APPENDIX A

Target Species for the Dutch Slough Restoration Project

Target Species for the Dutch Slough Restoration Project

	MSCS status	Fed. status	State status	CNPS status	Notes
Tier 1 Species					
Sacramento splittail *Pogonichthys macrolipidotus*	(R)	T	CSC		Fish. Spawning and rearing
Chinook salmon *Oncorhynchus tshawytscha*	(R)	varies	varies		Fish. Rearing habitat (all runs). Listing status varies by run.
Delta smelt *Hypomesus transpacificus*	(R)	T	CT		Fish. Spawning (questionable, need more research)
Antioch Dune Scrub species					
Tier 2 Species					
California black rail *Laterallus jamaicensis coturniculus*	(r)		CT/FP		Bird. Nesting Habitat
Giant garter snake *Thamnophis gigas*	(r)	T	CT		
Lange's metalmark *Apodemis mormo langei*	(R)	E			Butterfly. Antioch dune species
Western pond turtle *clemmys marmota*	(m)		CSC		Observed at lower Marsh Creek
Tri-colored black bird *Agelaius tricolor*	(m)		CSC		Bird. Observed at lower Marsh Creek
Yellow-breasted chat *Icteria virens*	(m)		CSC		Bird. Observed at lower Marsh Creek.
Western burrowing owl *Athene cunicularia hypugea*	(m)		CSC		
Mason's lilaeopsis *Lilaeopsis masonii*	(R)		R		Plant. Freshwater tidal marsh.
Delta tule pea *Lathyrus jepsonii* var. *jepsonii*	(r)			1B	Plant. Freshwater tidal marsh.
Suisun marsh aster *Aster lentus*	(R)			1B	Plant. Freshwater tidal marsh.
California hibiscus *Hibiscus lasiocarpus*	(m)			2	Plant. Freshwater tidal marsh.
Delta Mudwort *Limosella subulata*	(r)		R	2	Plant. Freshwater tidal marsh.
Sanford's Arrowhead *Sagittaria sanfordii*	(m)			1B	Plant. Freshwater tidal marsh.
Marsh skullcap	(m)			2	Plant. Freshwater tidal marsh.

Target Species for the Dutch Slough Restoration Project

	MSCS status	Fed. status	State status	CNPS status	Notes
Scutellaria galericulata					
Waterfowl					
Shorebirds and wading birds					
Tier 3 Species					
Long-billed curlew *Numenius americanus*	(m)		CSC		Bird. Observed on site.
White-tailed kite *Elanus leucurus*	(m)		FP		Bird. Observed on site.
White-faced ibis *Plegadis chihi*	(m)		CSC		
Northern harrier *Circus cyaneus*	(m)		CSC		Bird. Observed on site.
Shorebirds and wading birds					
Other Potential Tier 2 or 3 Species (need more research on habitat preferences)					
Sacramento Perch *Archoplites interruptus*	(r)				
Valley elderberry longhorn beetle *Desmocerus californicus demorphus*	(R)	T			
Curved-footed hygrotus diving beetle *Hygrotus curvipes*					Known from a single shallow muddy pool in Oakley area.
California red-legged frog *Rana aurora draytonii*	(m)	T	CSC		
Western spadefoot toad *Scaphiopus hammondii*	(m)		CSC		
Silvery legless lizard *Anniella pulchra pulchra*			CSC		
Coopers hawk *Accipiter cooperi*	(m)		CSC		
Swainson's hawk *Buteo swainsoni*	(r)		CT		
Numerous Antioch dune insect species					

R – recover species within ERP Ecological Management Zones. (r) – contribute to recovery of the species. (m) undertake action to maintain species. F – federal endangered. T – federal threatened. CT – state threatened. CSC – state species of special concern. FB – state fully protected. R – rare under California Native Plant Protection Act.

APPENDIX B

Topographic and Hydrographic Surveys

PWA
PHILIP WILLIAMS & ASSOCIATES, LTD
ENVIRONMENTAL HYDROLOGY
720 California St., Suite 600
San Francisco, California 94108-2404
TEL 415.262.2300 FAX 415.262.2303
www.pwa-ltd.com

MEMORANDUM

Date:	May 4, 2006
To:	John Cain
Organization:	Natural Heritage Institute
From:	Nick Garrity and Dave Hansen
PWA Project #:	1780
PWA Project Name:	Dutch Slough Baseline Data Collection
Subject:	Dutch Slough Baseline Data Collection Technical Memorandum
Copy(ies) To:	Jeff Melby and Tom Hall

Summary

This technical memorandum documents the collection of baseline data by PWA for the Dutch Slough Tidal Marsh Restoration Project. PWA collected cross-section surveys of Little Dutch Slough, spot elevations of the lower edge of tule growth in Little Dutch Slough and the abandoned mouth of Marsh Creek north of the Emerson Parcel, and performed limited surveys to check the Carlson, Barbee, and Gibson (CBG 2000) topographic survey data. A CD containing the survey data accompanies this memorandum.

The survey results increase the certainty in the accuracy of the CBG topographic data used by PWA in the Dutch Slough Tidal Marsh Restoration Conceptual Plan and Feasibility Report (Dutch Slough Conceptual Plan and Feasibility Report) (PWA and others 2006). PWA used the Little Dutch Slough cross-section and tule elevation survey data for technical analyses in the Dutch Slough Conceptual Plan and Feasibility Report.

Survey Methods and Control

PWA performed real-time kinematic (RTK) GPS and Total Station surveys at the Dutch Slough site on May 11 and 12, 2005. PWA performed these RTK GPS surveys with a survey grade GPS unit consisting of a base station and a rover unit. PWA used National Geodetic Survey (NGS) Tidal Benchmark R465 (PID JS1909) – located on the southwest footing of the Jersey Island Rd. Bridge over Dutch Slough – to establish vertical control and horizontal positioning. PWA tied the survey to two additional benchmarks:

1. Contra Costa County BM #3095 located on the Cypress Rd. bridge over Marsh Creek, used (along with BM R465) as vertical control for the CBG topographic survey, and

2. The benchmark set by Ronald Greenwell & Associates (RGA) on the East Bay Regional Parks District (EBRPD) bridge over Marsh Creek, used as vertical control for Marsh Creek topography and tide data collected by Wetland and Water Resources (WWR).

PWA surveyed elevations in feet National Geodetic Vertical Datum of 1929 (NGVD) and horizontal coordinates in feet WGS-84 (and converted to California State Plane coordinates, Zone 3).

Little Dutch Slough Channel Cross-Section Survey

PWA surveyed four channel cross-sections across Little Dutch Slough on May 12, 2005, using a total station and canoe (Figure 1). The locations of the cross sections are shown in Figure 2. PWA surveyed one cross-section at the mouth of Little Dutch Slough, one cross-section just downstream of the drainage culvert and road crossing in Little Dutch Slough, and two cross-sections in between these downstream and upstream locations. Each cross-section extended over the levees adjacent to the slough channel. Each cross-section included tule elevations and breaks in slope along each transect.

Semi-permanent cross-section end markers were installed along Little Dutch Slough. The elevations of these markers were set during the RTK GPS survey described above. These markers were used as vertical control points for each cross-section survey.

PWA used the surveyed cross-sections in a hydrodynamic model of Little Dutch Slough for the Dutch Slough Conceptual Plan and Feasibility Report (Appendix H of PWA 2006).

Topographic Data Check

The Carlson, Barbee, & Gibson (CBG 2000) photogrammetric topography survey used NGS Tidal BM R465 and Contra Costa County BM #3095 for vertical control. PWA confirmed that the vertical datum of the CBG data is NGVD by comparing CBG's topographic monument records (CBG 2002) with the NGS data sheet for BM R465.

PWA surveyed one longitudinal profile from south to north across the Emerson parcel, extending from Contra Costa Canal embankment to Dutch Slough, to check the accuracy of the CBG photogrammetry data relative to the benchmarks used by CBG for vertical control. The presence of on-site vegetation can obscure the ground surface and introduce a potential source of error in photogrammetric survey methods. Photogrammetric surveys typically correct elevations in vegetated areas by assuming a height of vegetation, which may have limited accuracy.

Figure 3 shows the surveyed profile and a transect cut at the same location from the digital terrain model (DTM) built from the CBG photogrammetry data. The surveyed profile shows close agreement with the CBG data over most of the transect and indicates that the CBG photogrammetry data is relatively accurate relative to BM R465. The difference in the transects near the sand mounds (approximately station 4000 ft in Figure 3) may be due to a slight difference in the transect locations (e.g., the DTM transect may cross

farther down the slope of the sand mound). The difference in the northern portions of the transects (approximately stations 150 – 1500 ft in Figure 3) may be due to the presence of tule vegetation or a slight difference in transect locations through this depression.

To check the accuracy of the CBG data to tide levels (i.e., tidal datums) in Dutch Slough, PWA surveyed the elevation of the RGA benchmark used as vertical control for WWR tide data collection relative to the CBG vertical control points. PWA located a paint mark on the EBRPD bridge near the location of the RGA benckmark shown in the RGA Marsh Creek topography data. PWA assumed this mark was the RGA benchmark; however, the RGA benchmark was not located with certainty. The elevation of this mark relative to BM R465 showed close agreement (0.015 ft) with the RGA benchmark elevation. This suggests that the CBG data is accurate relative to tide levels in Dutch Slough. (Note that PWA used the conversion from MLLW to NGVD reckoned by WWR from their tide data to calculate tidal datums for the Dutch Slough Conceptual Plan and Feasibility Report.)

PWA also conducted a GPS static survey on May 12, 2005, to check the NGVD elevation of BM R465. PWA set the GPS base station over BM R465 and recorded data for four hours. PWA then sent the data to the NGS OPUS web site. OPUS conducted the necessary post processing and generated a current solution for the benchmark elevation of BM R465 (Attachment 1). The elevation of BM R465 reported by NGS agreed with the elevation reported by OPUS, within the accuracy of the OPUS elevation (0.05 m); however, the accuracy of the OPUS elevation is not high. The results of the GPS static survey increase the certainty of the NGVD elevation of BM R465 (e.g., BM R465 has not greatly subsided).

Tule Elevations

PWA surveyed spot elevations of the lower edge of tule growth in Little Dutch Slough and the abandoned mouth of Marsh Creek north of the Emerson Parcel. These tule/mudflat edge elevation data are shown in Figure 4. In Little Dutch Slough, tule/mudflat edge elevations ranged from -1.7 to -0.2 ft NGVD, or -1.4 to 0.1 ft MLLW. Tule/mudflat edge elevations in the abandoned mouth of Marsh Creek ranged from -0.6 to 0.3 ft NGVD, or -0.3 to 0.6 ft MLLW. The deepest part of the abandoned mouth of Marsh Creek was higher in elevation than the lowest edge of tule growth surveyed in Little Dutch Slough. Thus, the tule/mudflat edge elevations in the abandoned mouth of Marsh Creek do not represent the lower limit of tule growth.

PWA used the surveyed elevations of the lower edge of tule growth in Little Dutch Slough to inform the selection of the design elevation for low marsh areas in the Dutch Slough Conceptual Plan and Feasibility Study (see Section 8.1.1 and Figure 13).

