canal have been proposed in previous studies (see documents 1 through 10, 12, and 14 listed in Table 2-1). Some of these options even included isolated conveyance to the Banks Pumping Plant (see documents 3 through 6 listed in Table 2-1). For this LFI technical analysis, six locations were selected as potential LFI sites (Figure 5-1).

5.1.2 Screen Technology (On-river or Off-river)

The most promising screen technologies are either flat-panel screens or V screens. These are sometimes referred to as on-river and off-river, respectively. DWR specified investigating non-salvage approach alternatives, so it is assumed that no fish collection facilities or trucked bypass systems would be used. However, a pumped bypass system associated with V screens that conveys all the fish and debris collected at screens to a remote outfall location with desirable hydraulic characteristics on the Old River/West Canal seems acceptable. Multiple cone screens might also be considered as a unique form of on-river screens with the benefit of wide dispersal; however, they do not provide much opportunity for major expansions of the diversion capacity.

The *Fish Passage Criteria and Guidance Report* prepared previously for this task order (Ott et al., 2008) describes several projects, so that information is not repeated in this technical analysis. However, that report and the history of fish screens in California and the Northwest illustrate that on-river and off-river classifications can be confusing, so some quick examples are provided:

- A V screen downstream of a levee and head gates is generally agreed to be off river.
- A V screen behind trash racks but upstream of the levee could be considered on river since it is subject to the full range of flood levels.

A similar dichotomy exists for flat-panel screens:

- On-river flat-panel screens at Wilkins Slough or Sutter Mutual Water Company Tisdale do not employ bypasses.
- Larger flat-panel projects such as Glen-Colusa Irrigation District and the Tehama-Colusa Canal Authority at Red Bluff considered using internal bypasses.

In the range of size for the LFI project (no greater than 2,000 cfs) it is even possible to consider six screens of the size used at the CCWD Old River diversion for Los Vaqueros or 40 cone screens at sufficient spacing to eliminate the need for bypasses.

This discussion illustrates that many screen technologies are available for any given site. Screen technology selection will be heavily driven by the judgment of the state and federal fisheries agencies with regard to the adequacy of the sweeping flow, exposure time, and mortality associated with potential pumped fish bypasses. This is why all previous concepts studied in the CCF area included salvage. In the absence of salvage, improved flows in the Old River, a waiver of sweeping flow requirements, or pumped bypasses may each make an LFI alternative acceptable. Consequently, it is unlikely that one screen technology will evolve as preferable in this report.

5.1.3 Screened Water Conveyance to the Banks Pumping Plant

DWR has asked that this technical analysis consider two methods of conveying water to the Banks Pumping Plant:

- The first method conveys the water through CCF and the SDFPF
- The second method provides conveyance isolated from CCF, with flows from the LFI going directly to the Banks Pumping Plant.

The operational difference between these two conveyance schemes has to do with the extent to which screened water is mixed with CCF water. LFI operations will need to be refined during the feasibility study, but for the purposes of this analysis, the following operations are assumed:

- Through-CCF conveyance: It is assumed that during April, May, and June, the LFI would operate and the radial gates would be closed. This would mean that on the last day of March, fish drawn into CCF would still be there or would have moved through the SDFPF. On the first day of April, screened water (up to 2,000 cfs) would enter CCF and mix with the fish and water in CCF.
- Isolated conveyance: The existing radial gates and proposed new gates between CCF and the SDFPF would be closed, which would trap fish present in CCF. The LFI would convey up to 2,000 cfs of screened water directly to the Banks Pumping Plant. As part of the future feasibility study, a specific operational and biological study should be conducted to determine the merits of including isolated conveyance.

5.2 LFI Alternatives

The following potential LFI projects are defined by the three key design factors previously described. In general, the alternatives are named by location and conveyance (isolated conveyance or direct to CCF) and are assigned an alternative number. Figure 5-1 (presented at the end of this section) indicates all the potential sites addressed in this technical analysis. Each alternative description describes the applicable fish screen technology(s), the conveyance of water to the Banks Pumping Plant, and the biological factors that favor either the site or the technology.

It has been suggested by DWR that a pumped bypass system be investigated for the existing (or improved) SDFPF. Although this is not within the scope of this technical analysis, it is a suitable alternative to be considered in future feasibility studies because it affects the overall fish survival at the site. The fact that fish from the SDFPF have been trucked to offsite release points which are considered to be beyond the influence of the diversion facilities to avoid re-entrainment, would indicate that a bypass system directly to Old River was not appropriate.

To simplify the technical analysis, we have assumed that all the alternatives provide a reliable flow (up to 2,000 cfs) continuously during the months of April through June. It may be possible to run the LFI using just gravity, but this would cause the screen area to be larger to guarantee that flow. If the LFI is to be used at the same time as the Radial Gates, it would have to use pumps and gravity. There does not seem to be any opportunity for high-head pumps except in the isolated conveyance alternatives.

5.2.1 Alternative 1: Italian Slough Isolated

Screen Technology and Conveyance Method

This alternative site was recommended by DWR as a potential site for an isolated conveyance scheme to Banks Pumping Plant. As shown on Figure 5-2, it is a V screen configuration located on the channel leading to the SDFPF. The levee near Mile 0.0 on Italian Slough would be breached, and a log boom and trash rack entrance would be provided. The trash rack would be followed by a V screen with pumped fish bypass. The bypass pipe could be routed along the levee between CCF and Italian Slough but more likely would be routed on piers directly across CCF to an outfall on Old River/West Canal. Pumps would be required to lift the water to take full advantage of the tidal cycle. To make this system truly isolated from CCF, gates would have to be added to the entrance leading to the SDFPF.

Biological Factors

The most significant biological benefit is that an Italian Slough facility would provide up to 2,000 cfs of screened water delivered to SDFPF whenever it was in use. During LFI operation isolated from CCF, SDFPF would not be in operation. However, this alternative would require a very long pumped fish bypass system including multiple pump lifts. A long bypass would increase risk of injury and losses and predation at the outfall. It is likely that it would be biologically beneficial to align the bypass pipe directly across CCF to discharge bypass flows into the West Canal because fish would spend less time in the bypass. The receiving water conditions at the West Canal outfall may provide greater survival and lower injury risks to bypassed fish than a bypass aligned on the Italian Slough levee and discharging near the Old River-Italian Slough confluence. Locating the bypass outfall may require additional investigation and design to minimize or eliminate predation. Additional predator management strategies in Italian Slough would also need to be developed for periods during LFI diversion. This would reduce losses from predators congregating in a nearly dead-end slough. These strategies could include increased bag limits in Italian Slough during months when the LFI operates, and smaller size restrictions for predator species (such as striped bass and white catfish) near the Italian Slough screened intake. It may also be possible to plan and conduct seasonal predator harvests using trawls or traps by DFG or USFWS crews to remove predator species from Italian Slough near the LFI facility.

Planning for reductions in predation rates and predator management at the SWP will likely be required for future SWP operations that include any new LFI project.

5.2.2 Alternatives 2A and 2B: Northwest Byron Tract and Northwest Widdows Island

Screen Technology and Conveyance Method

The northwest site has received a substantial amount of study in the past (see documents 2, 3, 4, 5, 7, 8, 9, 10, 12, 13, and 14 listed in Table 2-1). This site is attractive because it is downstream of the Old River-West Canal confluence, which means the flat-panel screens would be exposed to more sweeping flows that reduce fish entrainment. For this technical analysis, the site is defined as the land north and west of CCF including Kings, Eucalyptus, and Widdows islands as well as the eastern tip of Byron Tract. Two alternatives are suggested at this site.

Either alternative could discharge directly to CCF, but are presented with an isolated conveyance system using a sheet-pile wall inside CCF’s western shore. During the feasibility-level study, the use of a sheet-pile wall should be compared to either an earthen embankment or a Gunderboom. The Gunderboom option has been investigated before (see document 6 listed in Table 2-1) for use in CCF proposals.

Alternative 2A, Northwest Byron Tract, is a slight variation of the DWR V screen concept from 2000 (see documents 3, 4, 5, 8, 12, 14 listed in Table 2-1), but employs a pumped bypass rather than fish salvage. As shown on Figure 5-3, this alternative is on the eastern end of Byron Tract, with the standard log boom, trash rack, V screen, pumped bypass, and pump station configuration. This location would require a siphon under Italian Slough.

Alternative 2B, Northwest Widdows Island, uses a flat-panel on-river screen with pumps to connect to the channel between Eucalyptus and Widdows islands (Figure 5-4). Levees would need to be added, and the channel would need to be dredged and connected directly to CCF for water conveyance. The isolated conveyance would be the same as proposed for Alternative 2A. This alternative includes using and cutting off some existing river channels, and virtually all the work would be marine construction with limited access. The isolated conveyance would deliver water upstream of SDFPF.

Biological Factors

Alternative 2A, Northwest Byron Tract, employs a short bypass from the V screen to the fish bypass outfall that provides biological advantages over a much longer bypass system (such as described for Italian Slough). Locating the bypass outfall may require additional investigation and design to minimize or eliminate predation. This concept would deliver up to 2,000 cfs of screened water to Banks Pumping Plant whenever the LFI operates. Isolated conveyance provided by the sheet-pile-lined channel though CCF and closed gates between CCF and the SDFPF would eliminate the need to operate the SDFPF during LFI operation.

Alternative 2B, Northwest Widdows Island, employs flat-panel screens that provide biological benefit because the fish are not handled in a bypass system, therefore reducing predation at any bypass outfall that a V screen would require. By diverting and conveying water isolated from CCF, this concept would deliver up to 2,000 cfs of screened water to SDFPF whenever the LFI operates. The benefits of the sheet-pile-lined conveyance channel discussed above also apply to this alternative.

5.2.3 Alternative 3: Northeast through CCF

Screen Technology and Conveyance Method

The northeast site is just north of the levee between CCF and West Canal (Figure 5-5). In past studies (see documents 7, 8, 10, 11, and 14 listed in Table 2-1), several arrangements were developed to screen flows through a V screen structure at the north end of CCF. These had a direct connection to deliver screened water to CCF. Flows in this alternative can be driven by gravity or pumps, similar to the West Canal alternative. The V screen is a well-tested technology in the 2,000-cfs flow range, and the pumped bypass has been tested at Banta Carbona near Tracy and found to have little to no effect on delta smelt and salmon fry. However, discharging a concentration of fish in the bypass flow back into Old River could cause a substantial loss of fish due to predation. This has been well documented at the outfall fish returns used by the SDFPF salvage operation. This alternative can be easily configured with isolated conveyance by using a sheet-pile channel inside CCF. This alternative involves a standard V screen with pumping directly to CCF. The screen structure should be located as far south as possible on the levee to maximize the distance available to build the bypass pipe to the northeast corner of the levee on the Old River; this would put the bypass outfall at a significant distance from the screens.

Any alternative screen technology described next under West Canal could also be constructed at the Northeast site, which has more dry land area upon which to work.

Biological Factors

A V screen would require a pumped fish bypass system. The short bypass from the screen to the outfall has biological advantages over a much longer bypass system (such as described for Alternative 1 at Italian Slough). However, locating the bypass outfall may require additional investigation and design to minimize or eliminate predation.

Options using either flat-panel or cylindrical screens in lieu of a V screen would eliminate the need for pumped fish bypasses, which potentially eliminates or minimizes predation that would occur at a bypass outfall. Compared to the V screen, the flat-panel option provides a small biological benefit when the LFI operates; because fish are not “handled” through a bypass system, risk of injury, disorientation, and consequent loss from predation at the outfall are eliminated. Overall, either flat-panel or cylindrical screen technology for this alternative would potentially provide a small biological benefit of reduced predation at the LFI facility over a V screen option.

This alternative would deliver up to 2,000 cfs of screened water into the CCF when the LFI operates. During LFI operation, the SDFPF would need to operate continuously to salvage any fish entrained in CCF through the radial gates.

5.2.4 Alternative 4: West Canal through CCF

Screen Technology and Conveyance Method

The possible sites for this alternative are along the west side of the West Canal levee. The area extends north from the CCF radial gate intake to the Alternative 3 site. Figure 5-6 shows only a flat-panel configuration, but three types of screens are possible here:

- Flat-panel screens along the bank line
- Multiple cylindrical or cone screens
- V screen through the levee

Flat-panel Screens

A structure would be constructed in the bank with flat-panel screens along the bank line. Such an in-bank screen is operated by CCWD on Old River at the Las Vaqueros intake. It has no bypass and leaves fish in their Old River environment. This alternative can be installed in sections as shown on Figure 5-6 or in one long structure. It also has the advantage of being cleaned by a vertically traveling brush to remove debris. This is especially advantageous in areas without sweeping flows or in tidal areas with sweeping flows in both directions. A structure with screens for 2,000 cfs and low-lift pumps would likely be an improvement on the CCWD design, but the facility could be operated with or without a pump system. It could be installed in one long structure or several smaller ones, but about 800 feet of screen length would be required. The structure would be about 30 feet high. The screens would be about 16 feet high to accommodate the 0.2 fps approach velocity. The structure would be built through the levee separating West Canal from CCF and could deliver water by gravity or pumps. In the gravity arrangement, the structure would have to be longer to deliver similar flow over a tidal cycle. Gates would also be necessary to prevent backflow at low tides. For the pump option, the pump lift would only be about 3 feet. The pumps would be variable speed to maintain a constant flow over the range of heads. Flap gates or shutoff gates would be placed on the downstream side of the pumps to prevent backflow during times when the pump was inoperable or being maintained. A study is recommended to determine if there is an economic advantage to building a larger screen structure for gravity operation versus a smaller structure with pumps.

Multiple Cylindrical Screens

For 2,000 cfs, about 25 units would be necessary. Each unit would consist of a cylindrical screen, a pipe over the levee with valving and apparatus for siphon priming, a pump in the pipeline on the back side of the levee, and a shutoff valve. One unit would be spare. The fish screens would have an approach velocity of 0.2 fps and would be about 7 feet in diameter and 15 feet long. They would be cleaned with a brush or air backwash system. These specifications are based on sizing guidance provided by the screen manufacturer, ISI, and are available at ISI's Web site:
http://www.intakescreensinc.com/files/ISIBrushedCylinder.pdf. These have the advantage of easy installation with plenty of other similar installations in the Delta.

However, the disadvantage is that it should have a sweeping flow to take away debris lifted off the screens by brush, air, or back-spray systems. Otherwise, debris could reattach itself to the screens. The number of units required would also be a disadvantage of these screens.

The pipes would be about 42 inches in diameter and would extend up the bank of the levee and through the levee above the 100-year flood level, but below the road. There would be one pump to draw water through each screen for a total of 25 pumps. They would be variable speed pumps to deliver the correct flow over the variable range of heads.

V Screens

The screen structure would be placed in a concrete channel that penetrates the levee. The screened water would be pumped from the downstream end of the channel directly into CCF. The bypass would be pumped, and the pipe would extend north to discharge an appropriate distance from the screen structure intake. If all the flow is through one structure, it would be about 400 feet long and extend into CCF. Each screen panel in the V screen would be between 10 and 15 feet long. The height of the screens would be similar to the on-river flat-panel screens. Multiple V screens could be installed along the length of the West Canal, but this would require multiple bypass pumps and pipe lines.

Biological Factors

The biological benefits and liabilities for this alternative would be the same as described for Alternative 3 except for the V screen option, which may result in greater fish bypass losses and injury risks, and losses from predation at the outfall. The V screen option may require a longer bypass piping system to move the fish to an outfall sufficiently far from the screens. If this were the case, the biological benefit of a V screen system at this site would diminish in comparison to the V screen option for Alternative 3.

Additional predator-management strategies and plans (as outlined for Alternative 3) would also likely be necessary for this alternative.

5.2.5 Alternative 5: Radial Gates through CCF

Screen Technology and Conveyance Method

The Radial Gates site is on the West Canal and spans the existing entrance to the radial gates into CCF (Figure 5-7). This alternative is the only one which does not rely on pumps, instead relying on gravity feed through the radial gates and CCF. It is proposed as the largest flat-panel on-river screen that will fit within the existing bathymetry or a future acceptable bathymetry due to dredging. The other unique characteristic about this alternative is that the screen would not be in place during July-March when diversions to the SWP can exceed 2,000 cfs. To avoid fish impingement during that period (July through March), the fish screens would be pulled out to allow free, unscreened flow to the radial gates.