References

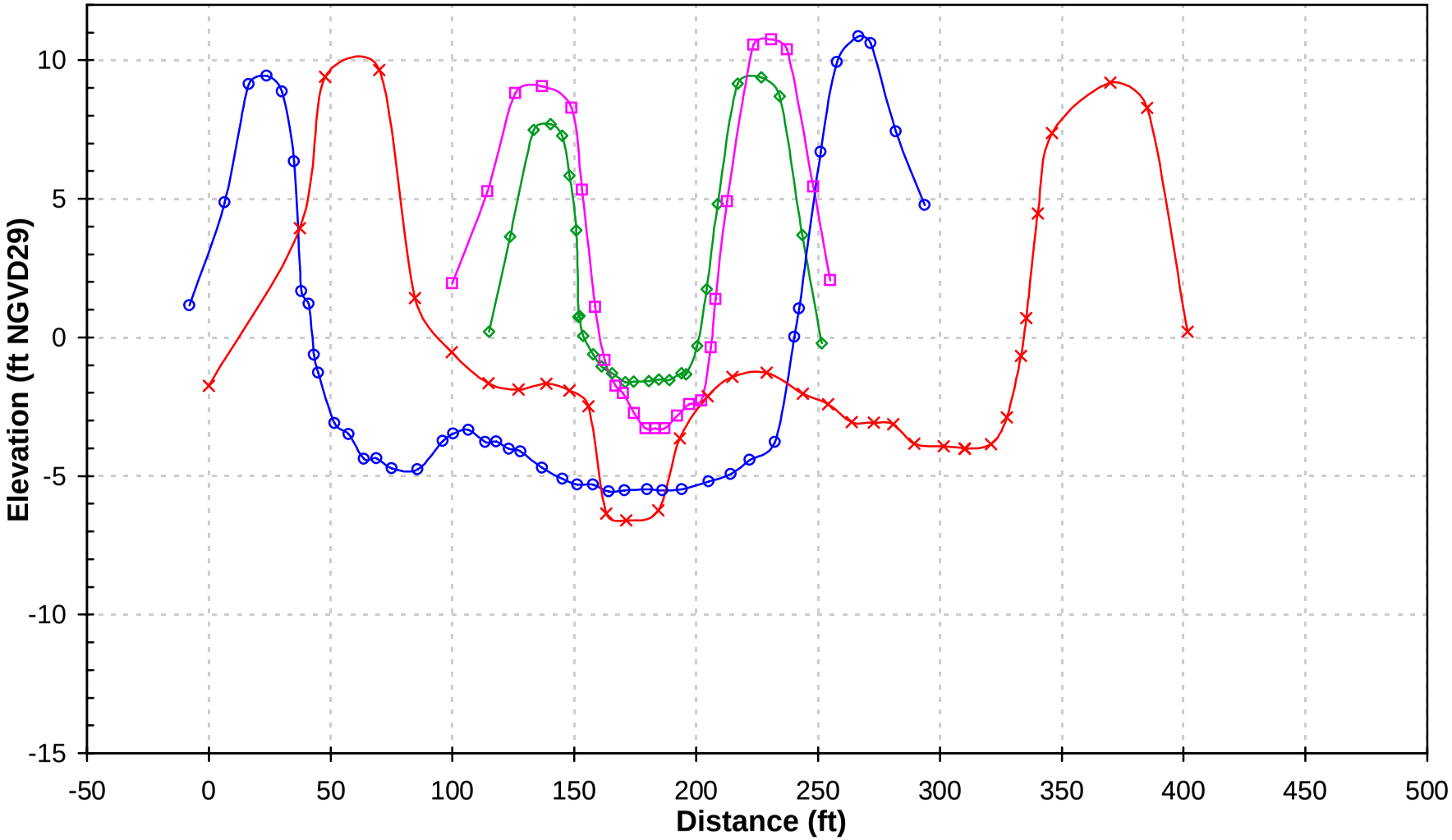
CBG (Carlson, Beebee, & Gibson). 2002. Fax transmittal from Michael Barbee to Sarah Beamish, Natural Heritage Institute. Cypress Corridor Study Area. Job No. 878-00. May 1.

CBG (Carlson, Beebee, & Gibson). 2000. Cypress Corridor Study Area Topographic Survey. Job No. 878-00.

PWA (Philip Williams & Associates, Ltd.). 2006. Dutch Slough Tidal Marsh Restoration Conceptual Plan and Feasibility Study. Prepared for The California State Coastal Conservancy; PWA Report 1714.

Figures

Figure 1. Little Dutch Slough Cross-Sections
Figure 2. Locations of Little Dutch Slough Cross-Sections
Figure 3. Emerson Parcel Transect Comparison
Figure 4. Tule/Mudflat Edge Elevations
Attachment 1. NGS OPUS Solution Report



XS1 XS2 XS3 XS4

Notes:
Survey was done by PWA on May 12, 2005.
Location of cross-sections are identified on Figure 1.

figure 1

Dutch Slough Baseline Data Collection
Little Dutch Slough Cross-Sections

PWA Ref 1780.00 **APPENDIX B** PWA

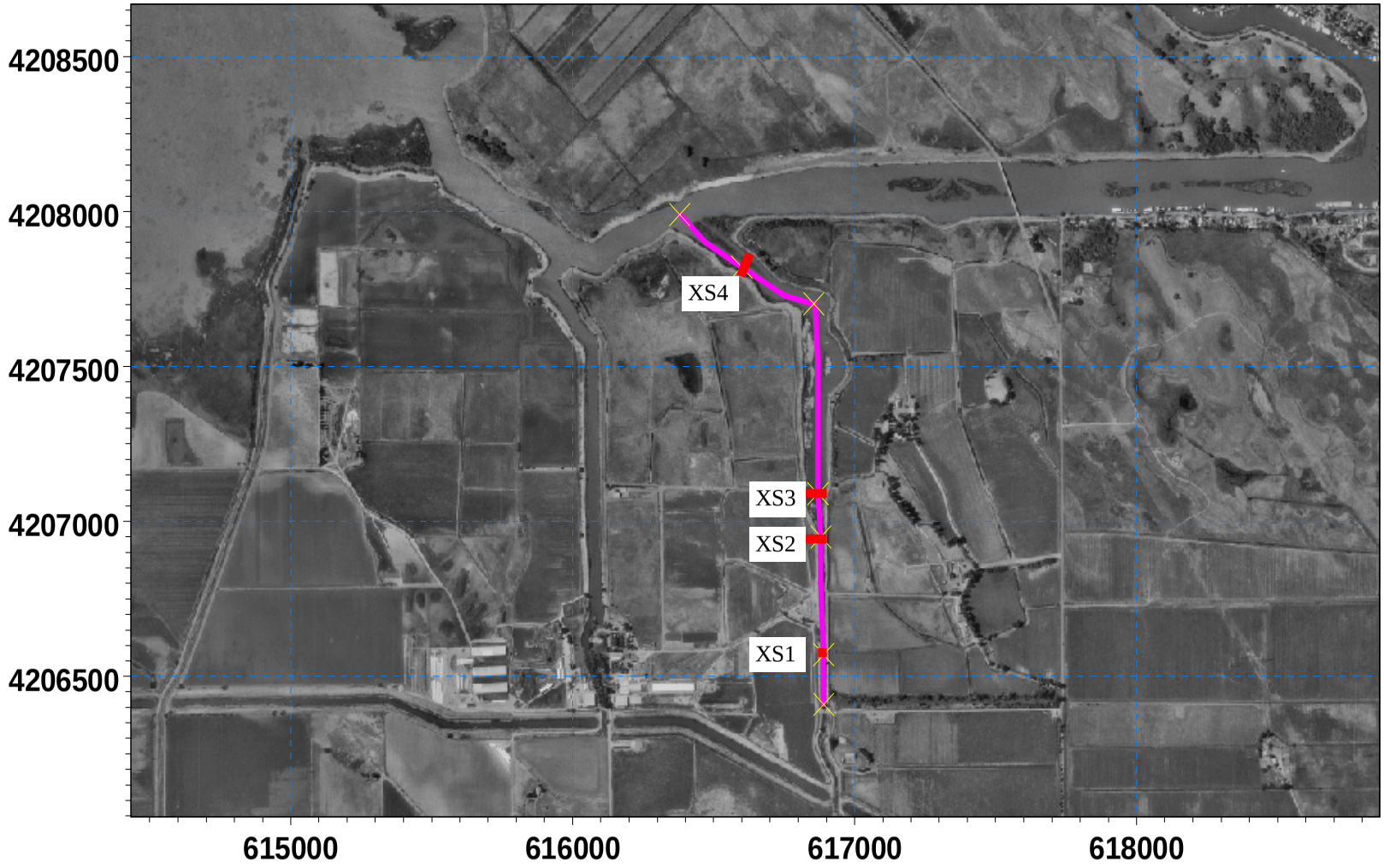
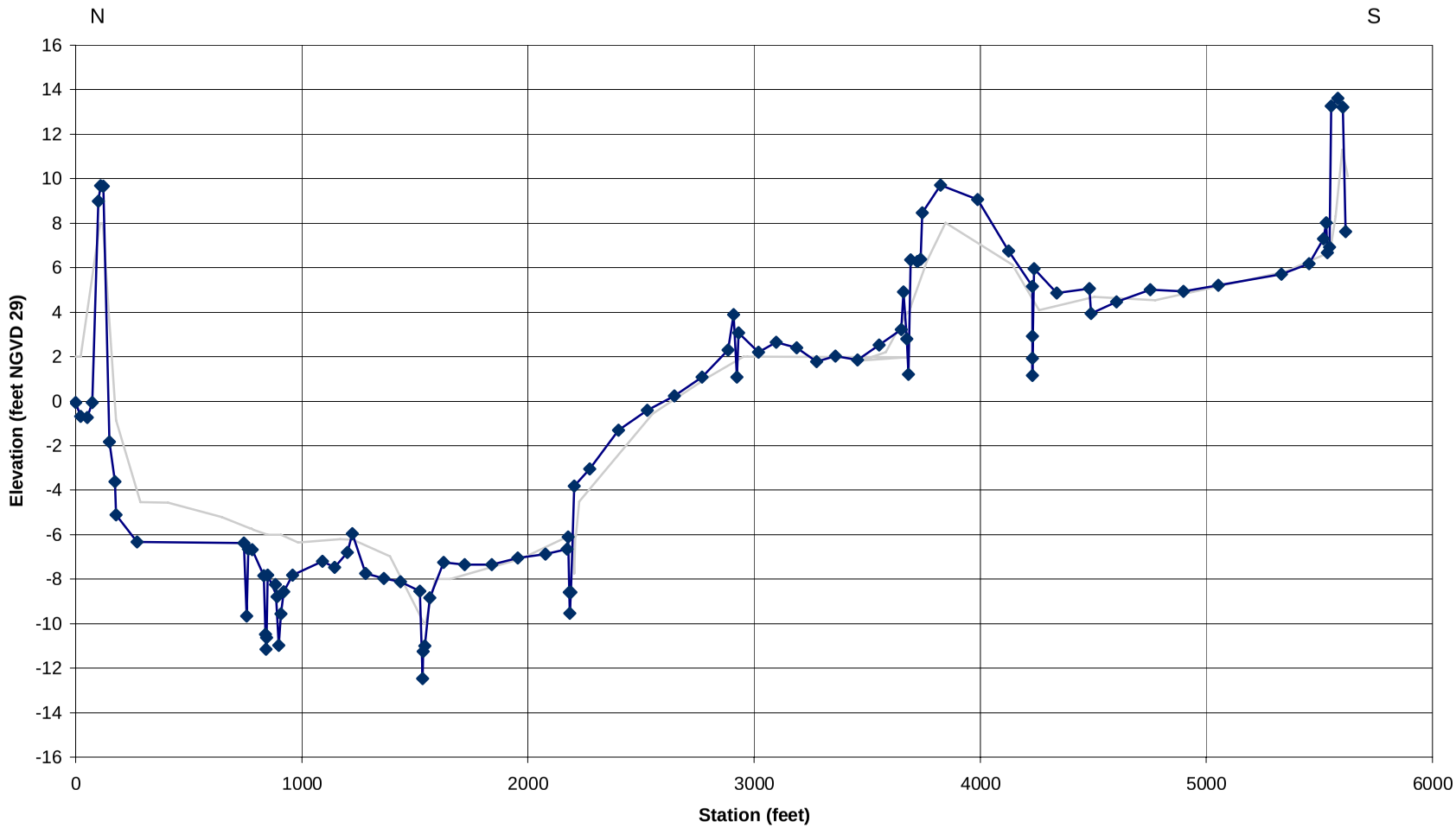


figure 2

Dutch Slough Baseline Data Collection

Little Dutch Slough Cross-Section Locations

PWA Ref 1780.00 **APPENDIX B** PWA



DTM (CBG, 2001)