Preliminary screen sizing for this site indicates that only 1,200 to 1,500 cfs of screened capacity is available within the existing entrance channel to the radial gates. This reduced capacity and the lack of fish protection during the 9 months when the radial gates must pass larger flows makes this alternative less attractive than the alternatives using pumped conveyance.

It would be feasible to enlarge the channel leading to the radial gates to the north if it were determined to be desirable to enlarge the screen capacity to 2,000 cfs. However, this larger screen would suffer from the same difficulty as the 1,500 cfs screen in that it would provide screened flow only in April, May, and June, providing very limited operational benefit.

Biological Factors

This alternative would provide 1,200 to 1,500 cfs of screened water during the April through June period and would eliminate the need to operate the SDFPF during that period and may require a waiver for sweeping velocities and screen exposure time criteria. This alternative cannot provide screened water during July through March, so its biological benefit is diminished compared to all other alternatives. Overall, this alternative would potentially provide only a marginal reduction in predation rates at the SWP.

Additional predator-management strategies and plans (as outlined for Alternatives 3 and 4) would likely be necessary for this alternative.

5.2.6 Alternative 6: Southeast Isolated

Screen Technology and Conveyance Method

Possible sites for fish screens at this location are on the west side of West Canal (Old River) and extend from the south side of the CCF radial gate intake to a point opposite the junction with Grant Line Canal (Figure 5-8, which shows a flat-panel configuration). Similar to Alternative 2B, this alternative would be sited directly on Old River before West Canal diverges, which increases the potential for more sweeping discharge. It also has the advantage of better land access for construction. The screened water would be discharged to a channel isolated inside the southern portion of CCF using sheet-pile walls (similar to the northwest alternatives) or, optionally, in a channel constructed south of CCF and parallel to the southern shore. Both conveyance options would terminate just before SDFPF or just after the SDFPF, north of the railroad line and the Byron Highway. Both configurations isolate the screened water from CCF.

Three types of fish screens can be used at this location (flat-panel screens along the bank line, multiple cylindrical screens, or a V screen), but pumps would be necessary to draw water through the screens and produce enough head to deliver the flow to Banks Pumping Plant at the correct elevation.

The screen structures would be the same as those described for Alternative 4 on the West Canal except that they would discharge to the head of the isolated conveyance channel:

- The flat-panel screens would discharge to a small forebay at the head of the channel as shown on Figure 5-8.
- The cylindrical screens would discharge to a channel paralleling Old River. This channel would join the isolated conveyance.
- A V screen would be built on land adjacent to Old River. The V screen channel would become the head of the isolated conveyance channel. The bypass would be pumped

north across the radial gate structure and discharged back to the river at the north end of West Canal.

It is also the only alternative that offers an isolated conveyance option that completely bypasses the SDFPF. Land ownership and proximity to power lines could complicate the design of this alternative.

Biological Factors

Because the conveyance options for this alternative are completely isolated from CCF, this alternative would likely provide the biological benefit of significantly reduced predation and overall fish loss and injury rates occurring within CCF. In addition, SDFPF operations could be eliminated April through June.

The V screen intake option would have less biological benefit over the flat-panel or cylindrical screen options because it requires a very long pumped fish bypass system. This bypass would require additional investigation and design to minimize or eliminate predation at bypass outfalls.

The flat-panel or cylindrical screen design options may require approval by the resources agencies with a waiver for sweeping velocities and screen exposure times.

5.3 Further Conveyance Considerations

All alternatives except 1 and 5 could be configured with isolated conveyance even though only two of the four are presented as such. As part of the feasibility study, a specific operational and biological study should be conducted to determine the merits of including isolated conveyance. This study should consider the percentage of SWP water delivered thorough the LFI compared to the annual diversion. It should also investigate the consequences of using the LFI and Radial Gates simultaneously. The potential effects and timing of any proposed north Delta diversions and isolated facilities should also be considered.

The key effort for the feasibility study will be a detailed site-specific river hydraulics study coupled with detailed operations and biology studies. Operations studies would be site-specific, but biological studies would be common to all alternatives.

The key recommendations for additional data needs presented in Section 7 should be implemented as part of the feasibility study.

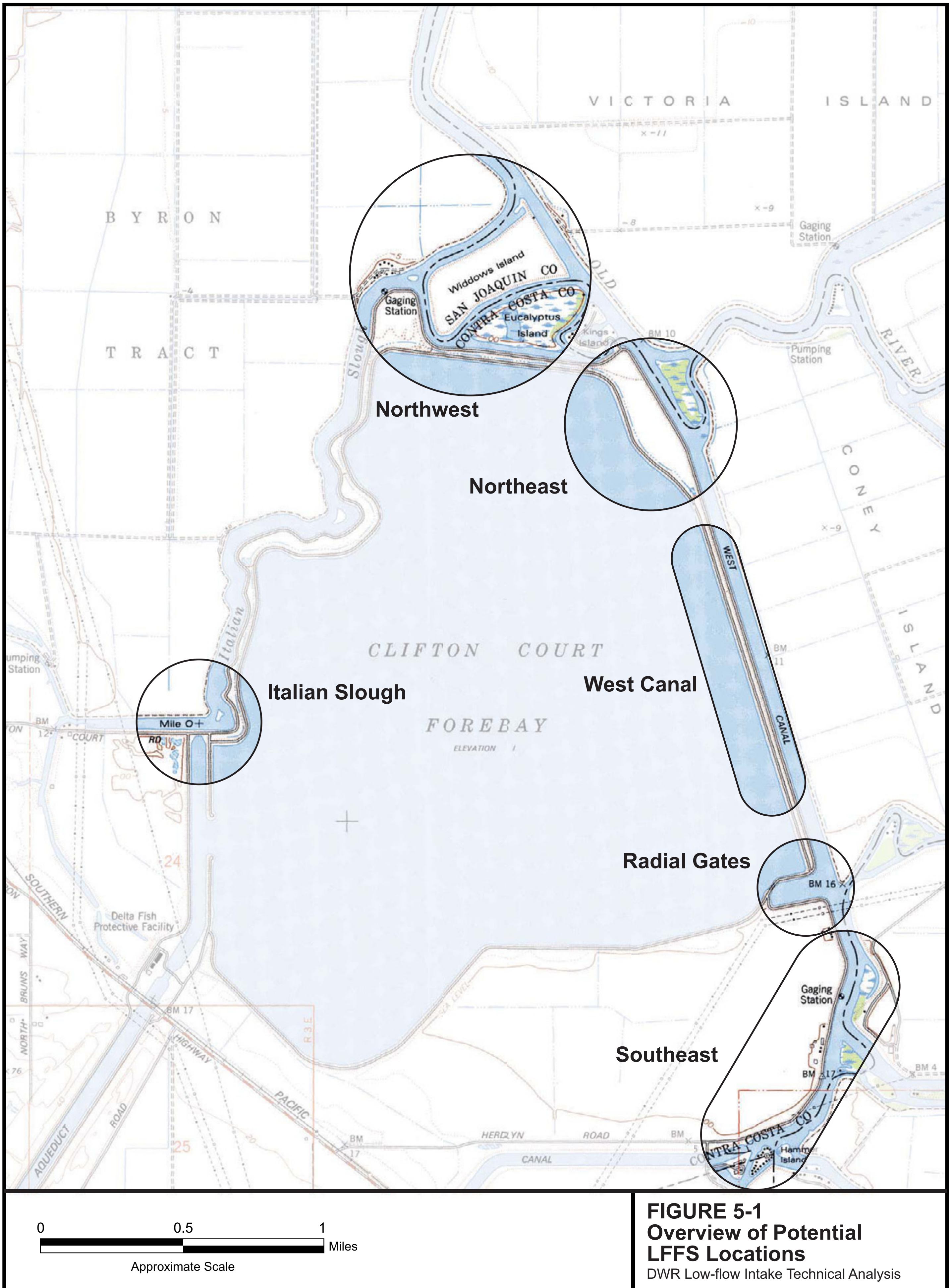

FIGURE 5-1
Overview of Potential LFFS Locations

DWR Low-flow Intake Technical Analysis

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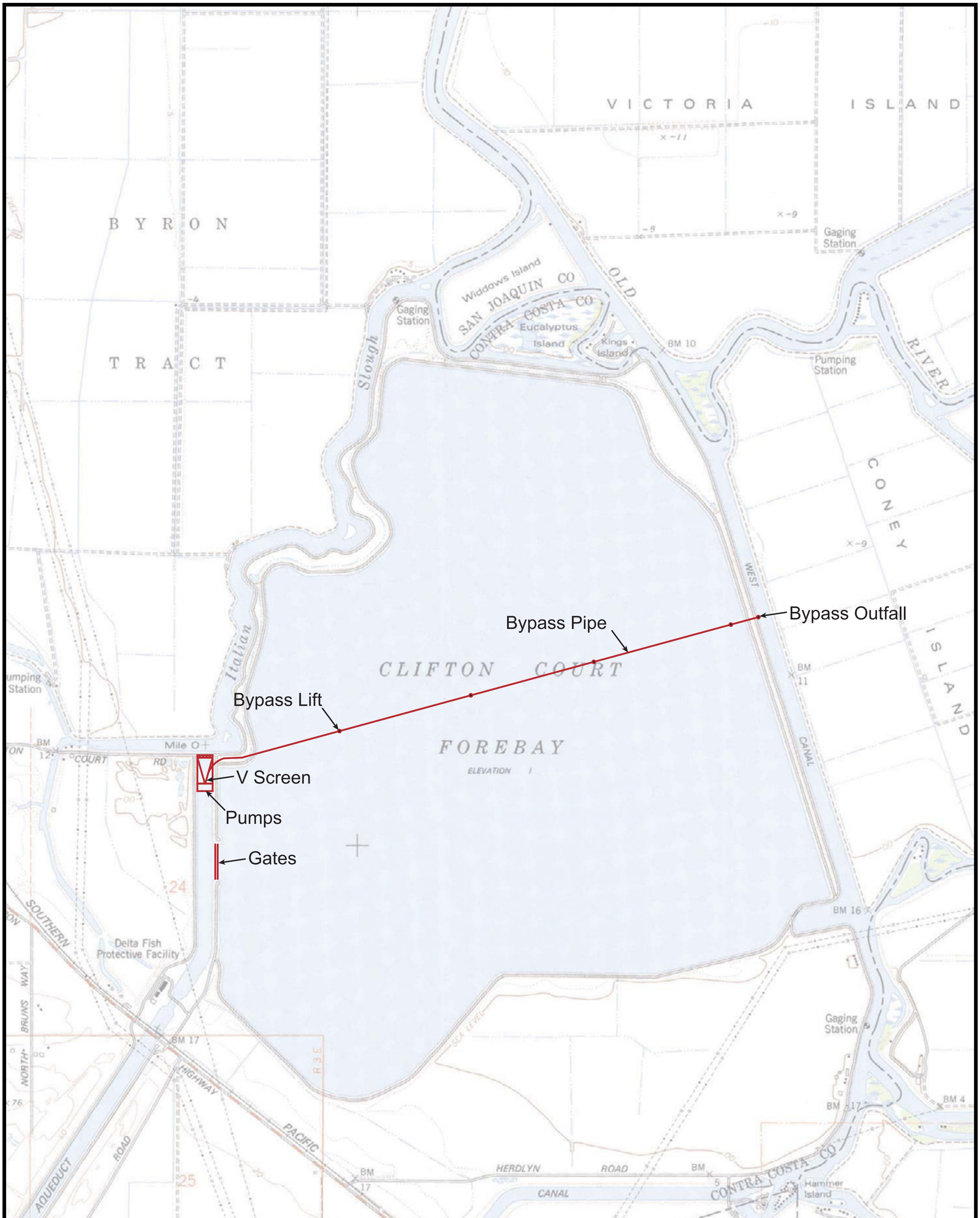

FIGURE 5-2
Alternative 1: Italian Slough Isolated
DWR Low-flow Intake Technical Analysis

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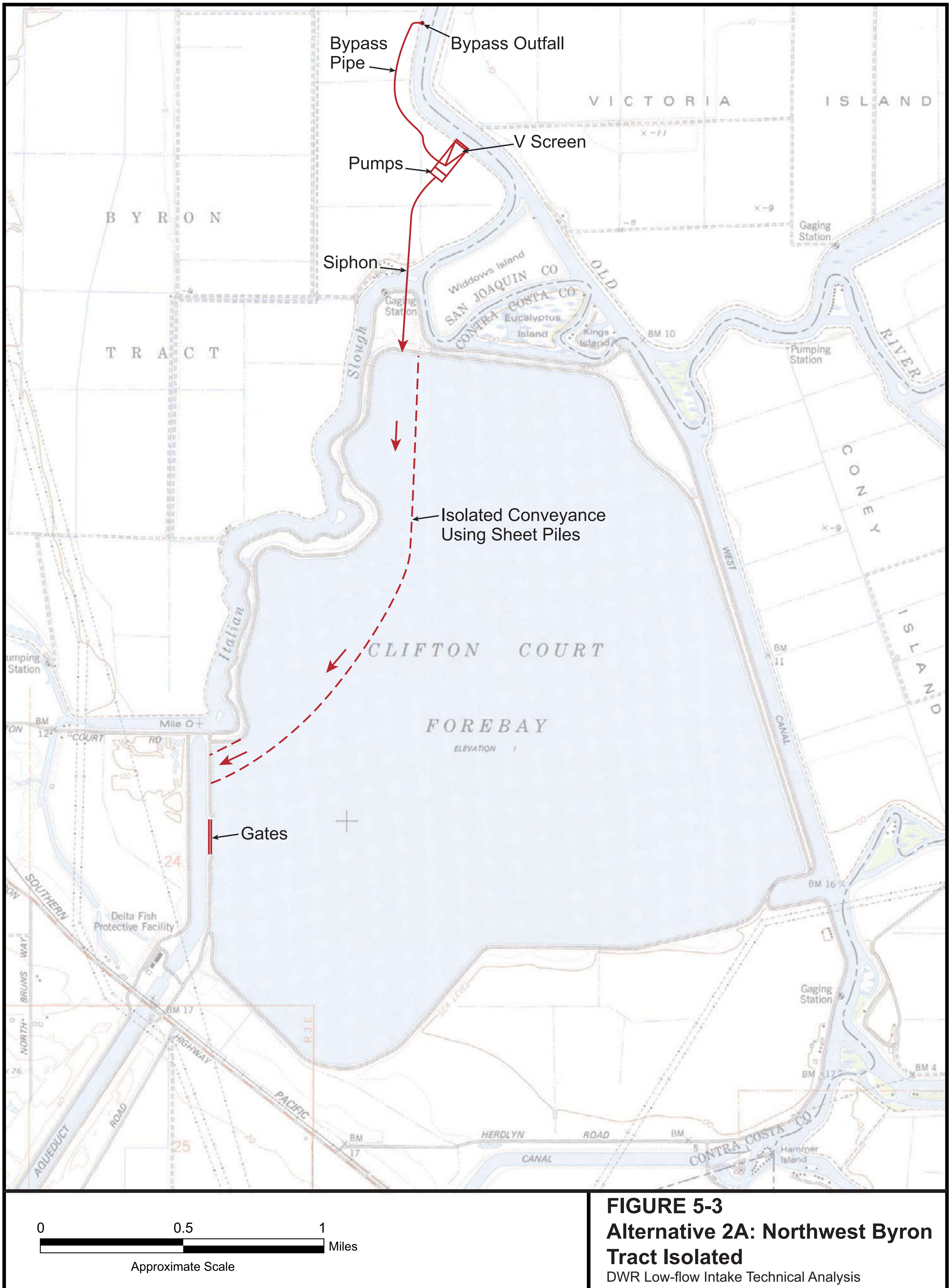

FIGURE 5-3
Alternative 2A: Northwest Byron Tract Isolated

DWR Low-flow Intake Technical Analysis

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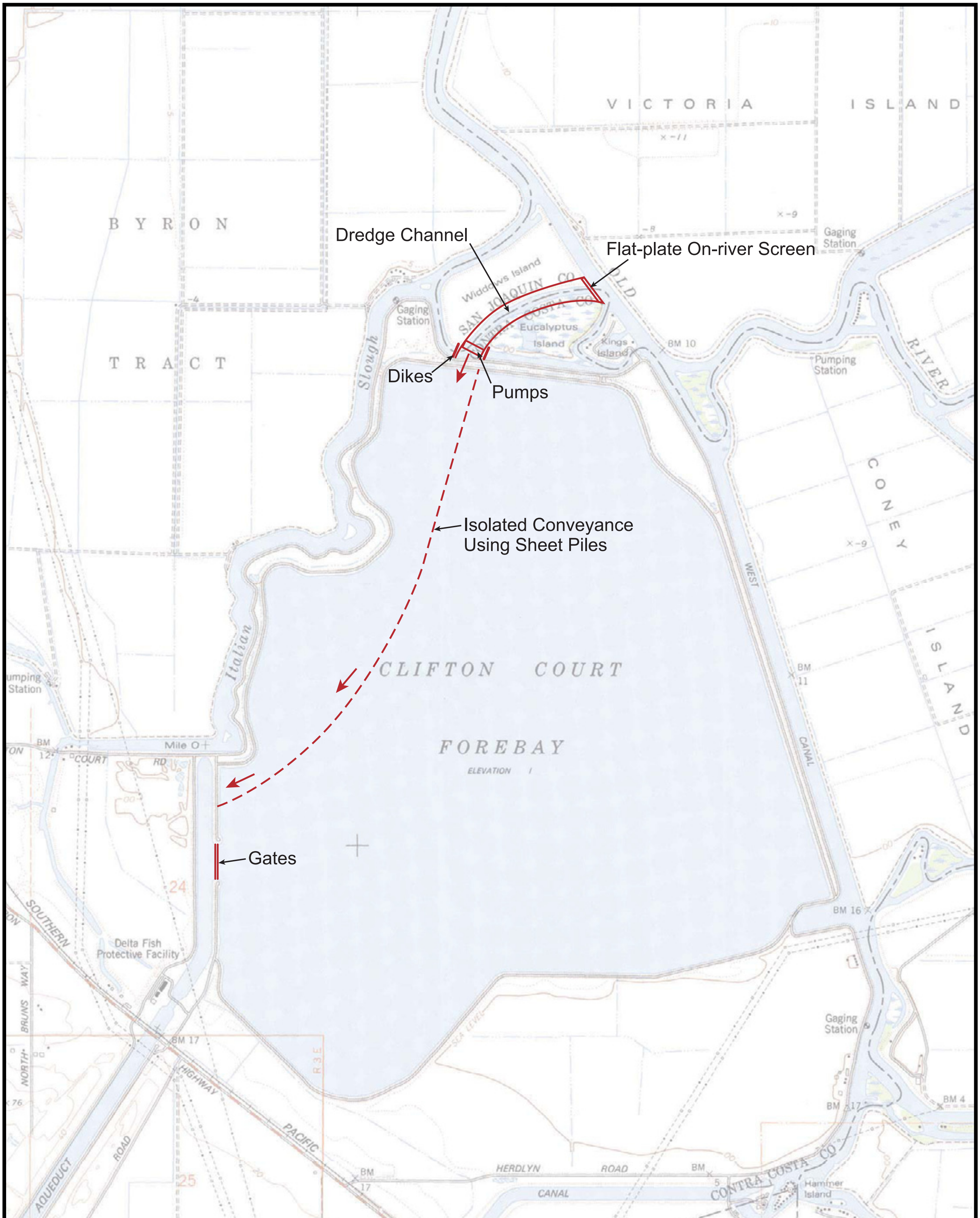

FIGURE 5-4
Alternative 2B: Northwest Widdows Island Isolated
DWR Low-flow Intake Technical Analysis

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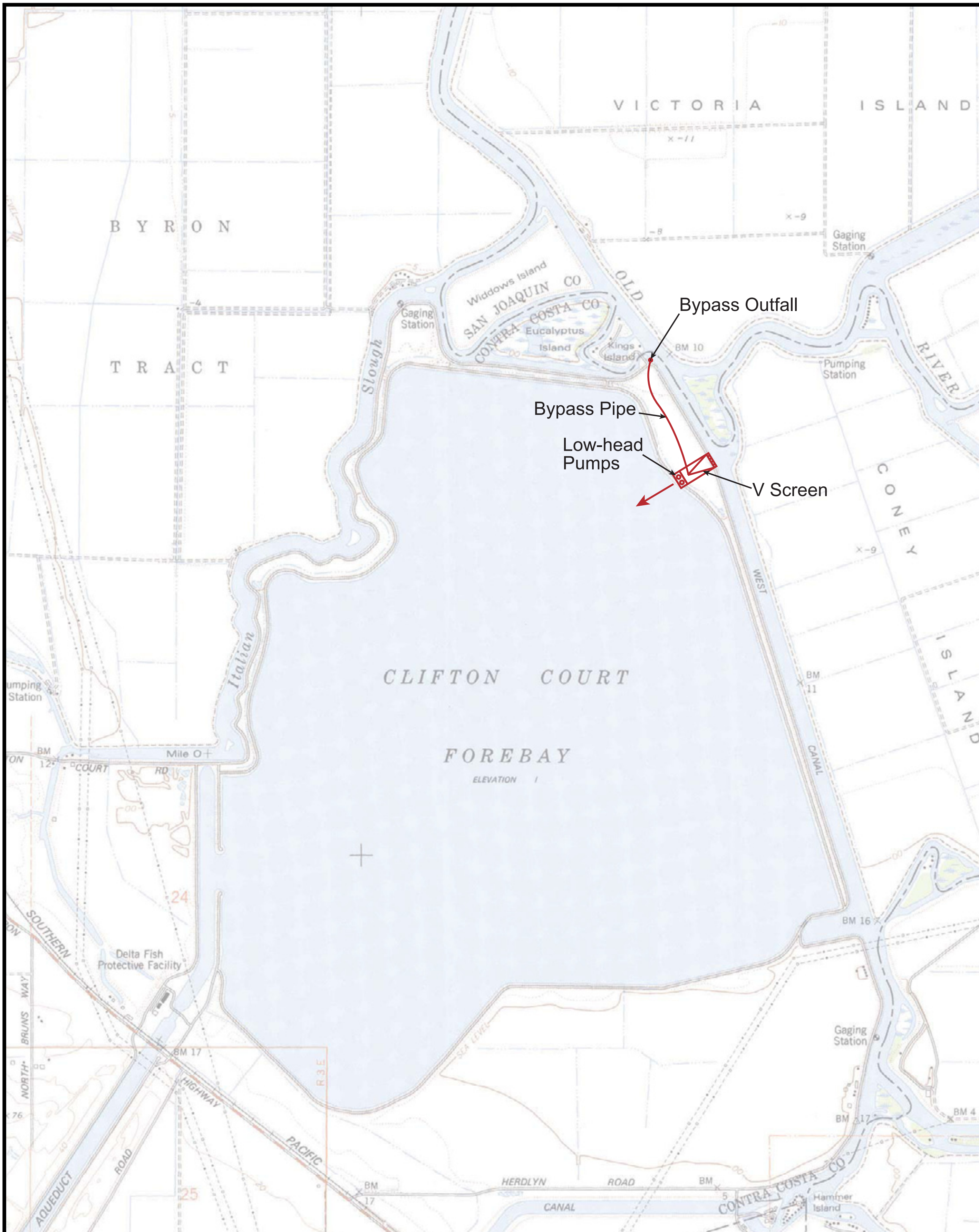

0 0.5 1 Miles

Approximate Scale

FIGURE 5-5
Alternative 3: Northeast through CCF

DWR Low-flow Intake Technical Analysis

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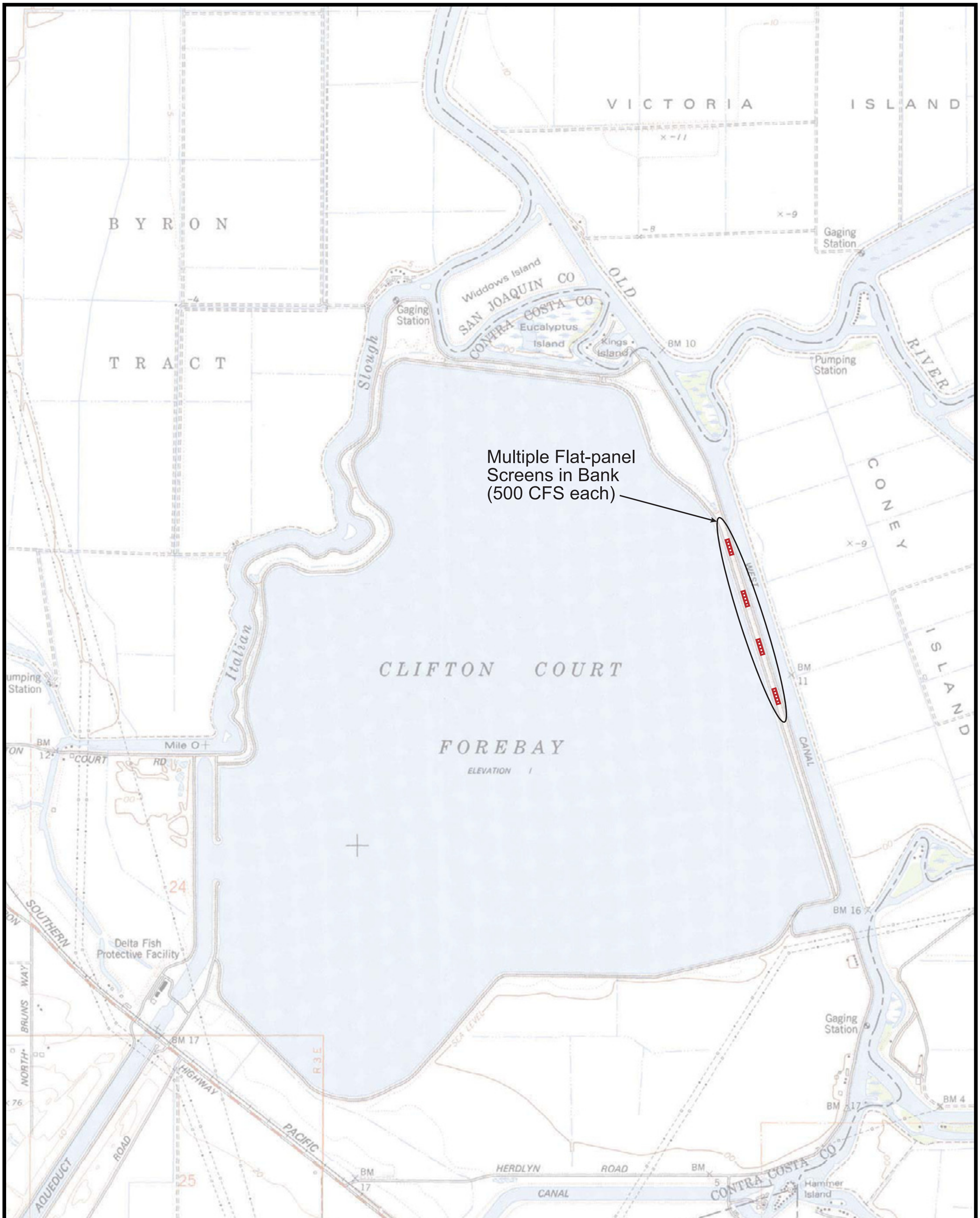

0 0.5 1 Miles

Approximate Scale

FIGURE 5-6
Alternative 4: West Canal through CCF
DWR Low-flow Intake Technical Analysis

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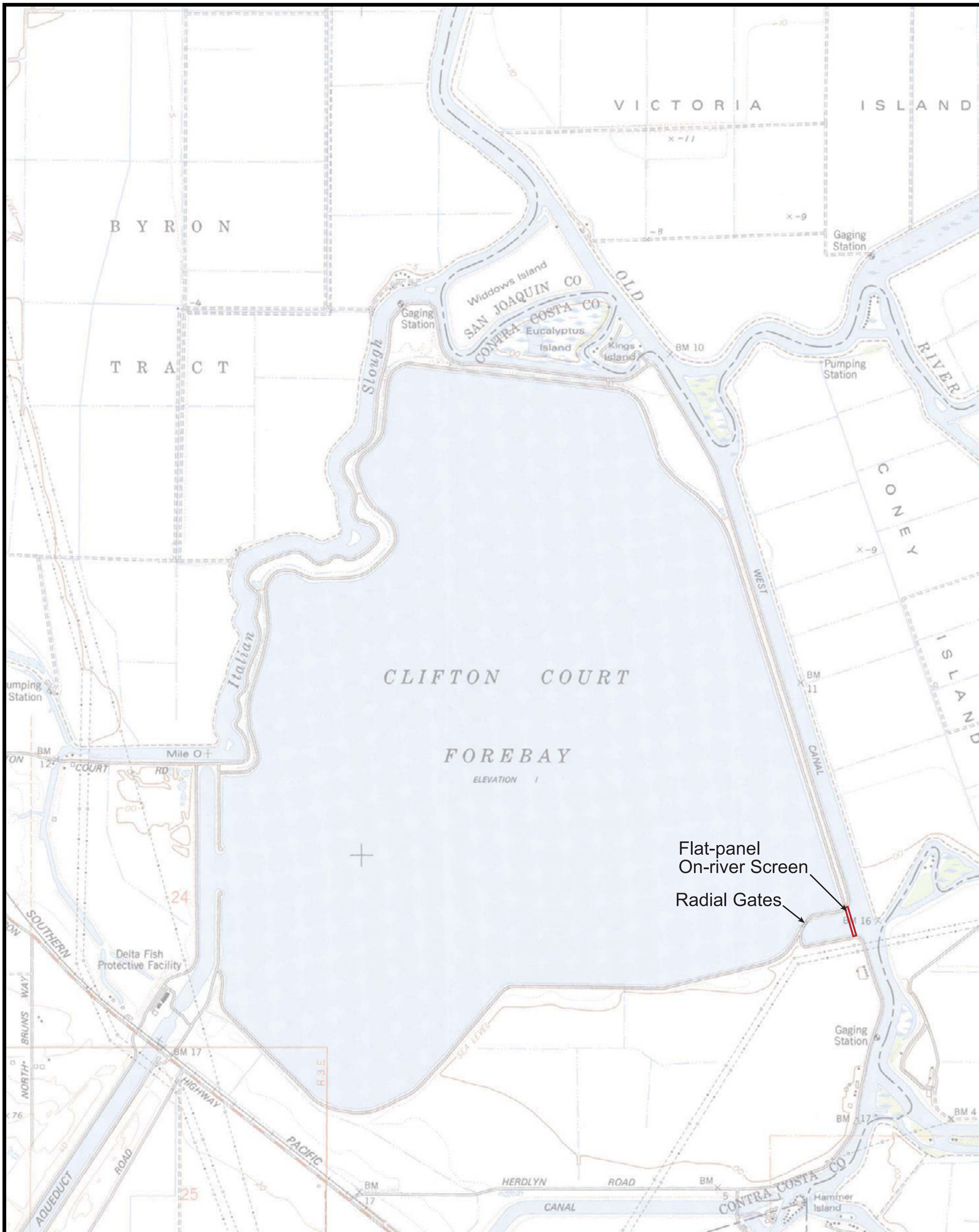

0 0.5 1 Miles

Approximate Scale

FIGURE 5-7
Alternative 5: Radial Gates through CCF
DWR Low-flow Intake Technical Analysis