Ground Survey (PWA, May 2005)

figure 3

Dutch Slough Baseline Data Collection

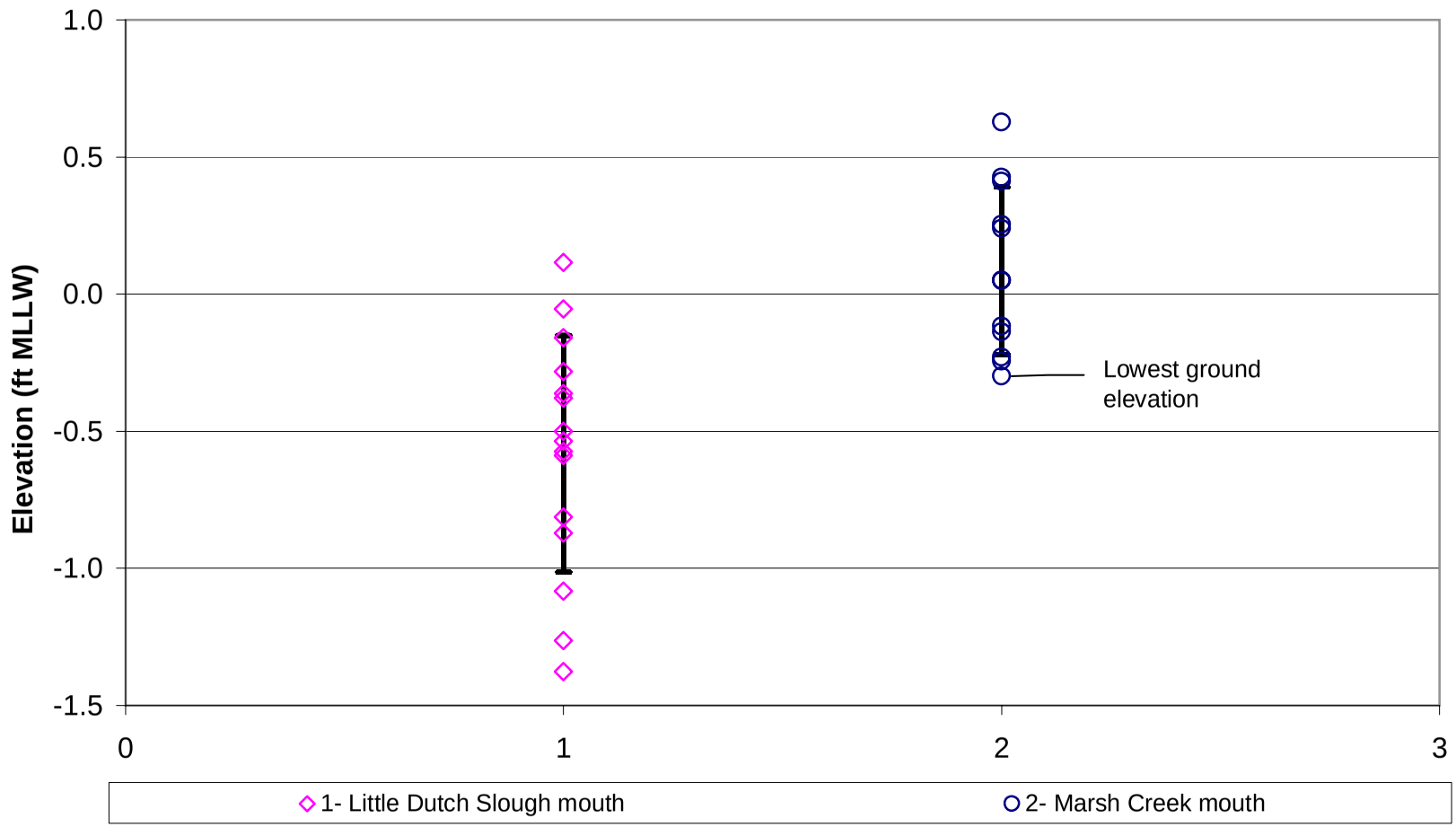
Emerson Parcel Transect Comparison

PWA Ref 1780.00

Appendix B

PWA

P:\Projects\1714_Dutch_Slough\Task6-Feasibility Report\Final_Report\Appendices\B.Fig3_Em_Transect_Compare.xls



Notes: The deepest part of the abandoned mouth of Marsh Creek was higher in elevation than the lowest edge of tule growth surveyed in Little Dutch Slough. Thus, the tule/mudflat edge elevations in the abandoned mouth of Marsh Creek do not represent the lower limit of tule growth. Bars indicate one standard deviation from the mean. Survey was done by PWA on May 11 and 12, 2005.

figure 4

Dutch Slough Baseline Data Collection

Tule/Mudflat Edge Elevations

PWA Ref 1780.00 Appendix B PWA

From: Eric Donaldson
Sent: Thursday, April 20, 2006 4:44 PM
To: Nick Garrity
Subject: FW: OPUS solution : 76851320.dat 000307766

OPUS Solution:

-----Original Message-----
From: opus@ngs.noaa.gov [mailto:opus@ngs.noaa.gov]
Sent: Wednesday, May 18, 2005 11:26 AM
To: Jarrett Price
Subject: OPUS solution : 76851320.dat 000307766

FILE: 76851320.dat 000307766

NGS OPUS SOLUTION REPORT
==========

USER: jarrett.price@geoline.com DATE: May 18, 2005
RINEX FILE: 7685132r.05o TIME: 18:26:27 UTC

SOFTWARE: page5 0411.19 master23.pl START: 2005/05/12 17:06:00
EPHEMERIS: igr13224.eph [rapid] STOP: 2005/05/12 21:33:00
NAV FILE: brdc1320.05n OBS USED: 11250 / 11322 : 99%
ANT NAME: TRM41249.00 # FIXED AMB: 46 / 46 : 100%
ARP HEIGHT: 1.366 OVERALL RMS: 0.011(m)

REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000) ITRF00 (EPOCH:2005.3611)

X:	-2641020.831(m)	0.026(m)	-2641021.593(m)	0.026(m)
Y:	-4282747.357(m)	0.046(m)	-4282746.078(m)	0.046(m)
Z:	3906470.165(m)	0.006(m)	3906470.165(m)	0.006(m)

LAT:	38 0 42.95143	0.027(m)	38 0 42.96518	0.027(m)
E LON:	238 20 21.53004	0.010(m)	238 20 21.47593	0.010(m)
W LON:	121 39 38.46996	0.010(m)	121 39 38.52407	0.010(m)
EL HGT:	-28.055(m)	0.043(m)	-28.598(m)	0.043(m)
ORTHO HGT:	4.327(m)	0.050(m) [Geoid03 NAVD88]		

	UTM COORDINATES (Zone 10)	STATE PLANE COORDINATES SPC (0403 CA 3)
Northing (Y) [meters]	4207985.106	668429.019
Easting (X) [meters]	617571.742	1898079.381
Convergence [degrees]	0.82487816	-0.71060922
Point Scale	0.99977025	0.99993951
Combined Factor	0.99977465	0.99994391

US NATIONAL GRID DESIGNATOR: 10SFH1757207985(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DG8210	P261 HUNTERHILLCN2004 CORS ARP	N380910.640	W1221303.086	51300.5
AH9962	S300 LLNL SITE S300 CORS ARP	N373959.410	W1213329.710	39391.0
AH8914	CNDR STOCKTON CORS ARP	N375347.043	W1211642.530	35955.1

NEAREST NGS PUBLISHED CONTROL POINT

JS1909	R 465	N380043.	W1213939.	13.0

This position and these vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

APPENDIX C

Water Quality

C-1. Final Dutch Slough Conceptual Plan & Feasibility Report Water Quality Assessment

C-2. Dutch Slough Water and Sediment Quality Monitoring Plan

C-3. Reconnaissance-Level Assessment of Pollutant Sources

APPENDIX C-1

Final Dutch Slough Conceptual Plan & Feasibility Report Water Quality Assessment

TECHNICAL MEMORANDUM 128296-900

January 27, 2006

TO: Michelle Orr, Phillip Williams & Associates
Nick Garrity, Phillip William & Associates

FROM: Michael Parenti, Brown and Caldwell
Laura Marshall, Brown and Caldwell
Sabre Duren, Brown and Caldwell

SUBJECT: Final Dutch Slough Conceptual Plan & Feasibility Report Water Quality Assessment

1.5.1 Overview/Introduction

1.5.1.1 Discussion of General Water Quality Issues

Good water quality is vital for ecosystem integrity of the proposed Dutch Slough tidal wetland. A prominent water quality contaminant within the Bay-Delta region is mercury. Many abandoned mercury mines throughout the California Coastal Range, and silver and gold mines dispersed throughout the Sierra Nevada have been depositing mercury-laden sediments into the Bay-Delta for the past 150 years (IEP, 1999). Due to this continuous source of mercury, many rivers, streams, and reservoirs have elevated concentrations of mercury. The abandoned Mt. Diablo Mine is located in the upper Marsh Creek watershed and is a potential source of mercury to the Dutch Slough restoration site (Dutch Slough site). Analysis of the quality of Marsh Creek incorporated data on mercury in order to assess possible degradations due to this abandoned mine.

The Brentwood Waste Water Treatment Plant (WWTP) is located along the lower reaches of Marsh Creek. WWTPs are regulated via the National Pollutant Discharge Elimination System (NPDES) to ensure hazardous and elevated concentrations of constituents are not surpassed. Even so, WWTP discharges do contain measurable concentrations of many regulated constituents, as well as some unregulated constituents such as endocrine disruptor compounds. Therefore, analysis of the load contribution of various constituents to Marsh Creek was included to determine the importance of the Brentwood WWTP as a source of contaminants to the Dutch Slough site.