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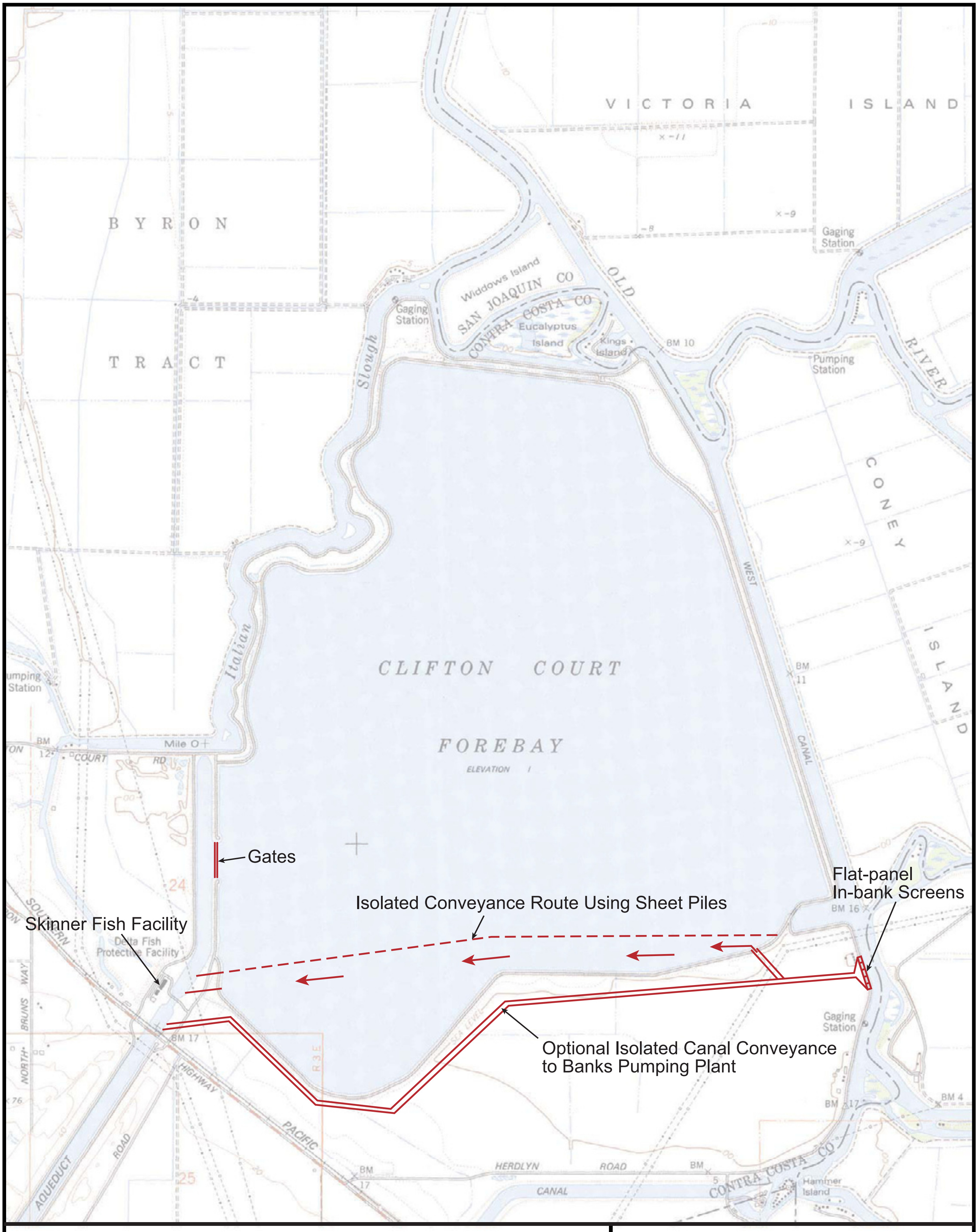

FIGURE 5-8
Alternative 6: Southeast Isolated
DWR Low-flow Intake Technical Analysis

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SECTION 6

Conceptual Construction Cost Estimates

For purposes of this Technical Analysis, conceptual construction cost estimates are provided solely for relative comparison of the proposed alternatives. These estimates should not be compared to any other options not included in this Technical Analysis. In addition, these conceptual construction-cost estimates do not include costs of planning, design, environmental impact analysis, permits, mitigation, land acquisition, construction management, administration, and operation.

At this level of study, the use of construction-cost data from other similar screened water intake projects seemed to be appropriate. For example, unit costs (costs per cfs) for fish screens or a pump station in this LFI Technical Analysis were based on construction costs for the CCWD Los Vaqueros diversion and the Banta Carbona diversion. These projects are located very near to CCF and have similar conditions and features. Unit costs (cost per foot) for conveyance facilities in this LFI Technical Analysis were based on construction costs for the proposed Red Bluff diversion project. For large gate structures needed for the CCF isolated schemes, size and cost data from the DWR Grant Line Canal project were used. The following section describes the general approach for using the known construction costs from similar projects, escalating them to 2009 dollars, and dividing by the flow or length depending on the parameter used.

6.1 Basis for Conceptual Construction Cost Estimates

The basis for estimating the key components of the alternatives are as follows:

- The Banta Carbona facility on the San Joaquin River at Banta Carbona Irrigation District, about 7 miles southeast of CCF, has a 250-cfs capacity, a similar approach velocity of 0.2 fps, is designed to resist a flood at about 25 feet above the low-water level, and includes features that will be necessary to incorporate into any V screen facility at CCF. It is founded on piles and has a brush screen cleaner, a sediment resuspension system, and a 2,000-foot-long pumped fish bypass. The Banta Carbona V screen facility was constructed in 2002 and had a construction cost of about $10,000,000. For estimating purposes, the cost was escalated from August 2002 to February 2009, and it was assumed that an economy of scale and designing for a lower flood level is offset by the more difficult dewatering and greater excavation required near CCF. The construction cost of the screening facility at present day value is estimated to be $45,000 per cfs. This cost does not include a pump station.
- The CCWD Los Vaqueros diversion screen and pump station is located on Old River about 10 miles northwest of CCF. The fish screens are flat-plate wedge wire inclined at about 20 degrees from vertical. It has a brush screen cleaner that lifts debris up onto a deck for offsite removal. A pump station behind the fish screen and intake structure pumps water westward to the Los Vaqueros Reservoir. The Los Vaqueros project has a

flow capacity of 250 cfs and an approach velocity of about 0.2 fps. The project was built in 1994, so the costs were escalated from August 1994 to February 2009. In 1994, the construction costs were approximately $38,700 per cfs for the intake and screens, and approximately $43,400 per cfs for the pump station. In 2009 dollars, the scaled estimated construction cost of the intake would be approximately $50,000 per cfs, and the pump station would be approximately $56,000 per cfs, including a power line and substation.

- Conveyance costs were based on the proposed 2,500-cfs diversion at Red Bluff, which uses a cast-in-place box siphon and sheet-pile forebay wall. This project is at the 60 to 90 percent design level and includes extensive sheet-pile work and a 2,000-foot-long triple-box siphon. The estimated cost for the siphon at the Red Bluff project is $54 million, or approximately $27,000 per foot. The estimated cost for the 1,200-foot-long sheet-pile wall is $6 million, or approximately $5,000 per foot.
- Gates necessary for closing the existing opening between CCF and SDFPF for the isolated conveyance alternatives were based on estimated costs for a gate proposed in Grant Line Canal as part of the South Delta Improvement Program. Cost estimates developed for 90 percent design of the gate structure is in the order of $22.9 million (2009 dollars). The proposed gate is 228 feet in width and 20 feet of submerged water depth. The unit cost of the gate is about $5,000 per square foot.

The cost assumptions for each alternative follow, and a summary table at the end of this section provides a comparison of conceptual construction cost estimates across all the alternatives by key component and overall conceptual construction cost.

6.2 Alternative 1: Italian Slough Isolated with V Screens

This installation would be similar in layout and facilities to the fish screen installation on the Banta Carbona facility. Based on the unit costs for that facility, the conceptual cost estimate for the V screen on Italian Slough would be $90 million. A pumped fish bypass would extend across CCF to discharge into West Canal. This bypass would require an additional 9,000 feet of 36-inch-diameter bypass pipe to convey the fish all the way to West Canal. This extra length will also require additional pump lifts. To account for the cost of this additional distance, $10 million was added to the cost derived from the Banta Carbona project, resulting in a conceptual cost estimate for the screening facility of $100 million. In addition, this V screen design would include a pump station to draw flow through the screen. A pump station unit cost was assumed to be the same as that at the CCWD Old River intake. Based on the unit costs for that facility, the conceptual cost estimate for a pump station would be $112 million. A gate structure where flows from CCF enter the channel leading to SDFPF would be needed to isolate flows from the proposed intake. Based on the unit costs for the Grant Line Canal facility and a gate sized at 20 feet deep and 100 feet wide, the conceptual cost estimate for the gate structure would be $10 million. Therefore, the overall conceptual construction cost estimate for this alternative would be $222 million.

6.3 Alternatives 2A: Northwest Byron Tract Isolated

This installation would be similar in layout and facilities to the fish screen installation on the Banta Carbona facility. Based on the unit costs for that facility, the conceptual cost estimate

for the V screen on Italian Slough would be $90 million. No additional costs were included for the fish bypass. Similar to Alternative 1, this alternative would include a pump station to draw flow through the screen. Based on the unit costs for the pump station component of the CCWD Old River intake, the conceptual cost estimate for a pump station would be $112 million. Additional costs include a siphon, conveyance via sheet-pile-wall channel across CCF, and the cost for a gate structure where flows from CCF enter the channel leading to SDFPF. Based on the unit costs for a siphon and sheet-pile barrier of the proposed Red Bluff project, the conceptual cost estimate for these elements of conveyance would be $126 million. Based on the unit costs for the Grant Line Canal facility, the conceptual cost estimate for the gate structure would be $10 million. Therefore, the overall conceptual construction cost estimate for this alternative would be $338 million.

6.4 Alternatives 2B: Northwest Widdows Island Isolated

This alternative uses an inclined flat-panel screen across the channel between Widdows and Eucalyptus islands. This installation would be similar in layout and facilities to the fish screen installation on the CCWD Old River intake. Based on the unit costs for that facility, the conceptual cost estimate for the flat-panel screen would be $100 million. The channel leading to the CCF levee would have to be dredged and the levees raised. A pump station would be required at the CCF levee to lift the screened water into CCF. Based on the unit costs for the pump station component of the CCWD Old River intake, the conceptual cost estimate for a pump station would be $112 million. Additional costs include a siphon, conveyance via sheet-pile-wall channel across CCF, and the cost for a gate structure where flows from CCF enter the channel leading to SDFPF. The conveyance cost for this alternative is assumed to be $10 million less than Alternative 2A. Therefore, the overall conceptual construction cost estimate for this alternative would be $338 million.

6.5 Alternative 3: Northeast through CCF

This installation would be similar in layout and facilities to the fish screen installation on the Banta Carbona facility. Estimated cost for this alternative is escalated and scaled-up from the Banta Carbona facility, because all of the components are similar, including the fish bypass, low-head pumps, and no isolated conveyance. Based on the unit costs for that facility, the conceptual cost estimate for the V screen on Italian Slough would be $90 million. Similar to other alternatives, this alternative would include a pump station to draw flow through the screen. Based on the unit costs for the pump station component of the CCWD Old River intake, the conceptual cost estimate for a pump station would be $112 million. No additional components were needed to isolate conveyance. Therefore, the overall conceptual construction cost estimate for this alternative would be $202 million.

6.6 Alternative 4: West Canal through CCF

This alternative uses an inclined flat-panel screen between West Canal and CCF. This installation would be similar in layout and facilities to the fish screen installation on the CCWD Old River intake. Based on the unit costs for that facility, the conceptual cost estimate for the flat-panel screen would be $100 million. In addition, this alternative would include a pump station to draw flow through the screen. A pump station cost was assumed to be the same as that at the CCWD Old River intake. Based on the unit costs for that facility, the conceptual cost estimate for a pump station would be $112 million. No additional components were needed to isolate conveyance. Therefore, the overall conceptual construction cost estimate for this alternative would be $212 million.

6.7 Alternative 5: Radial Gates through CCF

This alternative uses an inclined flat-panel screen at the radial gate intake to CCF. Conceptual cost estimates for this alternative are based on CCWD Old River intake costs for the flat-panel screens and no pump station. Based on the unit costs for that facility, the conceptual cost estimate for the 1,500 cfs flat-panel screen would be $75 million. However, no additional components are needed to pump water or isolate conveyance. Although this alternative yielded the lowest cost of all the alternatives, it does not have the potential to provide year-round fish-protection benefits similar to the others, because the screens must be raised out when high-flow radial gate operations are needed.

It may be possible to increase the capacity through the gates to provide up to 2,000 cfs of screened flow as discussed in Section 5. The effort to develop a cost estimate for a 2,000 cfs LFI should be pursued in subsequent investigations. For this report, the conceptual construction cost estimate for this alternative is based on 1,500 cfs and would be $75 million.

6.8 Alternative 6: Southeast Isolated

This installation would be similar in layout and facilities to the fish screen installation on the CCWD Old River intake. Based on the unit costs for that facility, the conceptual cost estimate for the flat-panel screen would be $100 million. A pump station would be required to lift the screened water into the isolated conveyance or into CCF. Based on the unit costs for the pump station component of the CCWD Old River intake, the conceptual cost estimate for a pump station would be $112 million. Additional costs include conveyance via a sheet-pile-wall channel across CCF, and the cost for a gate structure where flows from CCF enter the channel leading to SDFPF. For this alternative, cost is provided for the sheet-pile channel conveyance through CCF rather than the canal conveyance to a point downstream of SDFPF. Both options should be investigated at the feasibility level, but the canal option will be much more consumptive of hydraulic head. The conceptual conveyance costs include a 2,000-foot box siphon to convey water to the isolated channel inside CCF, a 10,600-foot sheet-pile wall in CCF, and a $10 million gate structure. The overall conceptual construction cost estimate for this alternative would be $329 million.

6.9 Summary of Conceptual Construction Cost Estimates

Table 6-1 presents a summary of the conceptual construction cost estimates for each alternative based on similar projects, escalated to 2009 dollars. As noted above, these conceptual estimates do not include planning, design, environmental impact analysis, permits, mitigation, land acquisition, construction management, administration, and operational costs. In addition, due to the conceptual nature of the estimates, they should not be compared to any other options not included in this LFI Technical Analysis.

TABLE 6-1
Project Construction Cost Estimates by Alternative
Low-flow Intake Technical Analysis

	Cost ($ Million)[a]			
Alternative	**Screens**	**Pump Station**	**Conveyance/Gates**	**Total**
Alternative 1: Italian Slough Isolated	$100	$112	$10	$222
Alternative 2A: Northwest Byron Tract Isolated	$90	$112	$136	$338
Alternative 2B: Northwest Widdows Island Isolated	$100	$112	$126	$338
Alternative 3: Northeast through CCF	$90	$112	$0	$202
Alternative 4: West Canal through CCF	$100	$112	$0	$212
Alternative 5: Radial Gates through CCF[b]	$75	$0	$0	$75
Alternative 6: Southeast Isolated	$100	$112	$117	$329

[a] February 2009 dollars

[b] Based on 1,500-cfs screened capacity

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SECTION 7

Additional Data Needs

Additional data needs required to conduct a feasibility-level study of the recommend sites for the LFI are identified in the following discussion. Emphasis is given to special studies or data collection activities considered additional to the normal DWR requirements for the feasibility-level study. A good example is the same level of investigation recently completed by DWR for the feasibility study of the Franks Tract alternatives. Likewise, many of the prerequisite studies and data collection requirements documented in the *Fish Passage Criteria and Guidance Report* previously submitted under this task order in November 2008 are not repeated here, but should be considered. Guidance is contained in Sections 5 and 6.

Four potential data needs were identified by DWR in the scope of work for this technical analysis; these are discussed first, and then several additional items are presented.

7.1 River Hydrology and Hydraulic Modeling

The hydrologic and hydraulic modeling for this project is very complex, especially considering the influence of diversions on historic south Delta flows and the potential impact of BDCP dual-conveyance options now under consideration.

Since the stage frequency curves for design are more than likely driven by tidal fluctuations, the actual discharge may not make significant difference to the screen setting. However, developing an accurate simulation of the discharges and more importantly the velocities at least for a few "typical design days" would be most valuable in discerning the subtle differences between the sites, especially when considering the LFI sites relative to the SWP and CVP intake hydrodynamics. This velocity data would also help inform the siting of bypass outfalls (if used). Some DSM2 model runs should be made with the operation of the screen alternatives inserted. This will indicate how LFI operation will affect the south Delta and CCF.

Screen alternative model runs using the Particle Tracking Model (PTM) should also be conducted to evaluate the effects of a low-flow intake on south Delta hydrodynamics and fish distribution and mortality. The PTM simulates the transport and fate of individual "particles" traveling throughout the Sacramento-San Joaquin Delta. The model uses velocity, flow, and depth output from DSM2 model results to simulate the movement of particles through a network of channel segments under the influence of flows and random mixing effects. With the ability to control parameters such as particle movement, settling velocity, and mortality over time, the PTM has been used to simulate the transport and fate of striped bass eggs and larvae.

7.2 Geotechnical Analysis

This data collection and analysis task should be conducted similarly to the recent drilling and geophysics work performed recently for the Franks Tract feasibility studies. The main purpose is to determine the foundation and dewatering conditions so that adequate allowance can be made in the cost estimates. This analysis should also identify any fatal flaws from a geotechnical perspective at the selected sites. Clifton Court Forebay is a jurisdictional dam. Any alterations to the forebay would have to be approved by Division of Safety of Dams, DWR. Also, the jurisdictional facilities would have to be upgraded to current hydrological and seismic standards.

7.3 Bathymetry Data

The bathymetric data should be sufficient to provide input to both the hydraulic modeling and the screen design. It should of course be on the proper vertical and horizontal datum and be in a digital terrain model format. An expert in this field should do a detailed review of the existing data and collaborate with the hydraulic modelers and design engineers to develop a program to obtain the required data. In addition to the river side of the project sites, current bathymetry data on the CCF side should also be collected. Shawn Mayr of DWR noted that the Resource Assessment Branch could respond to requests for obtaining additional bathymetric data and that such data is not difficult to obtain.

7.4 Evaluate and Recommend Operating Criteria

This is probably the most important data need and study to be conducted during the feasibility study. The essence of the task was captured best in DWR's original scope of work as follows:

> *It will be required to have a detailed review of the current Forebay radial gate and Banks Pumping Plant operations. It will be necessary to have consultation with DWR staff to evaluate possible scenarios to operate the new intake(s), and recommend a range of operating criteria with fish screening requirements that are important to the protection and reduction of stressors for species of concern. Facility operating criteria and constraints will be used as inputs in the model mentioned above under hydrologic modeling.*

We would recommend that DWR update the mass balance spreadsheet model of CCF and Banks developed in 2001 to assess the potential operational changes suggested by the LFI alternatives. This will require careful analysis of both the seasonal and year-round uses of the LFI. This analysis, coupled with a detailed assessment of the potential for predation management schemes for CCF, may provide the guidance for choosing the type of conveyance from the LFI to the Banks Pumping Plant.

7.5 Topographic and Property Surveys

In addition to the bathymetric surveys mentioned previously, detailed topographic surveys will be required. These surveys need to be linked to the established vertical datum and horizontal coordinate system for the existing structures and all river gages and stage data. Our preliminary look at available stage data indicates as much as 3 feet of difference in the data between different sources. Property and utility surveys should also be developed and incorporated into the project base mapping in accordance with DWR standard procedures.

7.6 Environmental Screening

The appropriate level of environmental screening should be performed at each of the selected LFI sites to ensure that there are no fatal flaws related to environmental considerations.

7.7 Predation-control Methodologies

Acceptable methods to reduce predation should be specifically investigated both in CCF and at the proposed LFI structures and bypass outfalls as this relates to operational changes made possible by the LFI. Best practices at other sites should be considered.

7.8 Resources Agency Coordination

Coordination with appropriate resource agencies as required for any in-Delta project should be implemented in a manner consistent with a feasibility-level analysis.

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SECTION 8

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Appendix A
CCF Screening Studies and Initiatives Provided by DWR

APPENDIX A

CCF Screening Studies and Initiatives Provided by DWR

A collection of electronic files related to previous CCF screening studies and initiatives were provided by DWR. Each file was reviewed, and its contents are summarized in Table A-1. In general, the files included conceptual schematics of screen alternatives, cost estimates, project schedules, fish loss modeling results, memoranda, and meeting presentations and materials potentially applicable to the LFI Technical Analysis.

TABLE A-1
Previous CCF Fish Screen and Intake Planning Efforts Data Inventory
Low-flow Intake Technical Analysis

Title	Prepared by and Date	Brief Description
1st Stage 2D Scheme-Fish Gravity Bypass	DWR DOE, 4/4/2002	Draft Plan layout and cost estimate. Draft Option 3: Fish Salvage Facility Plan with Leaky Louver. Gravity bypasses (4 pp).
1st Stage 2D Scheme-Fish Lift Bypass (Spread Sheets)	DWR DOE, 1/1/2002	Itemized cost estimates for 1st Stage 2D Scheme with (1) fish lift bypass and (2) gravity bypass (unit prices, quantities, total, and contingencies) (6 pp).
1st Stage 2D Scheme-Fish Lift Bypass 4	DWR DOE, 4/4/2002	Draft Plan layout and cost estimate. Draft Option 2: Fish Salvage Facility Plan with Leaky Louver. Fish lift bypasses (4 pp).
Airphotos of CCF Alternatives	Preparer and date unknown	Aerial photos with Northeast and Northwest Intake alignments (3 pp).
Alternatives Development: Practicability of New Screened Intake Locations	Preparer and date unknown	Chapter discussion of multiple screened intake alternative locations and configurations (5 pp).
Assumptions For Option 2-Salmon Criteria CCF Module 1	Preparer unknown, 2/22/2002	Biology modeling assumptions and results. Assumptions for Option 2–Salmon Criteria CCF Module 1. Includes fish mitigation, yield, pumping cost, and water curtailment analysis (3 pp).
CCF Fish Facilities Workshop Prospectus	Preparer and date unknown	Detailed workshop notes for workshop intended to start process of design concepts for CCFFF project alternatives (15 pp).
CCF Intake and Fish Facilities Alternative Construction Cost Estimate and Schedule	Preparer unknown, 1/2003	Northwest Installation Site and Short Circuit Alternative construction cost estimates and 9/20/2002 CCFI and Fish Facility Schedule (2 pp)
CCF Intake and Fish Facility project Alternative 1, 2 and 2A cost estimates (Spread Sheets)	Preparer unknown, 6/2002	CCF Intake and Fish Facility Project cost estimate for three alternatives for the period 2002–2010 (3 pp).

TABLE A-1
Previous CCF Fish Screen and Intake Planning Efforts Data Inventory
Low-flow Intake Technical Analysis

Title	Prepared by and Date	Brief Description
CCF Intake and Fish Facility Project Alternatives 1, 2, 2A (Spread Sheets)	Preparer unknown, 5/2/2002	CCF Intake and Fish Facility Project cost estimate for three alternatives for 2001–2010 (3 pp).
CCF Intake and Fish Facility project Module 1 planning Final Design and Construction (Spread sheet)	Preparer unknown, 12/2001	CCF Intake and Fish Facility Project cost estimate for three alternatives for 2001–2010 (1 pp).
CCF Intake and Fish Facility Project-Alternative 1 prototype Facility (Spread Sheets)	Preparer unknown, 4/4/2002	Cost estimate for planning, final design and construction of three CCFFF Module 1 alternatives for 2001–2010 (3 pp).
CCF Intake Data Collection Budget Estimate (Spread Sheets)	DWR DOE, 11/13/2001	CCF Intake bathymetry and channel survey data collection cost estimate. Includes proposed bathymetry survey locations and some equipment (3 pp).
CCF Intake Preliminary Intake Operation Modeling	Preparer unknown, 11/15/2001	Agenda for the CCF IFFPT meeting. CCF Intake Preliminary Intake Operations Modeling Presentation, which describes design issues. CCFBI Project coordination meeting (10/2001). Minutes of 11/2001 CCFIT meeting (21 pp total).
CCF Piping Schematics	Preparer and date unknown	Piping schematics for the existing Skinner Fish Screen Facility and a conceptual new fish screen facility (2 pp).
CCF Short-Circuit Alternative	Preparer and date unknown	CCF diagrams (3 pp): 1. CCF short-circuit alternative. 2. Positive barrier fish screen with LH pumps no salvaging. 3. Proposed intake site.
CCFIT Draft Meeting Notes	DWR, 10/10/2001	10/10/2001 meeting minutes (discussed project alternatives document, numerical/physical modeling direction, operating criteria progress, design status) (5 pp). 1/2001 proposed CCF Intake presentation (34 pp).
CCFIT Draft Meeting Notes	DWR, 6/28/2001	CCFIT meeting minutes (preliminary organization of CCFIT, discuss general intake concepts, operational issues, coordinate data needs, channel velocities) (14 pp).
Combined Efficiency Of New CCF1 and Old Intake At Banks PPT	Preparer unknown, 3/2002	Combined efficiency of New CCF1 and Old Intake at Banks monthly efficiency plot and table time series; tabular fish saved and fish loss time series from 1994–2003, and totals over period modeled (4 pp).
Conceptual DDC Schematic	Preparer and date unknown	Conceptual schematic for fish screens, pump station, fish pumps and conveyance facility. DCC schematic (1 p).
CVFF Review Team Draft Agenda and Spread Sheet Analysis of Fish Losses	DWR and Dan Odenweller, 2/28/2002	Central Valley Fish Facilities Review Team meeting (agenda, PowerPoint slides). Spreadsheet analysis by D. Odenweller of benefits of CCF Module 1.

TABLE A-1
Previous CCF Fish Screen and Intake Planning Efforts Data Inventory
Low-flow Intake Technical Analysis

Title	Prepared by and Date	Brief Description
Delta Fish Protection Facility Phase II Site plan	DWR DOE, date unknown	Site plan of Delta Fish Protection Facility Phase 2 (Skinner fish protection facilities) (1 p).
Design Considerations Used in Development of the CALFED South Delta Fish Facility Program	Dan Odenweller, NMFS, date unknown	Fish Screening Design Considerations used in the Development of CALFED South Delta Fish Facilities Program presentation slides. Includes agency design criteria for TFTF planning assumptions and NOAA and CDFG criteria (6 pp).
Draft CCF NW Intake Study For Preliminary Operating Criteria	DWR DOE, 9/7/2001	CCF NW Intake Study for Preliminary Operating Criteria (2001). Determines preliminary design parameters and operations criteria and assumption for the new intake at CCF (6 pp).
Draft Objectives of TFTF and Alternatives	Preparer unknown, 6/11/2002	Table of objectives of Tracy Fish Test Facility, alternatives to TFTF, and comments. TFTF and CCF intake and screen schedule options. South Delta Fish Facilities schedule (3 pp total).
DWR Comments and Recommendations on Fish Facilities Development	DWR, 10/30/2003	DWR comments/recommendations on Fish Facility Development memo for consideration by the South Delta Fish Facility Forum (2 pp).
ESO Fish Facility Clifton Court Research proposal Estimate for FY 2002/2003	Preparer and date unknown	ESO Fish Facilities CC research proposal estimate for FY 2002–2003 to estimate the minimum effort for DWR to continue evaluating technologies for a new intake at CC (2 pp).
Fish Efficiencies and Comparison of Exist Fish Facility and CCF Module I	Preparer unknown, 3/7/2002	Fish loss modeling results. General assumptions and graphs of existing and CCF Module 1 efficiencies (12 pp).
Fish Facility Design Criteria	CCFFFTAT, 7/2002	Fish facility design criteria table showing facility components and corresponding justification (5 pp).
Fish Screening and Fish Passage Analysis of the CALFED Bay-Delta Program Phase II Delta Conveyance Alternatives.	Darryl Hayes and Dan Odenweller, 7/28/1997	Fish Screening and Fish Passage Analysis Committee Status report, which provides recommendations on CALFED fish facilities planning. Contains a schematic of CCF (29 pp).
Historical Daily and Monthly Banks Pumping Rates from October to May	Preparer unknown, 3/7/2002	One-page graphic of Historical Daily and Monthly Banks Pumping Rates for each of the water years, 1993–2001 (9 pp).
Incremental Cost Of Intermediate Bypasses on CCF Module 1	Preparer unknown, 1/9/2002	Incremental cost estimate table of intermediate bypasses on Clifton Court Module 1 (1 p).
Intake Alternatives I, II, III and Combined	DWR DOE, 1/27/2003	Itemized cost estimate for three intake alternatives and a combined alternative (with unit costs, totals and contingencies) (14 pp).
Italian Slough Conceptual Schematics	Preparer and date unknown	Schematic for new intake on Italian Slough. Five-bay inline layout for 13,300-cfs plan (9 pp).

TABLE A-1
Previous CCF Fish Screen and Intake Planning Efforts Data Inventory
Low-flow Intake Technical Analysis

Title	Prepared by and Date	Brief Description
Monthly Average Efficiencies of CCF1 Under Different Banks Pumping Alternatives	Preparer unknown, 3/7/2002	Monthly average fish loss efficiencies of CCF1 under different banks pumping alternatives (8 pp).
Office Memo: CCF Fish Facility Planning and Design Nov 2000	DWR ESO, 11/2/2000	SWP Environmental Services Offices memo to DWR Office of Planning on Clifton Court Forebay fish facility planning and design that initiates and focuses the planning and design of the CCFFF within DWR, at the interagency level, and with the State Water Contractors (13 pp).
Options I, 2, 3 for CCF Intake and Fish Facility	Preparer unknown, 4/17/2002	Evaluation of three options for proceeding with CCF Module 1: 1. Delay CCF 1 until TFTF testing. 2. Build CCF 1 as prototype facility in conjunction with TFTF. 3. Build CCF 1 with existing criteria. All options include description, general benefits, fish benefits, water supply benefits, costs, risks, schedule (12 pp total).
Proposal For New CCF Intake Preliminary Operations Model	Preparer and date unknown	Proposal for New CCF Intake Preliminary Operations Model. A numerical model to facilitate design and operation. Lists assumptions, phases, when and how modeling will be performed, and a schematic of the proposal (4 pp).
Proposed Fish Facilities Components (Table)	Preparer and date unknown	Table of proposed fish facility components, capacity, and whether included in current criteria fish facility (Option 3) or prototype fish facility (Option 2) and general comments (1 p).
Proposed Fish Facility Components (Table)	Preparer and date unknown	Continued (same as above) (3 pp).
Pumping Storage Outflow Model Output (1921-1994)	Preparer unknown, 3/8/2002	San Luis Storage, Banks pumping flow, and excess Delta outflow CALSIM monthly time series from 1921–1994 (18 pp).
Request for Resolution: Potential Strategies for Module 1 of New Clifton Court Intake	CCFTAT and CCIFF Project Manager, 12/20/2001	Memo to determine if the fish facility design of CCFI FFI Module 1 should be dependent on the Tracy Fish Test Facility. Discusses the risks and benefits of longer or multiple bypasses (longer or shorter exposure times) and pumped bypass systems: gravity vs. pumped bypasses (6 pp).
Revised Fish Gravity Bypass Cost Estimate (Spread Sheets)	Preparer unknown, 11/25/2002	Revised fish gravity bypass itemized cost estimate with unit costs, totals, and contingencies (2 pp).
Revised Fish Gravity Bypass Cost Estimates (Spread Sheets)	Preparer unknown, 4/15/2002	Revised fish gravity bypass itemized cost estimate with unit prices, total cost, and contingencies (2 pp).

TABLE A-1
Previous CCF Fish Screen and Intake Planning Efforts Data Inventory
Low-flow Intake Technical Analysis

Title	Prepared by and Date	Brief Description
Schedule for CCF Intake and Fish Facility and Related Elements Project	Preparer unknown, 2/18/2003	CCFIFF and Related Elements schedule (1 p).
Second Stage Construction Plan	Preparer and date unknown	Plan diagram, second stage construction (4 pp).
Separator Holding Structure Schematic	Preparer unknown, 12/19/2001	1. Fish lift side. 2. Gravity side of separator holding structure schematic. (4 pp total)
Skinner Fish Facilities Upgrade	Preparer and date unknown	Background and alternatives for potential system upgrade to Skinner Fish Facilities. Includes benefits in regards to fish salvage (1 p).
South Delta Facilities Alternatives	Preparer and date unknown	13 South Delta facilities alternative diagrams with notes (13 pp).
South Delta Facilities Alternatives-Wide Range Draft	Preparer and date unknown	South Delta facilities for 17 alternatives (objectives, elements, special operations, assets, liabilities, costs, biological benefits, assumptions, risks, potential fatal flaws). Good summary of alternatives descriptions and biological benefits and risks (30 pp).
South Delta Fish Facilities State Water Project Alternative Configurations	Preparer unknown, 10/2002	South Delta Fish Facilities SWP Alternative Configurations presentation (50 pp).
South Delta Fish Facilities Alternatives	Preparer and date unknown	Presentation slides for two alternatives. Gunderboom alternative (5 pp).
South Delta Fish Facilities Implementation Strategy	Preparer unknown, 1/13/2003	South Delta Fish Facilities Implementation Strategy presentation (focus on TFTF) (9 pp).
South Delta Fish Facilities Issues	Preparer unknown, 1/29/2003	South Delta Fish Facility Implementation Issues presentation (with focus on TFTF) (contains some slides from above) (10 pp).
Staff Recommendation On Proposed Clifton Court Intake And Fish Facility	DWR, 1/31/2002	DWR Staff recommends (1) not to delay CCF and wait for TFTF testing and (2) consider viable alternatives which keep project on schedule. Pros, cons, and risks of considerations provided (6 pp).
SWP-Clifton Court Forebay Module 1	Dan Odenweller (assumed), 4/16/2002	Presentation of SWP-Clifton Court Forebay, Module 1 Assumptions, Chinook salmon data and simulation results. CALFED “assessments of fish losses” (14 pp).
TFTF and CCF Intake And Screen Evaluations-Significant Evaluations Impacting Design Decisions	Preparer and date unknown	TFTF and CCF intake and screen evaluations impacting design decisions (debris and sediment management, fish bypass system with fish-friendly lifts/pumps, gravity bypass and fish holding system, fish transport and releases, fish separation systems, presorting screens/leaky louver) (2 pp).