In order to comprehensively assess the water sources that would provide water from freshwater and tidal sources for the Dutch Slough site, data from Big Break was also incorporated as a surrogate of the water quality of Little Dutch Slough and Emerson Slough. Big Break is located just to the northwest and was determined to be the most representative station with water quality data in close proximity to these sloughs Big Break is part of the Bay-Delta network, therefore, a mixture of water from the Sacramento River, San Joaquin River, and ocean create the resultant quality of water. Because the Bay-Delta water is “downstream” of many abandoned mines, and agricultural and urban areas, Big Break data was analyzed to assess if these sources have caused concentrations of mercury and other constituents to exceed aquatic life criteria.

Potential export water quality from the Dutch Slough wetland restoration site needs to be assessed; organic carbon and mercury are two constituents of concern for export water quality from the site. Wetlands can potentially increase organic carbon levels. Organic carbon, while generally beneficial for ecosystem productivity, is a concern in the Delta because it can potentially increase to levels that reduce the ability of drinking water treatment facilities to apply treatment processes to source waters that will result in finished or potable water that meets drinking water regulatory standards. Mercury is a prominent water quality contaminant within the Bay-Delta. According to available data, wetlands often convert mercury into methylmercury (MeHg) (DiPasquale, 2003) which is a bioavailable form that can accumulate in the food chain and adversely affect the health and fitness of fish and birds. Elevated MeHg levels in fish can also result in mercury exposure in humans who consume contaminated fish (National Research Council Committee on the Toxicological Effects of Methylmercury, 2000). For this reason, constructing a wetland in an area where there is a source of mercury can be a concern. While there are currently no enforceable standards for organic carbon and mercury in the Delta, there may be in the future and these issues should be closely examined. In addition, wetlands can often filter out some contaminants, therefore providing an improvement in export water quality in comparison to the influent water quality.

1.5.1.2 Analyzing the Feasibility of Diverting Marsh Creek On or Off Site

In order to assess the feasibility of diverting Marsh Creek onto the Dutch Slough site several data sources were analyzed to define the quality of Marsh Creek. In addition, projections were made for urban loads of constituents of concern to gage the magnitude of future Marsh Creek degradation.

1.5.2 Site Information

Soil and Groundwater Remediation

As part of the review of water and sediment quality, BC reviewed existing available site information related to potential pollution of groundwater, surface water, or soil. Three Phase I Site Assessments (Phase I) for properties which are included as part of the Dutch Slough site were conducted in 2003 (Engeo, 2003a; Engeo, 2003b; Sequoia, 2003). The three properties encompass most of the project site.

Several potential sources of pollution were identified as a result of the Phase I Site Assessments. Phase II soil and groundwater remediation issues associated with the purchase and sale agreements for the Dutch Slough Properties were completed and Phase II soil and groundwater testing on the Gilbert and Emerson parcels indicated that nitrate and nitrite levels in the soil are well below residential and aquatic toxicity levels and the average nitrite and nitrate concentrations in the groundwater were well below state drinking water criteria (Department of Water Resources, 2003). Phase II soil and groundwater testing on the Burroughs parcel showed trace levels of petroleum hydrocarbons and mercury levels were below the detection limit (Department of Water Resources, 2003). Residual pockets of petroleum are not high enough to be of concern and bioactivity will breakdown component parts and be adsorbed by organic material and silt (Department of Water Resources, 2003).

Land Use

Historic and current land use of these properties includes dairy operations, a ranch complex, cattle grazing, livestock care, holding pens, manure separation, storage areas, natural gas wells, residences, and related structures. Surrounding land use is similar to that of the project site and is primarily used for agricultural purposes. However according to zoning maps provided by the City of Oakley, which detail the General Plan for 2020, much of the surrounding land is scheduled to be developed, primarily into residential area.

1.5.3 Source Watersheds Water Quality Data

1.5.3.1 Marsh Creek

Flow. Flow data for Marsh Creek at Brentwood was obtained from the USGS National Water Information Systems (http://waterdata.usgs.gov/nwis/rt). The monthly average flow from 2001 to 2003 ranged between 1.4 and 11.2 ft^3/s, with an average annual flow of 4.1 ft^3/s (Figure 1). The flow in Marsh Creek was greater during the wet weather season from January to April, with the exception of February.

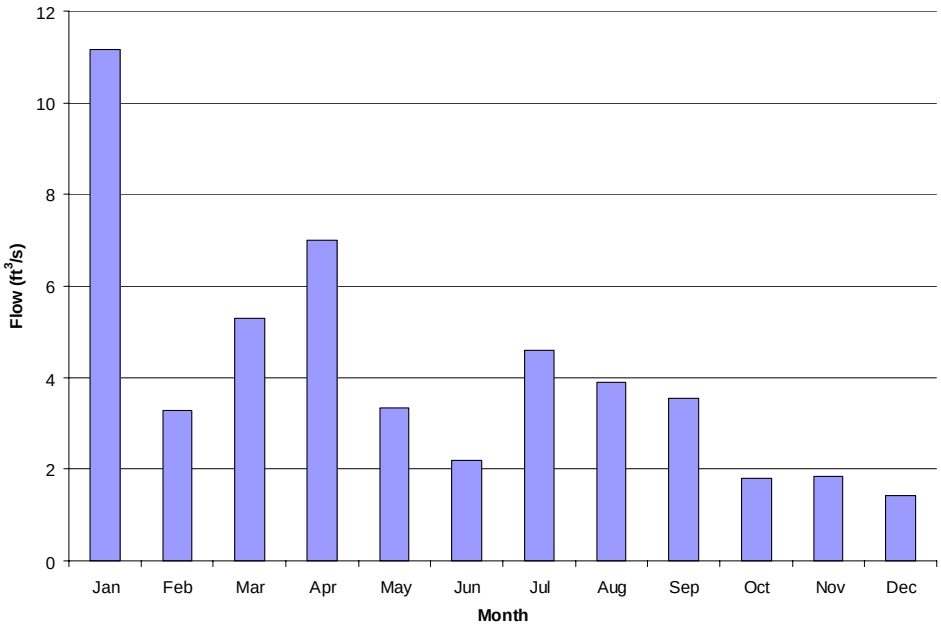


Figure 1. Marsh Creek Average Flow (2001-2003)

TOC. Water quality data for Marsh Creek provided by the Contra Costa Water District was analyzed for the years 2001 through 2003 (See Appendix A). Average monthly TOC concentrations in Marsh Creek were fairly consistent with an annual average of 4.36 mg/L (Figure 2). The minimum TOC concentration was 3.05 mg/L and the maximum was 7.40 mg/L.

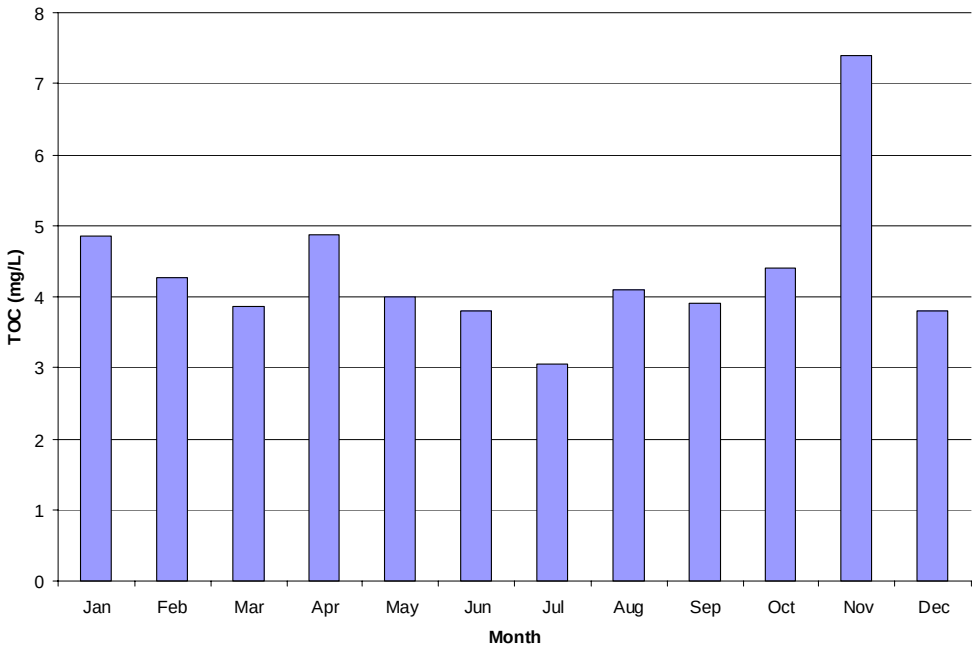


Figure 2. Marsh Creek Average TOC (2001-2003)

Loads were calculated using the following equation:

Conc. (mg/L) * Flow (ft^3/s) * 28.32 L/ 1 ft^3 * 86,400 s/day * 1 mg/1,000,000 kg.

Applying the average monthly flow from Figure 1 to the TOC concentrations yielded monthly average loads between 27 – 133 kg/d, with an annual average load of 55 kg/d (Figure 3). The TOC loads followed a similar trend as the flow values, with increased loads frequently occurring during higher flow periods.

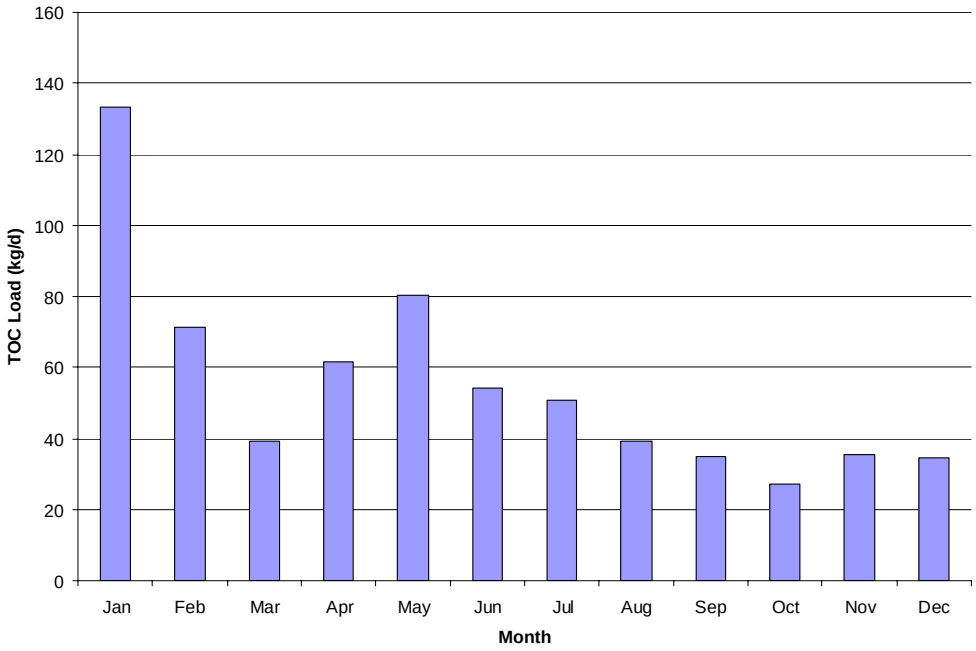


Figure 3. Marsh Creek Average TOC Loads (2001-2003)

Mercury

Surface Water and Sediment Data. Slotton et al. (1996) investigated the variations in total, dissolved, and sediment adsorbed mercury at several locations along Marsh Creek and associated tributaries. The sampling event took place in March of 1995, following a storm event during high flow. In addition to collecting mercury water quality, flow measurements were also taken during the sampling event. Sampling incorporated sites from above Mt. Diablo mine, an abandoned mercury mine, above and below Marsh Creek Reservoir, and also a station farther downstream near the city of Oakley. A summary of their findings is provided in Table 1.