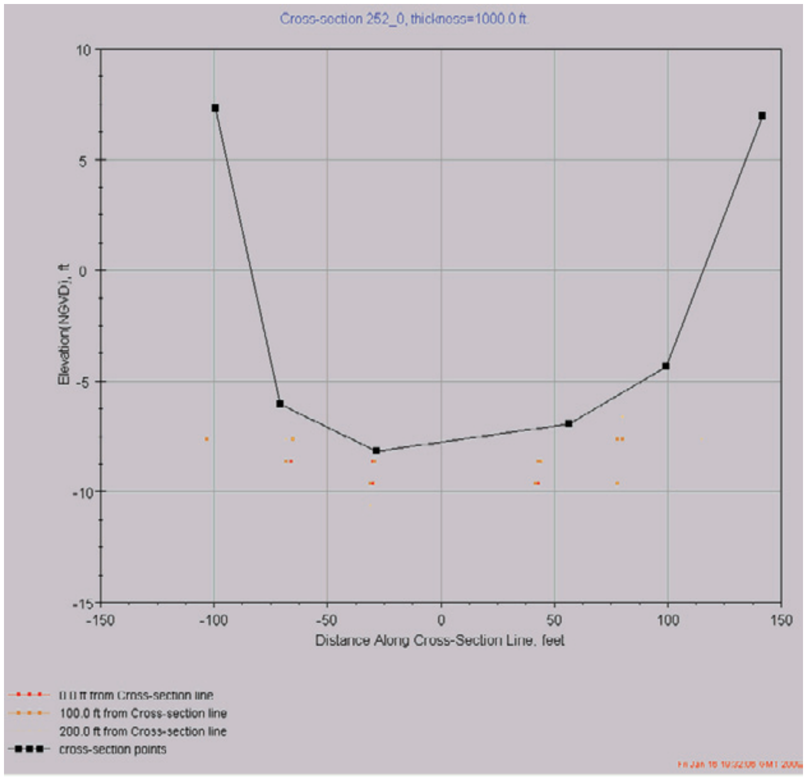
TABLE A-1
Previous CCF Fish Screen and Intake Planning Efforts Data Inventory
Low-flow Intake Technical Analysis

Title	Prepared by and Date	Brief Description
Tracy Fish Test Facility (Overview)	Preparer unknown, 4/17/2002	Tracy Fish Test Facility description, fisheries benefits, water supply benefits, costs, benefit/cost (3 pp).
Tracy FTF and CCFFF (Milestones and Schedules)	Preparer unknown, 5/28/2002	TFTF South Delta Improvement Program EIR/EIS and CCFIFF Milestones and CCFIFF cost projections from 2001–2010 for three alternatives (5 pp).
CCF Module 1 Simulation	Preparer and date unknown	CCF Module 1 simulation results of four CCF Module 1 scenarios (3 pp).

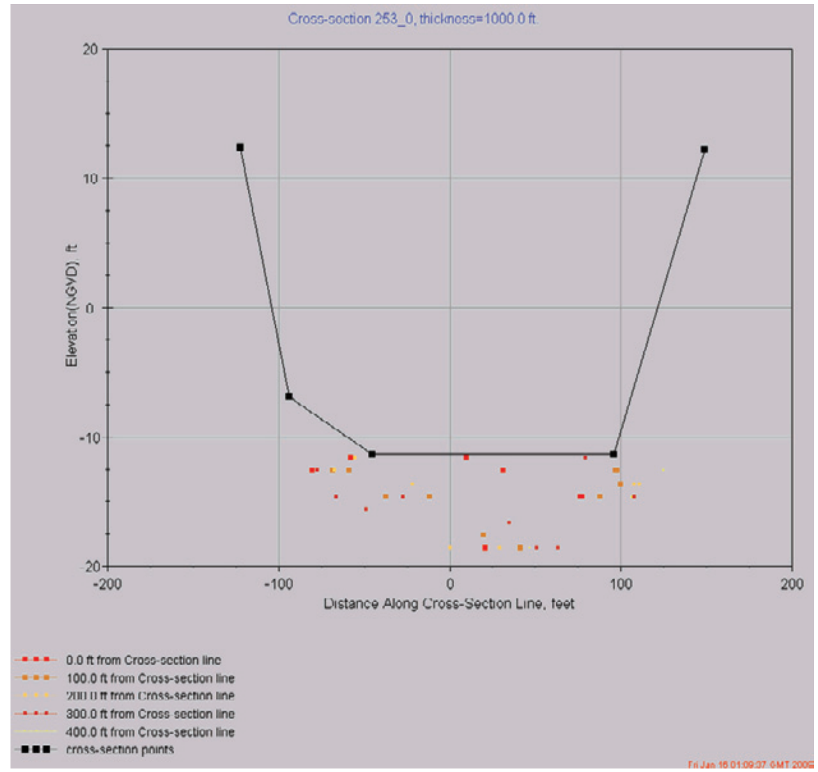
Appendix B
Bathymetry Cross Sections and Area/Elevation Tables

APPENDIX B: BATHYMETRY CROSS SECTIONS AND AREA/ELEVATION TABLES

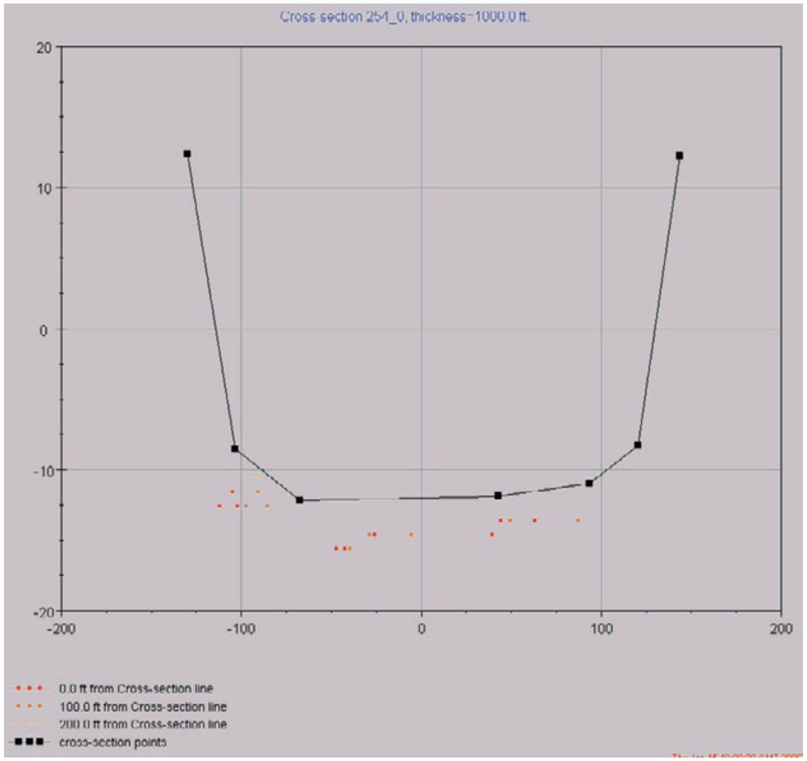
Italian Slough – Clifton Court Road



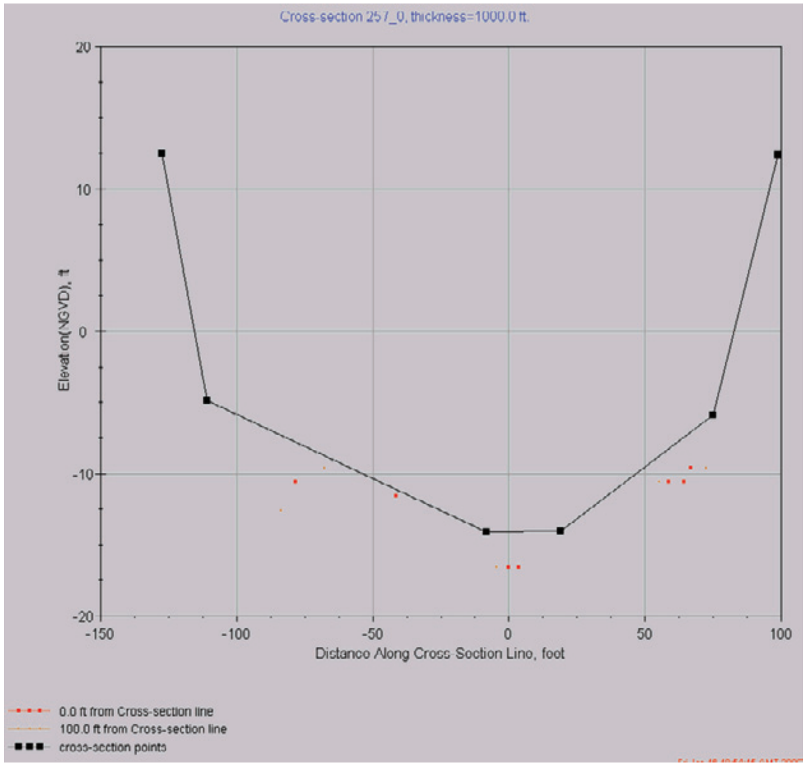
Cross Section 253: Italian Slough – South



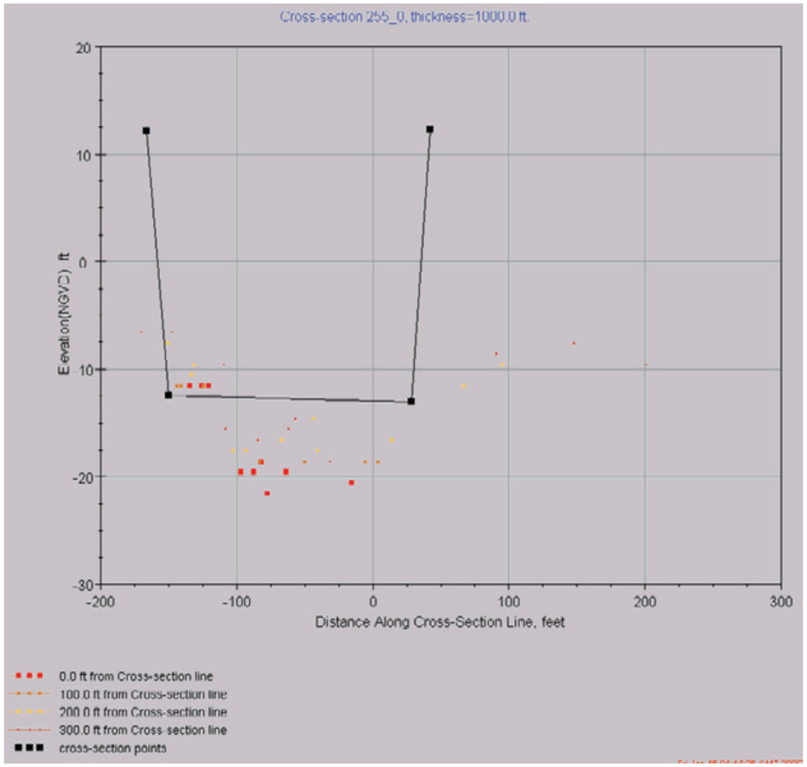
Cross Section 254: Italian Slough – Central



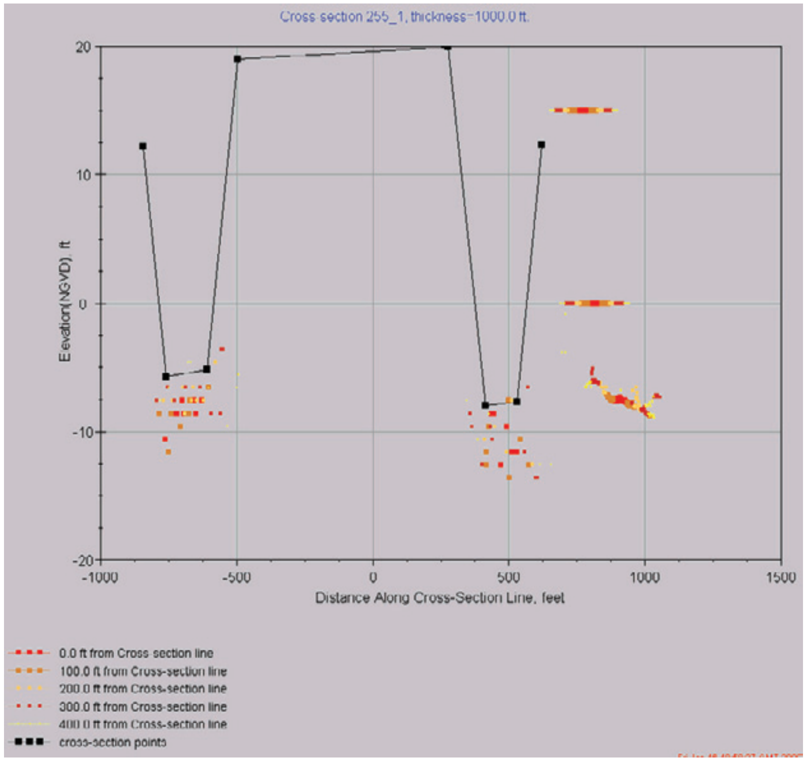
Cross Section 257: Italian Slough – North



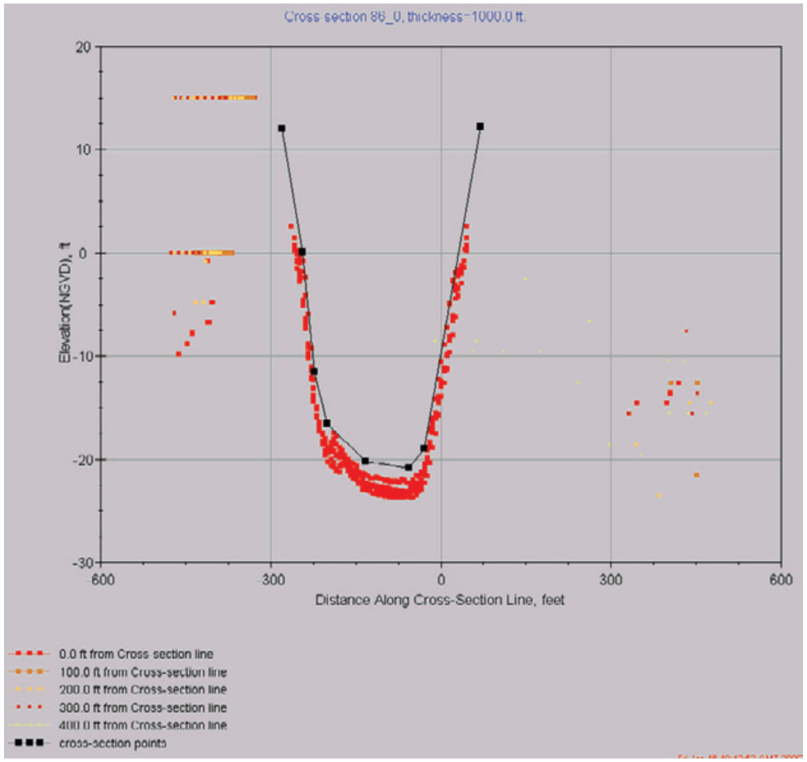
Cross Section 255_0: West of Widdows Island



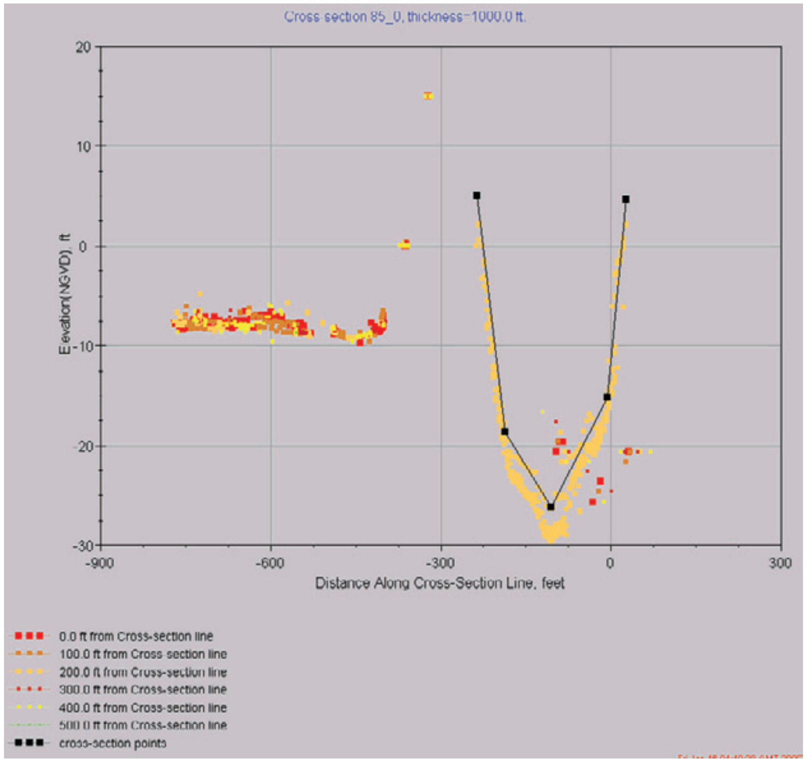
Cross Section 255_1: North and South of Eucalyptus Island



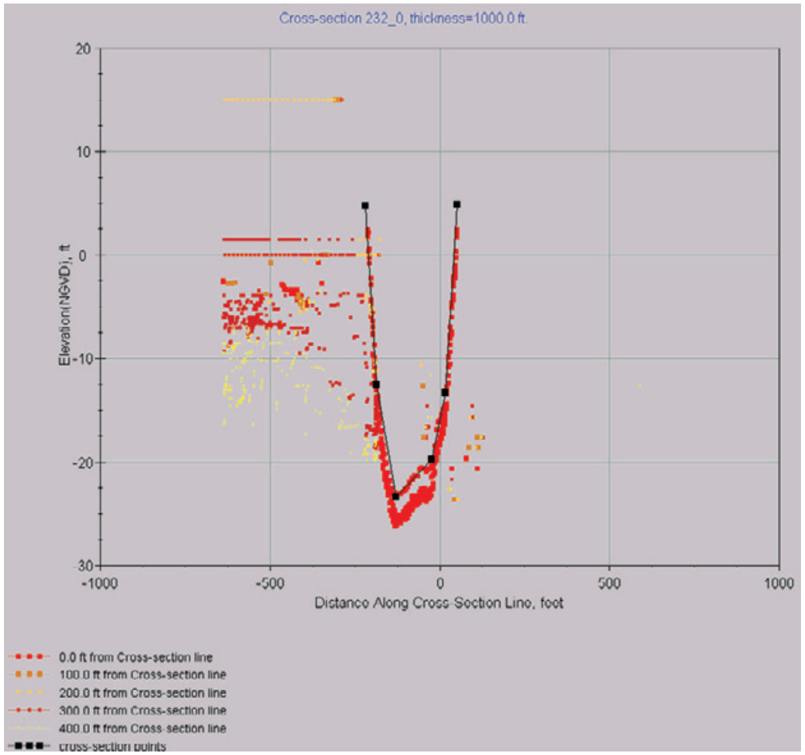
Cross Section 86: Old River – North



Cross Section 85: West Canal – North



Cross Section 232: West Canal – South



Cross Section 82_0: Old River – Near Forebay Intake

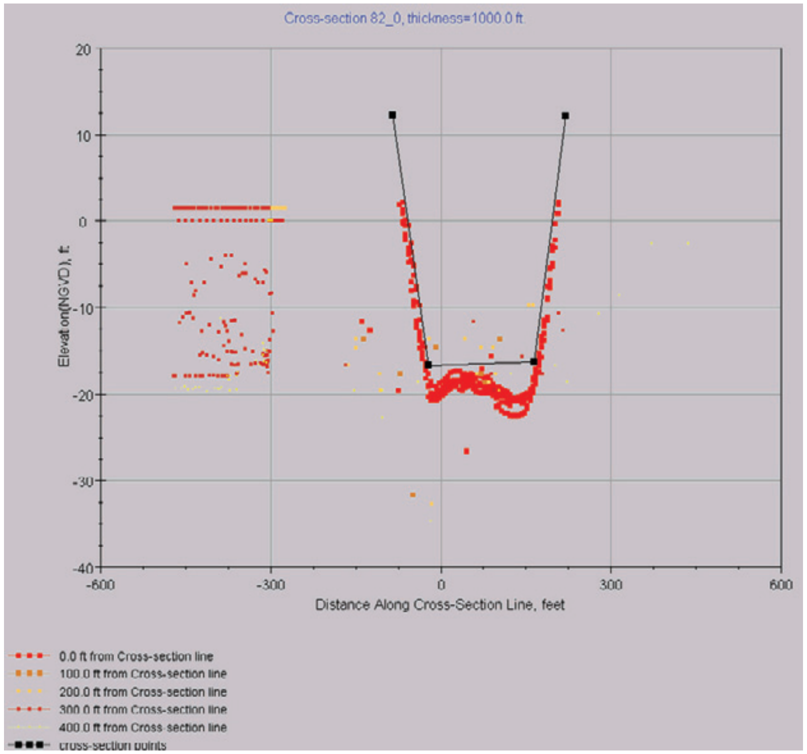


Table A-Elevation and Area of Bathymetric Cross-Sections near Clifton Court Forebay

DSM2 Channel	252_0	253_0	254_0	257_0	255_0	255_1	86_0	85_0	232_0	82_0
Elevation (ft, NGVD)	Italian Slough-Clifton Court Road	Italian Slough-South	Italian Slough - Central	Italian Slough - North	West of Widdows Island	North and South of Eucalyptus Island	Old River - North	West Canal - North	West Canal - South	Old River - Near Forebay Intake
10	*3518.06*	4669.84	5183.35	4043.77	4361.45	7043.92	7422.54	6990.62	6958.05	6377.94
5	2326.45	3401.65	3872.7	2968.4	3347.8	4375.4	5815.23	5680.81	5605.35	4951.13
0	1256.67	2226.87	2622.24	1949.22	2364.83	2173.3	4362.29	4414.78	4296.1	3628.17
-5	336.97	1145.51	1431.96	986.33	1412.54	300.49	3048.4	3241.45	3080.87	2409.06
-10	0	202.29	324.3	261.06	490.94	0	1859.1	2160.89	1959.72	1293.8
-15	0	0	0	0	0	0	811.13	1173.09	948.96	282.4
-20	0	0	0	0	0	0	43.6	373.8	194.68	0

All areas are in square feet.

Appendix C
Stage, Flow, and Velocity Data for Key Locations

APPENDIX C: STAGE, FLOW, AND VELOCITY DATA FOR KEY LOCATIONS

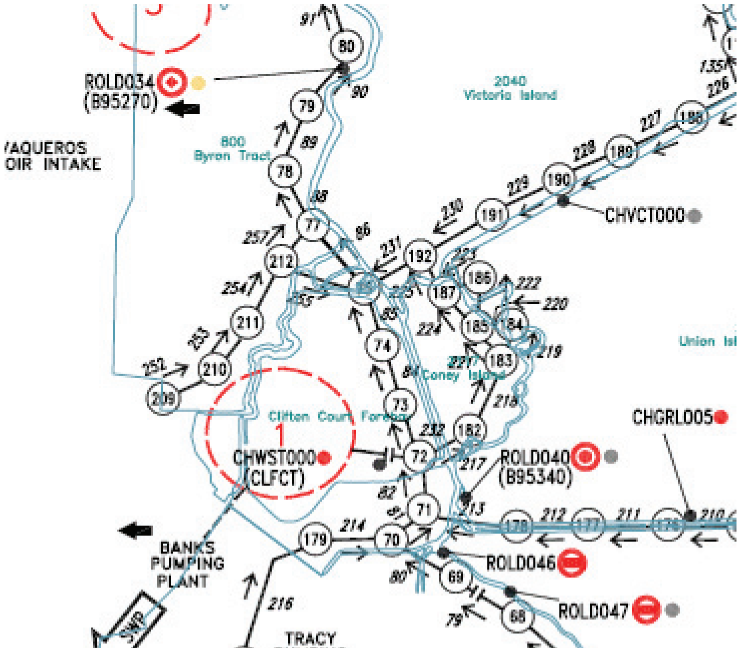


Figure C-1: DSM2 Grid near Clifton Court Ferry

STAGE DATA

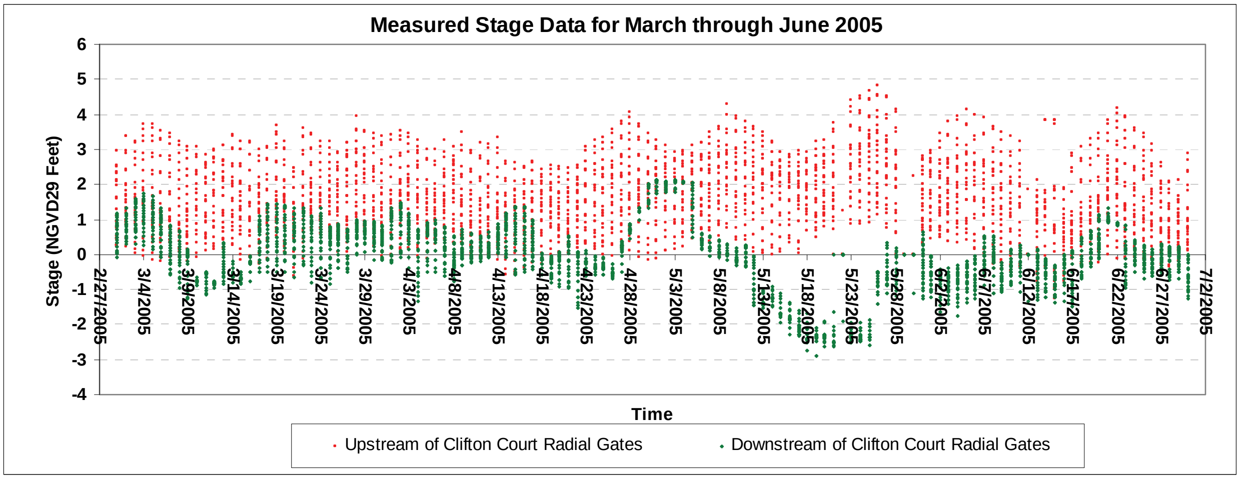


Figure C-2: Measured Stage Data for March through June 2005

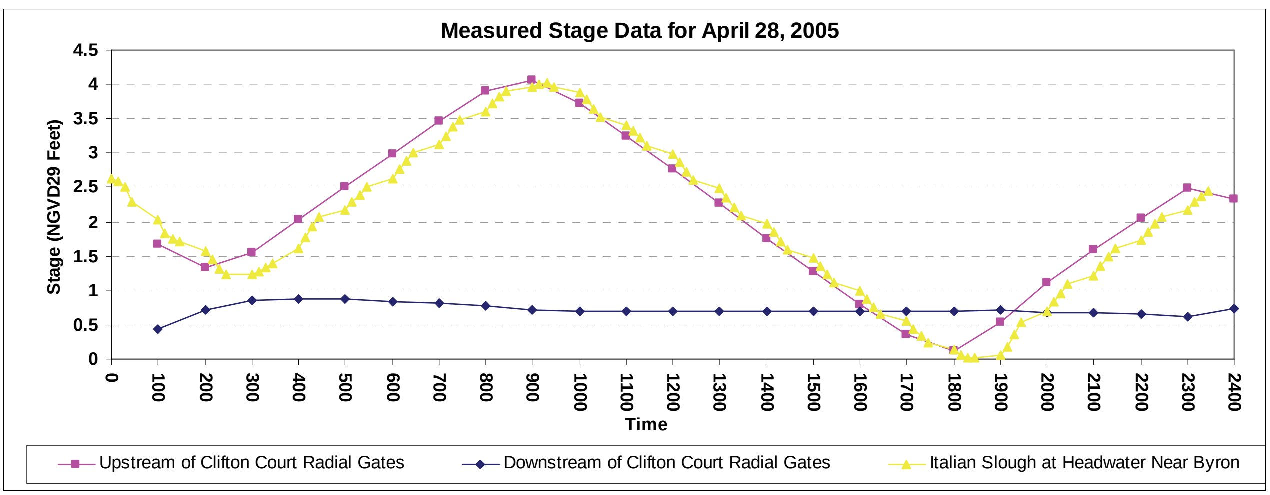
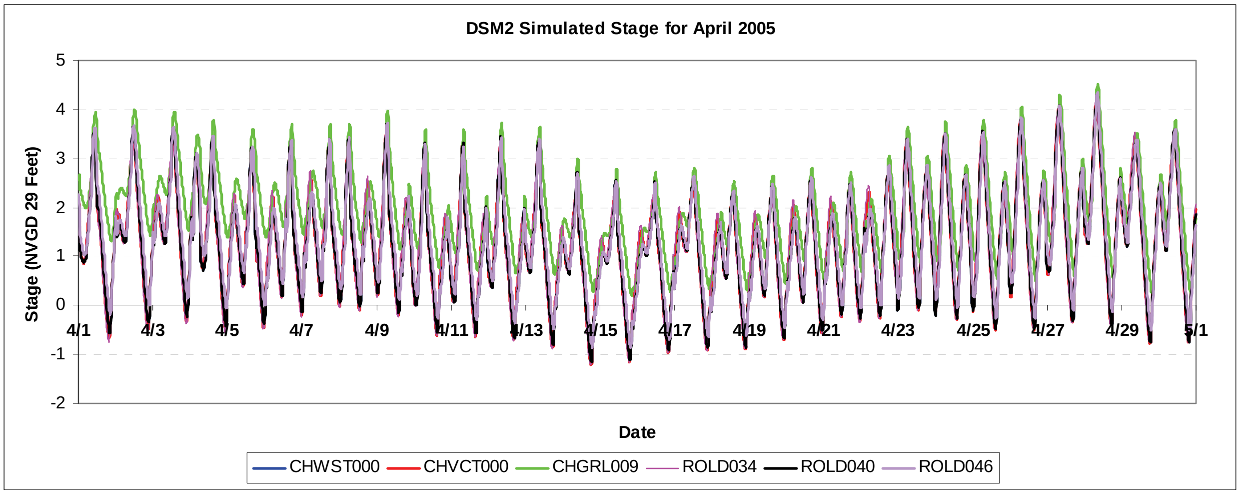


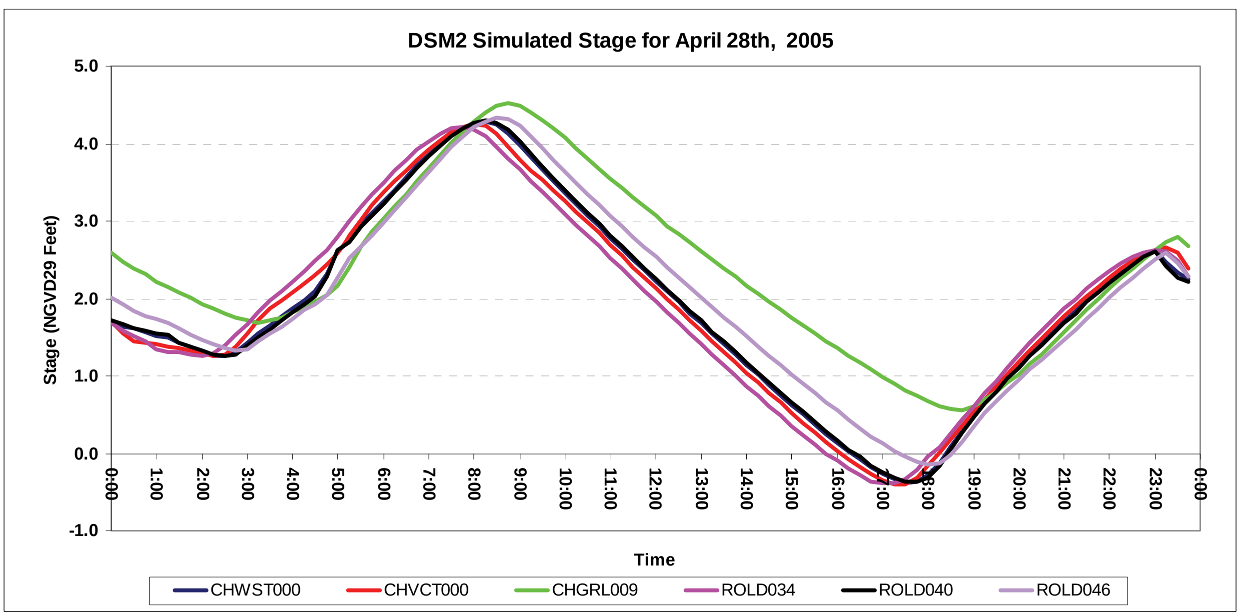
Figure C-3: Measured Stage Data for April 28, 2005