Table 1. Marsh Creek Flow and Mercury Concentrations from March 1995 Sampling Event

Site		Concentration				Load			
	Flow (cfs)	Mercury, Total (ng/L)	Mercury, Dissolved (ng/L)	Total Suspended Solids (mg/L)	Solids Mercury (mg/kg TSS)	Mercury, Total (g/day)	Mercury, Dissolved (g/day)	Total Suspended Solids (kg/d)	Solids Mercury (g/d)
Marsh Creek above Reservoir	111	37.67	8.80	23	1.25	10.23	2.39	6,273	7.84
MarshCreek below Reservoir	116	43.70	7.47	35	1.05	11.87	2.03	9,396	9.87
Marsh Creek @ Delta Road	107	37.80	6.44	54	0.58	10.27	1.75	14,610	8.47
Note: Slotten et al, 1995 Report source of data									

Flow during the time of sampling was significantly greater than the monthly averages calculated from the USGS 2001 - 2003 data. This is most likely due to sampling taking place directly following an intense storm event which causes rapid brief increases in flow. The technique Slotten et al.(1996) used to quantify flow was to measure the cross-sectional area of the channel and to drop a current float into the creek. The time was then recorded for the float to travel a specified distance. This method is known to over-estimate flow because the float is transported downstream in the higher velocity currents and does not account for the lower velocities along the cross-channel. Sampling intentionally occurred under these conditions because rain events are conducive to runoff from mine tailings and their investigation focused on the significance the Mt. Diablo abandoned mine has on the Marsh Creek system as a source of mercury contamination. In addition, Slotton et al. (1996) noted that 1995 was an exceptionally wet year. Therefore these mercury concentrations and loads are representative of high flow conditions during a wet year. During peak flows, concentrations of metals and other constituents are diluted, thus the concentrations are lower. During the summertime in Marsh Creek, the flows are lower which provide less dilution of metals, such as mercury. Therefore, the March event results from Slotton et al. (1996) may be indicative of an annual minimum concentration in Marsh Creek, with the rest of the year having higher mercury concentrations. In contrast, loads of various constituents are usually greatest during high flow, therefore, Marsh Creek mercury loads would be lower during lower flow events and dry season base flow conditions.

Results from the March 1995 sampling event found total mercury concentrations remained fairly steady from above Marsh Creek Reservoir to the furthest downstream site near Oakley, with concentrations varying between 37.67 – 43.70 ng/L (~0.04 µg/L). In addition, dissolved mercury concentrations were also relatively consistent, with concentrations ranging from 6.44 – 8.80 ng/L (~0.01 µg/L). These findings suggest total and dissolved mercury concentrations do not necessarily decrease from upstream to downstream along lower Marsh Creek below Marsh Creek Reservoir.

Total suspended solid (TSS) samples were collected during the Slotton study. The amount of mercury associated with these solids was incorporated into analysis to determine the importance of TSS with respect to the transport of mercury within Marsh Creek. The TSS concentration was found to increase longitudinally from upstream to downstream. In contrast, the amount of mercury adsorbed to these solids decreased from 1.25 mg/kg TSS to 0.58 mg/kg TSS. This can be attributed to the majority of the additional TSS entering Marsh Creek as runoff lower down in the watershed, with a lesser source being instream re-suspension of creek sediments. The main source of mercury transported via TSS most likely originated predominately from the upper watershed in close proximity to the Mt. Diablo mine.

Loads were calculated using the flows and concentrations reported from Slotton et al. (1996) for the wet year high flow event. Similarly to concentration results, the total and dissolved mercury loads did not vary substantially from above Marsh Creek Reservoir to the Oakley station. Total mercury loads showed a slight increase from 10.23 g/d to 10.27 g/d. In contrast, dissolved mercury loads decreased from 2.39 g/d to 1.75 g/d. The TSS load more than doubled from the upper to lower Marsh Creek site, increasing from 6,273 kg/d to 14,610 kg/d. In contrast to the TSS mercury concentration results, the mercury load associated with TSS showed an increase longitudinally, increasing from 7.84 g/d to 8.47 g/d.

Benthic Macroinvertebrate and Fish Data. Results from Slotton et al. (1998) provided information on the mercury concentrations bio-accumulated in benthic macroinvertebrates and fish whole body composites and muscle tissues. It is important to note these results are not directly comparable because different trophic levels of benthic macroinvertebrates and different size and weight of fish were analyzed in this study. The larger and older the fish, the more opportunity there is for mercury accumulation. In addition, as mercury is transported up through the trophic levels, it biomagnifies in the food chain.

Benthic macroinvertebrates are often used as indicators of stream health. They can provide more information than a water grab sample because the success of survival is dependent on the on-going annual stream quality. Benthic macroinvertabrates are often seen as more useful bio-indicators than fish because they are not as mobile and also have a short life span (one year for most species) (Slotton et al., 1998).

In total, there were 14 benthic macroinvertebrate samples taken from above Marsh Creek Reservoir and 10 samples below. The dry weight mercury concentration above Marsh Creek Reservoir resulted in a minimum of 0.04 ppm, a maximum of 0.57 ppm, and an average of 0.27 ppm. The downstream of the reservoir sampling site results were similar to above, with a dry weight mercury minimum of 0.04 ppm, a maximum of 0.50 ppm, and an average of 0.25 ppm. Therefore the bioavailability of mercury does not appear to change significantly above and below the reservoir during these sampling years of 1995-1997.

Slotton et al. (1998) found a lack of benthic macroinvertebrates insects at the Marsh Creek Oakley site from 1995 – 1997, therefore, crayfish samples were taken instead to determine mercury concentrations. They attributed the absence of typical insect species to local agricultural and urban drainage causing extensive degradation to Marsh Creek. The average dry weight tail muscle mercury value for 1995-1996 was 0.28 ppm. This is not directly comparable to the benthic macroinvertebrate insects results because of the difference in life span and size of crayfish. Even so, the average dry weight mercury concentration for these invertebrates from above the reservoir to the Oakley station only ranged between 0.25 – 0.28 ppm.

In total, composite whole body fish data were analyzed for mercury concentrations in 13 fish above Marsh Creek, 8 fish below, and 3 fish at the lower Oakley site for the years 1995 – 1997. The average whole body fish mercury level was 0.17 wet wt ppm above the reservoir, 0.23 ppm below the reservoir, and 0.09 ppm near Oakley. These results could be misleading because of the variations in fish sizes at these sites since mercury bio-accumulates as organisms grow and eat. The average weight was 7.22 g above the reservoir, 8.09 g below the reservoir, and 6.37 g near Oakley. Mercury concentrations and fish weight show the same trend, indicating the mercury concentrations may be correlated to fish size rather than available in-stream mercury concentrations.

In addition to composite whole body analysis of fish mercury levels, the muscle tissue was also analyzed for mercury concentrations. Mercury preferentially accumulates in muscle tissue, therefore these concentrations are usually greater than composite whole body concentrations. The results for muscle mercury concentration showed, on average, a continual decrease from upstream to

downstream. The average mercury wet wt concentrations were 0.52 ppm for 4 fish above the reservoir, 0.43 ppm for 6 fish below the reservoir, and 0.12 ppm for 7 fish at the Oakley site. The corresponding average weights were 18.5 g, 24.0 g, and 19.6 g longitudinally along Marsh Creek. The weight and average mercury concentrations do not follow the same trend in this case.

Comparison to Regulatory Criteria and Biota Thresholds. Mercury concentration and load results from Slotton et al. (1996) provided important information that is directly applicable to the viability of diverting Marsh Creek to the Dutch Slough site. The US EPA continuous total mercury concentration criteria for freshwater aquatic life protection is 0.77 µg/L and for marine aquatic protection is 1.4 µg/L (EPA, 2002). The lower Marsh Creek sampling location had total mercury concentrations of about 0.04 µg/L and dissolved mercury concentrations of about 0.01 µg/L, both of which are below aquatic criteria. In addition to these concentrations, the 54 mg/L TSS transported in Marsh Creek at this site contained 0.58 mg/kg TSS of mercury, which corresponds to 0.031µg/L total mercury transported via TSS.

The loads determined from Slotton et al. (1996) show that Marsh Creek was a significant source of mercury during the March 1995 storm event. Loads for the various mercury species were 10 g/d total mercury, 2 g/d dissolved mercury, and 8.5 g/d TSS mercury. Therefore, if Marsh Creek were to be diverted into the Dutch Slough project site, it may function as a continual source of mercury. The mercury associated with the sediments may provide a source of mercury for methylation. This could further increase the concentrations of bioavailable mercury to aquatic organisms.

Brentwood WWTP

Water quality and flow data provided by the Brentwood NPDES Monitoring Program were analyzed to determine the significance of the WWTP as a discharge to Marsh Creek. For the years 2000 – 2004, minimum, maximum, and average concentrations for various constituents are shown in Table 2.

The Brentwood Waste Water Treatment Plant contributes a significant amount of flow to Marsh Creek. An analysis of the WWTP and Marsh Creek flows showed that an average of 18% of the wet weather flow and 61% of the dry weather Marsh Creek flow comes from the WWTP. Therefore, the WWTP may have a significant effect on the water quality of Marsh Creek at the proposed point of diversion.

Table 2. Brentwood WWTP Discharge Concentrations (2000-2004)

2000-2004	Flow MGD	BOD mg/L	NH3 mg/L	NO3 mg/L	P mg/L	TDS mg/L	Total Coliform MPN/100 mL
Minimum	0.5	1	0.05	0.22	0.69	820	2
Maximum	3.0	12	1.90	13.00	3.40	1,400	1,600
Average	2.1	3	0.38	3.04	1.97	1,231	128

Loads were also calculated for the Brentwood WWTP effluent from the years 2000-2004. Table 3 contains the summary results of the various constituent loads. The WWTP contributed a substantial load of all constituents analyzed to Marsh Creek.

Table 3. Brentwood WWTP Loads (2000-2004)

2000-2004	BOD kg/d	NH3 g/d	NO3 kg/d	P kg/d	TDS kg/d
Minimum	82,625	189	70,240	136,569	70,240
Maximum	429,374	5,429	429,374	401,019	429,374
Average	348,276	2,199	305,295	297,430	294,100

There is a heightened awareness in recent years of the environmental implications of endocrine disrupting chemicals (EDCs) and pharmaceuticals and personal care products (PPCPs) (Ying et al., 2004). Endocrine disruptors are exogenous compounds that alter the synthesis, secretion, transport, binding, action, or elimination of natural hormones in organisms that maintain homeostasis, reproduction, development, and/or behavior (EPA, 1997). Sources of endocrine disruptors include synthetic chemicals and also natural chemicals, such as phytoestrogens derived from plants (EPA, 1997). PPCPs include pharmaceutical drugs, ingredients in cosmetics, food supplements, and their associated metabolites and transformation products (Daughton and Ternes, 1999). Currently, the effects on organisms from PPCPs are poorly understood (Daughton and Ternes, 1999). Even so, PPCPs are designed to serve a biologically active role in humans, therefore, they may have unintentional effects to organisms in the environment (Ying et al., 2004). Currently there are not any Marsh Creek data available for these chemicals, however the concerns they present should be considered given the location of the Brentwood WWTP on Marsh Creek.

Both EDCs and PPCPs have been measured in WWTP effluents, with concentrations ranging in magnitude from ng/L to µg/L (Ying et al., 2004). In general, hormones are detected in the < 10 ng/L range, but alkylphenols and their ethoxylates are commonly detected in the µg/L range (Ying et al., 2004). Purdom et al. (1994) proposed alkylphenol-polyethoxylates and ethynylestradiol are the predominant estrogenic compounds found in WWTP effluents.

The presence of EDCs and PPCPs is of concern because there is increasing evidence that these chemicals, at continuous low-level concentrations, can deleteriously affect the endocrine systems of

aquatic organisms (Hayes et al, 2002; Damstra et al., 2002). Some of the effects observed to date for EDCs include thyroid malfunctions, sex alterations, hindered reproductive success, and reduced growth (EPA., 1997). For example, hermaphroditic fish have been found in waterbodies downstream of WWTPs (EPA, 1997).

Urban and Agricultural Runoff

Currently, data are not available for constituent concentration and loads from sources of urban and agricultural runoff within the Marsh Creek watershed. A study of the storm water runoff in the City of Sacramento can be used to provide the best available data that may be representative of what may be found in the Marsh Creek watershed. The study included the collection of samples from three discharges, including Strong Ranch Slough, Sump 111, and Sump 104 (LWA, 2003). Water samples were collected for analysis of organic carbon, nutrients, TDS, and pathogens during both dry and wet seasons during 2002 and 2003. A summary of the Sacramento City stormwater results is provided in Table 4. As is shown, urban runoff can be an important source of TOC and dissolved organic carbon (DOC) during both wet weather and dry weather seasons.

Table 4. Sacramento City Seasonal Urban Concentrations (2002-2003)

2002-2003		Ammonia as N (mg/L)	Nitrate + Nitrite as N (mg/L)	Phosporus, Total (mg/L)	Total Kjeldahl Nitrogen (mg/L)	E. coli (MPN/100mL)	Fecal Coliform (MPN/100mL)	Total Colifrom (MPN/100 mL)	DOC (mg/L)	TOC (mg/L)	TDS (mg/L)
Dry weather	Minimum	0.2	0.1	0.2	1.0	300	300	30,000	8	9	60
	Maximum	1.2	5.2	0.6	2.4	30,000	30,000	500,000	28	29	960
	Average	0.5	1.6	0.4	1.5	6,333	8,667	220,000	14	15	405
Wet Weather	Minimum	0.2	0.3	0.2	0.7	800	800	28,000	5	6	26
	Maximum	0.5	0.8	1.3	1.7	70,000	70,000	1,600,000	60	69	72
	Average	0.4	0.5	0.4	1.4	23,644	24,089	419,778	17	20	41

Urban and agricultural runoff present an additional concern during dry weather months. The low flows during dry weather periods may become concentrated with pollutants from runoff and other discharges. At times, creeks in urban areas are subjected to illegal discharges (such as water containing oil/grease, solvents, cleaning chemicals, pesticides, and chlorinated water from swimming pools). During low flow periods, there is less water available in the creek to dilute these substances, which may create a risk to the receiving ecosystem.

1.5.3.2 Emerson Slough and Little Dutch Slough

Water Quality Data. Currently, flow and water quality data are not available for either Emerson Slough or Little Dutch Slough. Data from the Big Break station is the best available data that may be representative of water quality in the sloughs. Emerson Slough and Little Dutch Slough receive water from Dutch Slough with Big Break located directly to the west and the southern tip of Frank's Tract located to the east. The direction of flow in Dutch Slough is controlled by the volume of flow, pumping practices at the Rock Slough intake, and tide cycles.

Total mercury concentrations in Big Break (west of the Dutch Slough site) were consistently 1 µg/L from 1988 – 1993, with samples taken twice annually, every May and September

(http://baydelta.ca.gov/). The Big Break mercury data may not be representative of total mercury concentrations because the sampling design did not account for the variation in mercury concentrations associated with the diurnal tidal cycle. In addition to total mercury, a summary of other water quality constituents from the years 1994 – 1995 is provided in Appendix A. More current data are not available for Big Break at this time.

Comparison to Regulatory Criteria and Biota Thresholds. The freshwater and marine surface water criteria for aquatic life are 0.77 µg/L and 1.4 µg/L total Hg respectively. The concentration of total mercury in Big Break is currently unknown, but was 1 µg/L from 1988 – 1993. As a result, establishing a tidal connection to the Dutch Slough site could potentially expose site biota to total mercury concentrations that exceed the criteria for aquatic life in addition to providing a source of mercury for MeHg production within the project site. However the usefulness of the Big Break data is limited for the reasons discussed above, and therefore no significant conclusions can be drawn.

1.5.4 Export Water Quality

There are many factors that can affect the quality of the water exported from a restored wetland, which can make predicting outflow concentrations or loads difficult. Since a tidal wetland does not currently exist on this site, there is not any available site-specific data for export water quality. However, information regarding the potential export water quality can be obtained by reviewing available literature, as well as water quality data from similar projects.

Overall wetlands are often good filters of pollutants, particularly for constituents such as nutrients, metals, biological oxygen demand (BOD), total suspended solids (TSS), and some pathogens. Therefore, wetlands can provide an improvement in export water quality in comparison to the influent water quality. Even so, wetlands can also increase certain constituents, for example, DOC and MeHg. These two constituents are a primary concern for the Dutch Slough site.

1.5.4.1 Organic Carbon

Organic carbon, TOC and DOC, are two of the primary constituents that are of concern. Organic carbon, while generally good for ecosystem productivity, is a concern in the Delta because it can negatively affect drinking water quality. DOC is a disinfection byproduct precursor (DBP) for methods used to treat drinking water taken from the Delta (American Water Works Association, 1999). DBP's form during water disinfection chlorine reacts with certain organic materials to create trihalomethanes (THMs), including chloroform in particular. Toxicological studies undertaken on chloroform suggested that it was carcinogenic to laboratory animals, although at levels much higher than those found in drinking water. Through CALFED, a Record of Decision (ROD) was developed in 2000 to represent the long-term plans associated with ecosystem restoration and water quantity and quality management for the Bay-Delta system (CALFED, 2000). The ROD suggested a source water target of 3 mg/L TOC to achieve an optimal level of public health. There are three drinking water intakes located near the Dutch Slough site: the Contra Costa Old River intake, Contra Costa Rock Slough intake, and the Harvey O. Banks intake. Therefore, it is of interest to assess the effects a restored tidal wetland at the proposed site would have on the export of organic carbon from the restoration site.

Restored wetlands potentially have a high amount of organic carbon left in their system since a natural wetland once existed there. Wetland ecosystems naturally have a high productivity and in turn high organic carbon contents. As water is conveyed through the wetland, or in the case of a tidal wetland the diurnal tide cycle creates a flow in and out of the wetland, organic carbon can be entrained in the flow and be exported from the wetland resulting in high TOC and DOC concentrations and loads. However this process usually reaches equilibrium after several years and organic carbon concentrations will drop from what they were initially. A typical concentration for DOC leaving a restored wetland that has reached equilibrium is 5 mg/L (Crites, personal communication, 2005). Overall there is often a concern that wetlands can increase the amount of organic carbon in the water. As part of studies performed by the USGS, the following information regarding dissolved organic matter (DOM) was reported in a CALFED proposal (Bergamaschi et al., 2005):

> Waters from 10 sites, spanning representative tidal and non-tidal wetlands, rivers, channels, and agricultural lands were seasonally collected over 24 months. Preliminary results from this study indicate that wetlands are the source of up to 40% of the DOM in water diverted from the Delta despite the fact that only 5% of the present Delta landscape remains as wetlands (Bergamaschi et al., 2003). These preliminary results from the current study suggest that wetland DOM may have a large impact on the reactivity, bioavailability, methylation, and transport (loads) of Hg in the Delta and Estuary because of its substantial contribution to Delta channel DOM.

The USGS (Bergamaschi, personal communication, 2005) has studied DOC at Twitchell Island, non-tidal wetlands managed for small-scale subsidence reversal experiments located approximately 5 miles north of the Dutch Slough site. Data from the Twitchell Island wetland may not be representative of the export water quality that may occur at Dutch Slough for a number of factors. One primary factor is that while the Twitchell Island wetland is a flow through wetland, it is not a

tidal wetland that was restored primarily for habitat purposes. The wetland at Twitchell was primarily to address land subsidence issues and likely has higher residence times than would be expected at a tidal wetland. A longer residence time allows more time for the water to obtain DOC from the wetland substrates. Therefore, DOC concentrations seen in the outflow of the Twitchell Island wetland may represent a worst case for what could occur at the Dutch Slough site.

DOC export water concentrations and loads at Twitchell increased consistently from influent levels. DOC outflow concentrations typically ranged from 3.0 mg/L to 6.0 mg/L and outflow loads were approximately 1260 kg/yr. Outflow DOC concentrations were highest in the surface water during the months of April, May, and June. Preliminary results from Brown's Island indicate that the wetland there is a sink for sediment and a source for DOM to surrounding waters (Bergamaschi et al., 2003).

1.5.4.2 Methyl Mercury

Mercury, and the potential for mercury methylation in wetland environments, is a concern for export water quality from wetlands. MeHg is a bioavailable form of mercury, creating toxicity concerns for fish and other organisms as it bioaccumulates in the food chain. The study of mercury methylation in wetlands and other areas is an emerging science, and many unknowns exist. A source of mercury must be present for mercury methylation to occur, and several factors affect the process. The factors are believed to include the amounts of dissolved organic matter (DOM) and hydrogen sulfide (HS) present. These two constituents control whether sedimentary mercury becomes dissolved, which is a necessary first step in mercury methylation. The total net export of MeHg off of a site is influenced by other factors as well which are believed to include a number of site specific processes such as solubilization, oxidant supply, physical dynamics, microbial rates, atmospheric and sedimentary loss, and other variables. (Bergamaschi, 2003) As part of a proposal to CALFED (Bergamaschi et al., 2005) from the USGS, indicates that analysis of mercury samples and data could not establish a clear conclusion as to whether or not the net flux of resuspended material is onto or off of Browns' Island. The mercury data from Browns' Island is summarized as follows:

> Total and dissolved mercury samples were collected for 12 hours over a single tidal cycle and analyzed for methlymercury content. Variations in methlymercury content and partioning were observed over the tidal cycle. The peak concentration in total mercury occurred only in the unfiltered samples near the peak in tidal velocities in the channel, suggesting that particle resuspension is the cause of the peak rather than actual exchange between the wetland and river water. Insufficient data were collected to assess if the net flux of this resuspended material is onto or off of Brown's Island. More importantly, higher concentrations of both raw (2X) and filtered (5X) MeHg were found at max low tide than max high tide, suggesting that wetland derived water is higher in MeHg than the surrounding river water.

Mark Stephenson at Moss Landing Marine Labs has conducted research analyzing the varying amounts of MeHg being exported from wetlands, particularly in the Delta and Suisun Marsh. In a conversation with Mr. Stephenson, he explained the driving factors for mercury methylations may be low dissolved oxygen (DO) levels, poor circulation of water, and abundant organic matter. One marsh he has studied in Suisun Bay has been found to be a sink for MeHg while another was a

source. Mr. Stephenson's research is showing that depending on the situation, a marsh can either be a sink or a source for MeHg. He mentioned that without detailed mercury and flow data for a site, which is not available at Dutch Slough, a determination of whether it will be a sink or source cannot really be made (Stephenson, 2005).