CHWST000 = Clifton Court Forebay Radial Gates
CHVCT000 = Victoria Canal
CHGRL005 = Grant Line Canal

ROLD034 = Old River near Byron
ROLD040 = Old River at Clifton Court Ferry
ROLD046 = Old River at Tracy

Figure C-4: DSM2 Simulated Stage for April 2005



CHWST000 = Clifton Court Forebay Radial Gates
CHVCT000 = Victoria Canal
CHGRL005 = Grant Line Canal

ROLD034 = Old River near Byron
ROLD040 = Old River at Clifton Court Ferry
ROLD046 = Old River at Tracy

Figure C-5: DSM2 Simulated Stage for April 28, 2005

VELOCITY DATA

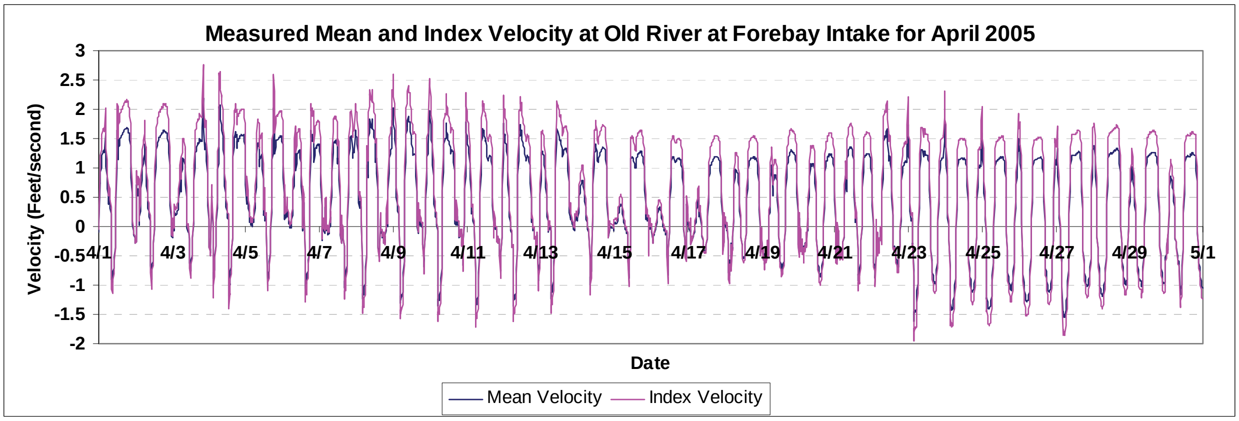


Figure C-6: Measured Mean and Index Velocity at Old River at Forebay Intake for April 2005 (USGS)

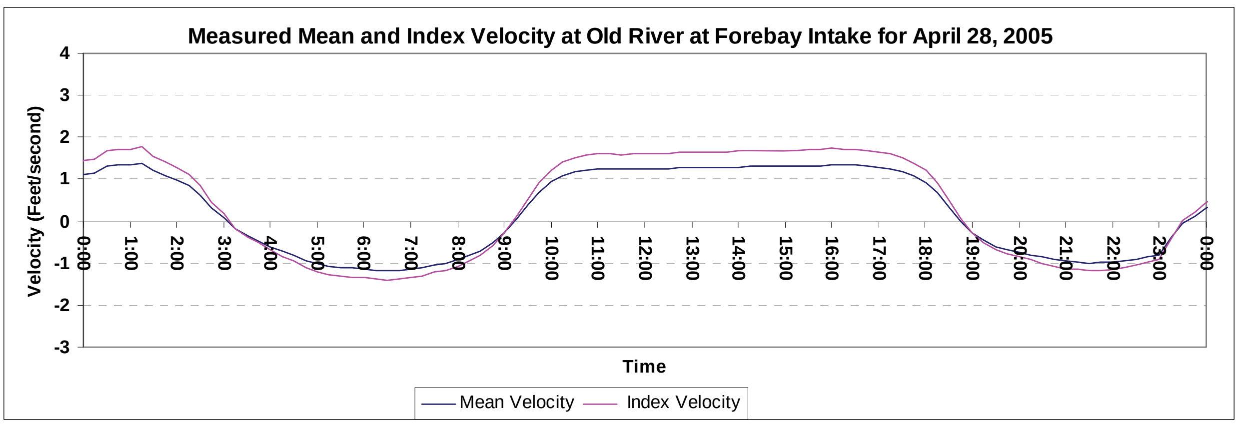


Figure C-7: Measured Mean and Index Velocity at Old River at Forebay Intake for April 28, 2005 (USGS)

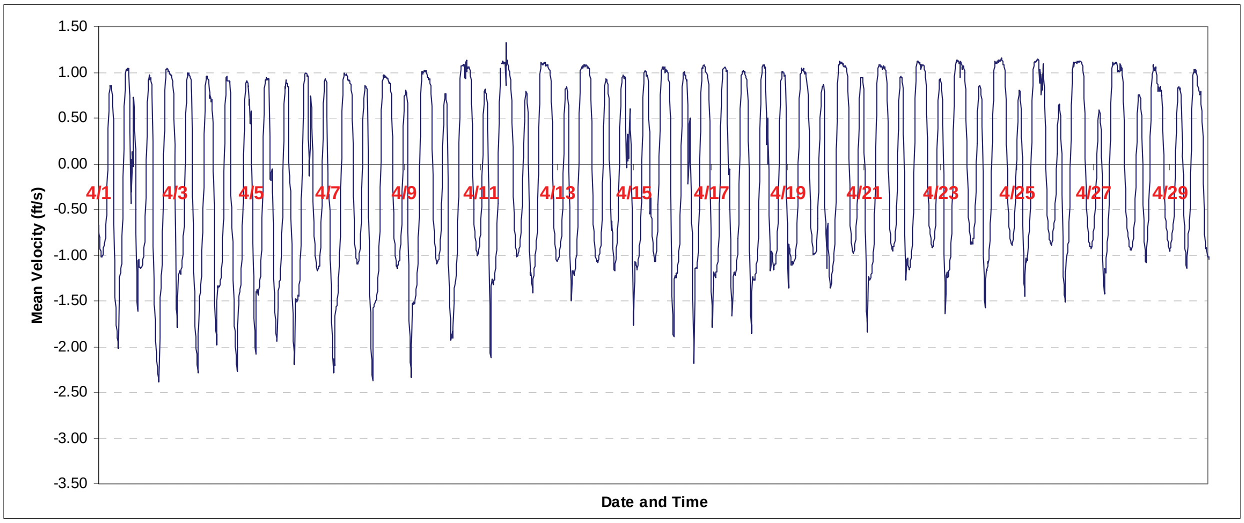


Figure C-8: Measured Mean Velocity at West Canal near Forebay Intake April 2008 (DWR)

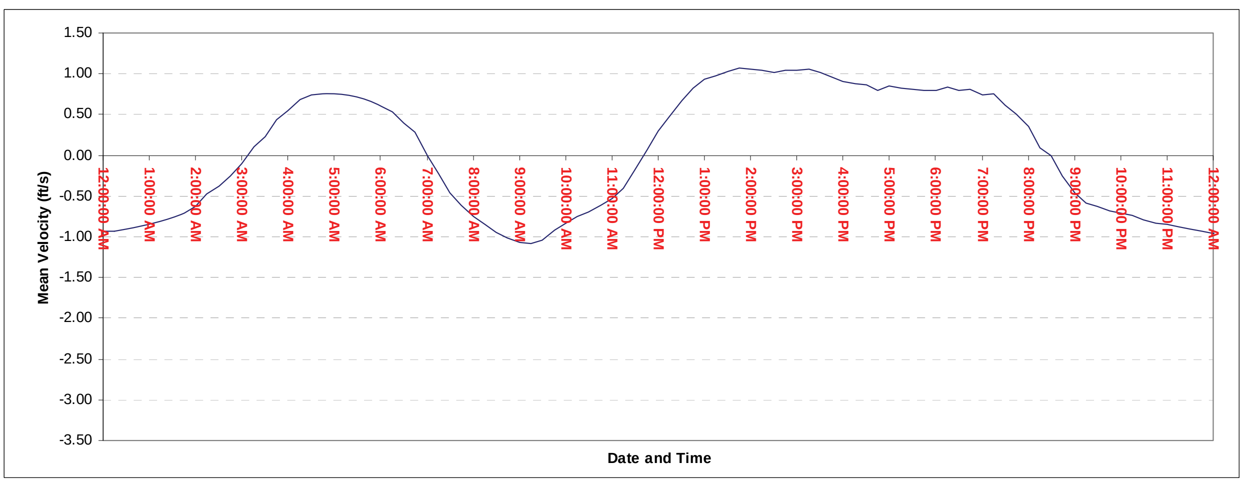
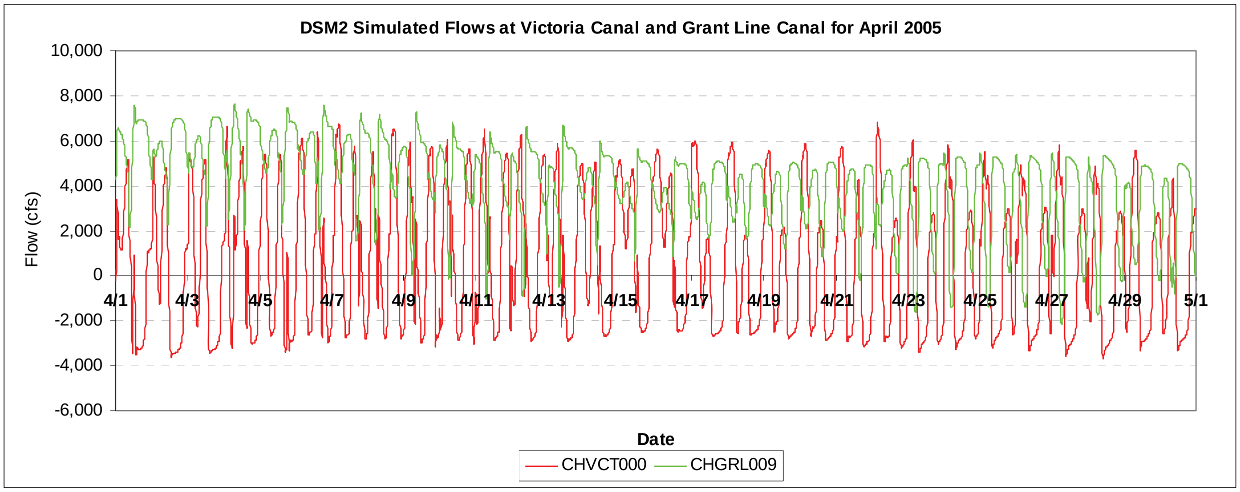


Figure C-9: Measured Mean Velocity at West Canal near Forebay Intake April 28, 2008 (DWR)

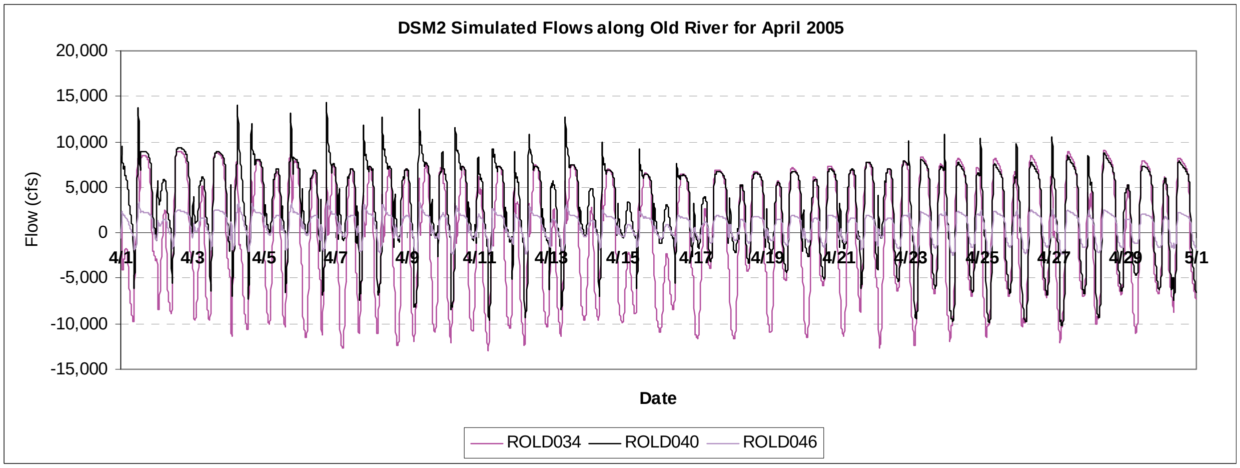
FLOW DATA



CHVCT000 = Victoria Canal

CHGRL005 = Grant Line Canal

Figure C-10: DSM2 Simulated Flows at Victoria Canal and Grant Line Canal for April 2005

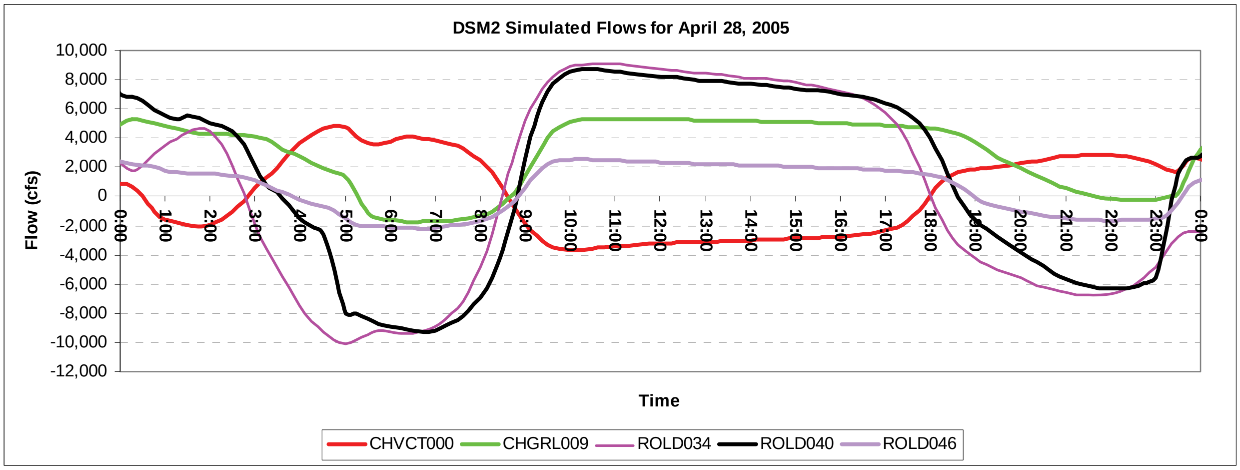


ROLD034 = Old River near Byron

ROLD040 = Old River at Clifton Court Ferry

ROLD046 = Old River at Tracy

Figure C-11: DSM2 Simulated Flows along Old River for April 2005



CHVCT000 = Victoria Canal

CHGRL005 = Grant Line Canal

ROLD034 = Old River near Byron

ROLD040 = Old River at Clifton Court Ferry

ROLD046 = Old River at Tracy

Figure C-12: DSM2 Simulated Flows for April 28, 2005