The Central Valley Regional Water Quality Control Board (CVRWQCB) is currently working on a Basin Plan Amendment to address mercury in the Delta. In a conversation with Chris Foe at the CVRWQCB, he stated that they will likely propose no net increase of MeHg exports from newly created marshes. (Foe, personal communication, 2005) As a result, MeHg concentrations in the inflow and outflow, both before and after the restoration project, would need to be monitored. The net increase would be determined by analyzing loads, not concentrations, so this is dependant upon flow as well as concentrations. If the wetland/marsh is found to be producing a net increase, monitoring and studies would be necessary to determine how to minimize these affects. Mitigation in another area would also be necessary. While it is uncertain whether the proposed no net increase for MeHg will be approved, the possibility should be considered.

1.5.5 Future Water Quality Conditions/Concerns

Multiple factors could affect the future water quality in Marsh Creek, some which cannot be predicted. However one that can be estimated is the affect that future development in the watershed may have on runoff concentrations and loads. The historic and present use of land immediately surrounding the project site has predominantly been agricultural and open space areas. The cities of Oakley and Brentwood are within the source watershed for the Dutch Slough site, and are currently expanding in population and converting agricultural and open space areas to urban land uses. Zoning maps for Oakley's 2020 General Plan show that most of this upstream land will be developed and converted into primarily residential areas, with a small amount of interspersed commercial, park, and public land. The Dutch Slough Tidal Marsh Restoration Project Preliminary Opportunities and Constraints Report indicated that the City of Oakley may approve plans to develop approximately 480 acres immediately south of the Dutch Slough site. The development would consist of more than 2,000 commercial and residential units and would likely be constructed in the following five years. (Natural Heritage Institute, 2004) Developing such a significant amount of area within a watershed and effectively changing the land use type could change concentrations and loads of constituents in Marsh Creek.

In order to determine possible water quality changes in Marsh Creek, it is important to identify and estimate increased loads that are associated with urban growth. The County of Sacramento monitored urban runoff from 1989 to 1995 and the data are representative of urban loads (LWA, 1996). Wet weather loads, dry weather loads, inter-storm loads, and annual total loads were determined in this study using empirical concentration and precipitation data, and developing regression relationships between precipitation and runoff using estimated runoff coefficients based on percent impervious area. These inputs were then applied to continuous simulation modeling for a 30 year period to determine seasonal loads.

Data sets were most complete for three storm drains (Sump 111, Sump 104, and Strong Ranch Slough), therefore only these drains were included in the model simulations performed by LWA. In

performing ANCOVA (Analysis of Covariance) and regressions on the wet weather concentration data, it was found that differences were insignificant between various urban land use types including industrial and residential/commercial. Due to this finding, the load simulations performed were not done individually for the three drains, but were rather averaged together to provide representative concentration values as input for the model.

The wet weather, dry weather, inter-storm, and annual total loads were determined for the entire Sacramento urban watershed which is about 302 mi^2 (193,280 acres) (Table 5). The loads found for the various constituents were normalized on a per area basis. This enables a projection of possible loads associated with urban areas of various sizes, namely Brentwood and Oakley in this case. As is shown in Table 5, urban runoff is a source of many pollutants including metals, nutrients, BOD, oil and grease, TDS, and TSS. In general, there is an order of magnitude difference between wet weather and dry weather loads for the various constituents. Therefore, loads associated with urban runoff would be predominately of concern for the integrity of Marsh Creek water quality during the winter and early spring during storm events.

Table 5. Normalized Urban Loads from Sacramento City (2002-2003)

Constituent	Units Normalized (per acre)	TOTAL	Wet Weather	Dry Season	Inter-Storm
Cadmium (TR)	lbs/ac/yr	7.30E-04	5.43E-04	9.31E-05	9.31E-05
Chromium (TR)	lbs/ac/yr	8.44E-03	6.46E-03	9.73E-04	1.01E-03
Copper (TR)	lbs/ac/yr	2.63E-02	1.65E-02	4.79E-03	5.00E-03
Lead(TR)	lbs/ac/yr	2.60E-02	2.45E-02	7.50E-04	7.81E-04
Zinc (TR)	lbs/ac/yr	1.85E-01	1.40E-01	2.22E-02	2.32E-02
Cadmium (D)	lbs/ac/yr	2.85E-04	1.55E-04	6.21E-05	6.21E-05
Chromium (D)	lbs/ac/yr	1.95E-03	1.08E-03	4.24E-04	4.45E-04
Copper(D)	lbs/ac/yr	1.61E-02	7.97E-03	3.97E-03	4.14E-03
Lead (D)	lbs/ac/yr	2.73E-03	2.12E-03	3.00E-04	3.10E-04
Zinc (D)	lbs/ac/yr	1.08E-01	7.19E-02	1.78E-02	1.86E-02
Ammonia	tons/ac/yr	5.38E-04	3.16E-04	1.09E-04	1.14E-04
BOD	tons/ac/yr	1.09E-02	8.57E-03	1.13E-03	1.18E-03
Hardness	tons/ac/yr	5.01E-02	1.12E-02	1.91E-02	1.99E-02
Nitrate	tons/ac/yr	4.20E-03	9.31E-04	1.56E-03	1.71E-03
Oil and Grease	tons/ac/yr	1.53E-03	1.33E-03	9.83E-05	1.03E-04
Phosphorous	tons/ac/yr	3.67E-04	1.97E-04	8.28E-05	8.80E-05
TDS	tons/ac/yr	1.12E-01	2.92E-02	4.04E-02	4.22E-02
TSS	tons/ac/yr	3.55E-02	3.18E-02	1.79E-03	1.87E-03

Load increases that could be expected if the 480 acres mentioned above were to be developed into commercial and residential area were calculated and are shown in Table 6. Most of the projected constituent load values associated with development of this area are low and would not be a concern to ecosystem integrity. Even so, a couple constituent loads are high, including zinc, with a total

recoverable load estimate of 89 lbs/yr. TDS loads were also high, with an estimated value of 54 tons per year.

Table 6. Estimated Potential Loads for Oakley Urban Development

Constituent	Units	TOTAL	Wet Weather	Dry Season	Inter-Storm
Cadmium (TR)	lbs/yr	0	0	0	0
Chromium (TR)	lbs/yr	4	3	0	0
Copper (TR)	lbs/yr	13	8	2	2
Lead(TR)	lbs/yr	12	12	0	0
Zinc (TR)	lbs/yr	89	67	11	11
Cadmium (D)	lbs/yr	0	0	0	0
Chromium (D)	lbs/yr	1	1	0	0
Copper(D)	lbs/yr	8	4	2	2
Lead (D)	lbs/yr	1	1	0	0
Zinc (D)	lbs/yr	52	35	9	9
Ammonia	tons/yr	0	0	0	0
BOD	tons/yr	5	4	1	1
Hardness	tons/yr	24	5	9	10
Nitrate	tons/yr	2	0	1	1
Oil and Grease	tons/yr	1	1	0	0
Phosphorous	tons/yr	0	0	0	0
TDS	tons/yr	54	14	19	20
TSS	tons/yr	17	15	1	1

1.5.6 Sediment Quality

1.5.6.1 Site Sediment Considerations for Restoration (excavation at open water areas)

Quality of sediment, both that which is currently on the project site as well as that which would be deposited in the future, is an important factor that should also be considered in evaluating the feasibility of the proposed alternatives. Although Marsh Creek does not currently empty onto the site, it did historically until sometime between 1978 and 1986. Therefore most of the sediment from Marsh Creek has historically been delivered to Dutch Slough site, not Big Break where the mouth of the creek is currently located (Natural Heritage Institute, 2004). Sediments that have been and will be deposited by Marsh Creek are potentially contaminated with mercury which may adversely affect wetland vegetation and biota.

One concern is that as part of the restoration activities these sediments are likely to be disturbed, primarily by grading or excavation work. Grading is proposed in all of the action alternatives. Excavation may be used to create tidal channels, open water areas, and to divert Marsh Creek onto the property. Disturbing contaminated sediments remobilizes them into the environment, spreading the contamination and potentially creating a greater risk. An additional concern is how this potentially contaminated excavated material will be used or disposed of. One option that was

identified in the Dutch Slough Preliminary Alternatives Memorandum is that excavated material may be used in other areas of the wetland restoration (PWA, 2005). However this would only increase the associated risk if the sediments are contaminated. Contaminated sediments may also be difficult to dispose of. In addition, future inflow and deposition of contaminated sediments both stored in the Marsh Creek channel and contained in the soils of Marsh Creek watershed could present an ongoing risk to the wetland and associated organisms.

1.5.6.2 Stream Sediments

Slotton et al.(1998) investigated sediment mercury concentrations within the Marsh Creek reservoir, but not at locations above or below the reservoir. Upstream sediments could be transported downstream as either bed load or suspended load and deposited in the lower sections or mouth of Marsh Creek. Since most of the source of mercury is located upstream, concentration of upstream sediments likely represent the worst case scenario of concentrations that would be found downstream, on or near the project site. The reservoir upstream on Marsh Creek is reported to capture 100% of coarse sediment (bed load) and a portion of the suspended sediment load. (Natural Heritage Institute, 2004). Concentrations of mercury in the sediment of this reservoir were found to range from 0.27 to 0.57 ppm during 1995-1997(Slotton et al., 1998).

1.5.7 Uncertainties and Data Gaps for Feasibility Assessment

A number of data gaps and uncertainties have been identified. BC has developed a Draft Dutch Slough Water and Sediment Quality Monitoring plan which was submitted in August, 2005 to address these data gaps.

The USGS flow station at lower Marsh Creek operated from 2000 to 2003. Currently, flow is not recorded at this station. In order to know the volume of water Marsh Creek would divert into the proposed project site and well as to quantify potential loads of constituents of concern, it would be advantageous to have continuous flow values for this lower Marsh Creek site.

The Contra Costa Water District monitored various constituents, including TOC, nutrients, TDS, and pathogens monthly starting at the end of 2001 and continuing through 2003. To have an accurate representation of fluctuations that occur in these constituents and to account for seasonal variability, it would be beneficial to have concentration data on a greater time scale resolution. Having a more complete data set would provide more insight into the Marsh Creek water quality as a source to the Dutch Slough site.

During the 2001 to 2003 monitoring, Contra Costa Water District did not sample for metals, including As, Cd, Cr, Cu, Pb, Se, Ni, Ag, and Zn, all of which can be toxic to aquatic organisms. Concentration data for these constituents would be valuable for assessing the water quality of Marsh Creek. In addition, it would enable an assessment of the possible effects to aquatic organisms if Marsh Creek were to be a source of water for the proposed tidal wetland.

Currently, there is one mercury value for the lower Marsh Creek for one day in March of 2005. This concentration was collected following a series of storm events during a wet year. Therefore, these

mercury data are not fully representative of the Marsh Creek flow regime. In addition, having this one value does not provide information on the variations in mercury annually. Quantification of mercury concentrations in the Marsh Creek water column is essential in order to gage the effect of diverting Marsh Creek onto the proposed project site.

Sediment may be an important source of mercury to the Dutch Slough site. During the March 1995 sampling event, one TSS sample was collected and analyzed for mercury concentration. Again, this data represents the amount of TSS transported during peak flows, therefore it is not representative of the amount of TSS in Marsh Creek during the range of flow conditions that make up the Marsh Creek flow regime. No data are currently available on the mercury concentrations of sediments along the streambed of Marsh Creek. These sediments may be transported as bed load and also via re-suspension of fine sediment as suspended sediment load during peak flow storm events. Therefore, it would be beneficial to have mercury concentration data associated with these sediments.

The concentrations of mercury and other contaminants in soils and sediments of the project site are not available. While the sediments in Marsh Creek represent a potential future source of mercury to the proposed wetland if Marsh Creek is diverted, on-site sediments may be a source of mercury. This is not only important to analyze as a source once the area is restored, but to examine for issues that may be as a result of the restoration construction as a result of moving, dredging, reusing, and grading on-site sediments.

Currently, no data exists for Emerson Slough and Little Dutch Slough. These two sloughs would provide the majority of water to the proposed tidal wetlands. Therefore, it is essential to quantify the quality of water in these sloughs to determine the possible effects it may have on aquatic organisms.

In addition to the quality of water in Emerson Slough and Little Dutch Slough, it would be beneficial to have flow for these sites to be used in conjunction with the new water quality data. With the relative flows of the different sources of water known, concentrations and loads of the various constituents of concern could be quantified. This would provide information on the possible effects these sources of water would have on aquatic life.

Predicting export water quality for a proposed wetland restoration is challenging. For organic carbon and MeHg, knowledge of the processes and factors driving the production, fate, and transport of these constituents is a developing science. There are ongoing and proposed studies and monitoring programs to learn more about these processes and factors, which may provide useful information in both predicting export water quality as well as in designing a wetland to minimize export of organic carbon and MeHg. In addition, while limited data are available from other similar projects, additional data that could be used for comparison would be helpful. Site specific water and sediment quality data would be particularly useful, which would need to be obtained by sampling. In conversations with Mark Stephenson at Moss Landing Marine Labs, he stated that to accurately make a determination of export water quality relative to MeHg, detailed mercury and flow data over a 24 hour period must be available. This sampling must also be done during both spring and neap tides, as well as during various seasons (Stephenson, 2005).

Application of the DSM2 model developed by the Department of Water Resources (DWR) would be useful to determine if the export of organic carbon from the proposed Dutch Slough site will cause organic carbon concentrations to exceed the ROD target of 3.0 mg/L at the three intakes located in the Delta nearby the Dutch Slough site (Rock Slough, Old River, and Banks).

1.5.8 Conclusions and Recommendations

A review of existing Phase I site assessments for parcels comprising the proposed restoration site was performed. While several environmental issues were identified, there were none that clearly posed a significant concern for the wetland restoration.

There are many uncertainties in predicting export water quality from a proposed wetland. A limited amount of data available on-site and regionally present additional challenges. Two constituents are primarily of concern for export water quality from wetlands: organic carbon and MeHg. A proposed wetland at Dutch Slough site presents a potential to increase these constituents. However, without further data and information, the extent of this concern is undefined. In some cases, wetlands can filter out contaminants, providing an improvement in export water quality in comparison to the influent water quality. These issues should be closely considered as part of the proposed wetland restoration, and additional data needs to be obtained to more accurately assess the concerns.

Data showing concentrations of constituents of concern in on-site sediments are not available. There is limited data available for mercury adsorbed to and transported by solids in the Marsh Creek flow. If Marsh Creek is diverted to the Dutch Slough site and if the Marsh Creek suspended load mercury concentrations are similar to the suspended load concentrations found during the 1995 sampling event a source of mercury would be present for the production of MeHg. Potentially contaminated sediments both in Marsh Creek and on-site could present a concern for the wetland restoration. The Monitoring Plan describes a sampling plan that will result in a better understanding of the mercury present in the Marsh Creek bed load and suspended load and mercury present (if any) present in on-site soils.

Currently there are limited aqueous mercury data available for Marsh Creek. One sample was collected in lower Marsh Creek during high flow of March 1995 for analysis of total mercury, dissolved mercury, and mercury adsorbed to TSS. The concentrations and loads from this one sampling event are not representative of seasonal and annual variations. Due to the limited available data, no significant conclusions can be drawn regarding mercury in Marsh Creek. The proposed sampling design in the Monitoring Plan includes recommendations for additional water sampling to better define the water quality of Marsh Creek. The sampling design includes analysis of metals to assess possible toxicity to aquatic organisms. Urban runoff and wastewater treatment effluent are components of the Marsh Creek flow and may be a source of contaminants that could have adverse affects upon biota and vegetation in the Dutch Slough site.

Collecting water quality samples in Little Dutch Slough and Emerson Slough would also be beneficial since these two sloughs would be the main source of water to the proposed project site. Currently no data are available, but mercury concentrations from Big Break (if representative of the

sloughs) indicate concentrations in the sloughs may be greater than the recommended aquatic organism criteria. However the Big Break data has limitations that do not allow significant conclusions regarding water quality in the Sloughs to be drawn. Obtaining continuous flow data for these sloughs would also be advantageous to gage the magnitude of constituent loads that would be carried into the proposed restoration site.

Several alternatives exist to learn more about the potential impacts the restored wetland could have on water quality, specifically with regard to Marsh Creek. One of these alternatives is to implement a test plot wetland from which site specific data could be obtained, without subjecting the entire site to the Marsh Creek waters and the potential effects. This would allow for the testing of water column mercury concentrations and sediment concentrations of deposited sediments within the site during the full range of flow conditions without exposing the entire site to unknown level of contaminants. Studies can be done either before or after the restoration is implemented. Performing them before would result in more informed restoration decisions, although this is not crucial.

In conclusion, restoring the Dutch Slough site and diverting Marsh Creek onto the restoration site presents both benefits and risks. Sufficient data and information to appropriately assess these considerations does not currently exist. Whether or not to divert Marsh Creek should remain an option in the design until additional data and information can be collected to more accurately assess the import and export water quality associated with proposed Dutch Slough tidal wetland. The additional data will also establish baseline conditions from which to evaluate the restoration effects. Water quality concerns will be an integral part of the adaptive management process during the restoration. Water quality will be monitored and studied before, during, and after the restoration. Information that is gathered will be used in the adaptive management process to help mitigate any negative water quality effects in the Dutch Slough Restoration as well as in future restorations in the San Francisco Bay Delta Estuary.

REFERENCES

American Water Works Association, 1999. Water and Quality and Treatment: A Handbook of Community Suppliers. Fifth Edition. Denver, CO.

BDAT. Data Retrieval. (http://baydelta.ca.gov/)

Bergamaschi, B.A., Downing, B.D., Wheeler, G.A., Schoellhamer, D.H., Ganju, N.K., Fram, M.S., Erickson, D.E., Kendall, C., Bemis, B.E., Stepanauskas, R., Hollibaugh, J.T., and Fujii, R., 2003, Quantifying the contributions of tidal wetlands to dissolved organic material in the San Francisco Estuary, California, USA. Conference Abstracts: 17th Biennial Conference of the Estuarine Research Federation, Seattle, Washington, September 14-18, 2003.

Bergamaschi, B.A., Personal Communication, June 22, 2005. United States Geological Service (USGS).

Bergamaschi et al, 2005. Mercury Release from Delta Wetlands: facilitation and fluxes; an amendment to existing CALFED Projects #2000-G01.

CALFED Bay-Delta Program. 2000. Programmatic Record of Decision.

Contra Costa Water District. 2002-2003. Marsh Creek Water Quality Data.

Crites, Ronald W., P.E. Personal Communication, May 5, 2005. Brown and Caldwell.

Damstra, T., Barlow, S., Bergman, A., Kavlock, R., and Van Der Kraak, G. 2002. Global assessment of the state-of-the-science of endocrine disruptors. WHO/PCS/EDC/02/2. (http://www.who.int/pcs/emerg_site/edc/global_edc_TOC.htm)

Daughton, C.G. and Ternes, T.A. 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? *Environmental Health Perspectives*. 107 (supplement 6), 907-942.

Department of Water Resources. 2003. Environmental Remediation Associated with Dutch Slough (Burroughs, Emerson & Gilbert Parcels). October 30, 2003 letter from Tom Hall, Department of Water Resources to Mary Small, State Coastal Conservancy.

Engeo Incorporated. 2003a. Phase One Environmental Site Assessment, Burroughs Property (State Parcels) Jersey Island Road, Oakley, California.

Engeo Incorporated. 2003b. Phase One Environmental Site Assessment, Emerson Properties (State Parcels) Sellers Avenue, Oakley, California.

EPA. 2002. National Recommended Ambient Water Quality Criteria for Aquatic Life Protection. (http://www.epa.gov/ost/pc/revcom.pdf)

EPA. 1997. Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis. EPA/630/R-96/012.

Foe, C., Personal Communication, June 24, 2005. Central Valley Regional Water Quality Control Board (CVRWQCB).

Hayes, T.B., Collins, A., Lee, M., Mendoza, M., Noriega, N., Stuart, A.A., and Vonk, A. 2002. Hermaphroditic, demasculinised frogs after exposure to the herbicide atrazine at low ecologically relevant doses. *PANS*. 99, 5476-5480.

IEP. 1999. Effects of Wetland Restoration on the Production of Methyl Mercury in the San Francisco Bay-Delta System: Preliminary results. IEP Newsletter.

Larry Walker and Associates. 1996. Sacramento NPDES Stormwater Discharge Characterization Program: 1996 DCP Update Report.

Larry Walker and Associates. 2003. Discharge Monitoring Report 2002/2003. Sacramento Stormwater Management Program. Prepared for the County of Sacramento, City of Sacramento, City of Citrus Heights, City of Elk Grove, City of Folsom, City of Galt.

Marvin DiPasquale MC, Agee JL, Bouse RM, Jaffe BE. 2003. Microbial cycling of mercury in contaminated pelagic and wetland sediments of San Pablo Bay, California. Environmental Geology 43(3):260-267.

National Research Council Committee on the Toxicological Effects of Methylmercury. 2000 Toxicological Effects of Methylmercury. In: Press NA, editor. Washington, DC.

Natural Heritage Institute, 2004. Dutch Slough Tidal Marsh Restoration Project Preliminary Opportunities and Constraints Report

Philip Williams & Associates (PWA), 2005. Dutch Slough Preliminary Alternatives Memorandum. March 28, 2005.

Purdom, C.E., Hardiman, P.A., Bye, V.J., Eno, N.C., Tyler, C.R., and Sumpter, J.P. 1994. Estrogenic effects of effluents from sewage treatment works. *Journal of Chemical Ecology*. 8, 275-285.

Sequoia Environmental Corporation. 2003. Phase I Environmental Site Assessment Report, 7100 Sellers Avenue (CALFED), Oakley California.

Slotton, D.G., Ayers, S.M., and Reuter, J.E. 1996. Marsh Creek Watershed 1995 Mercury Assessment Project.

Slotton, D.G., Ayers, S.M., and Reuter, J.E. 1998. Marsh Creek Watershed Mercury Assessment Project: Third Year (1997) Baseline Data Report with 3-Yr Review of Selected Data.

Stephenson, Mark. Personal Communication, May 4, 2005. Moss Landing Marine Laboratories Director, Marine Pollution Studies Labs, Department of Fish and Game.

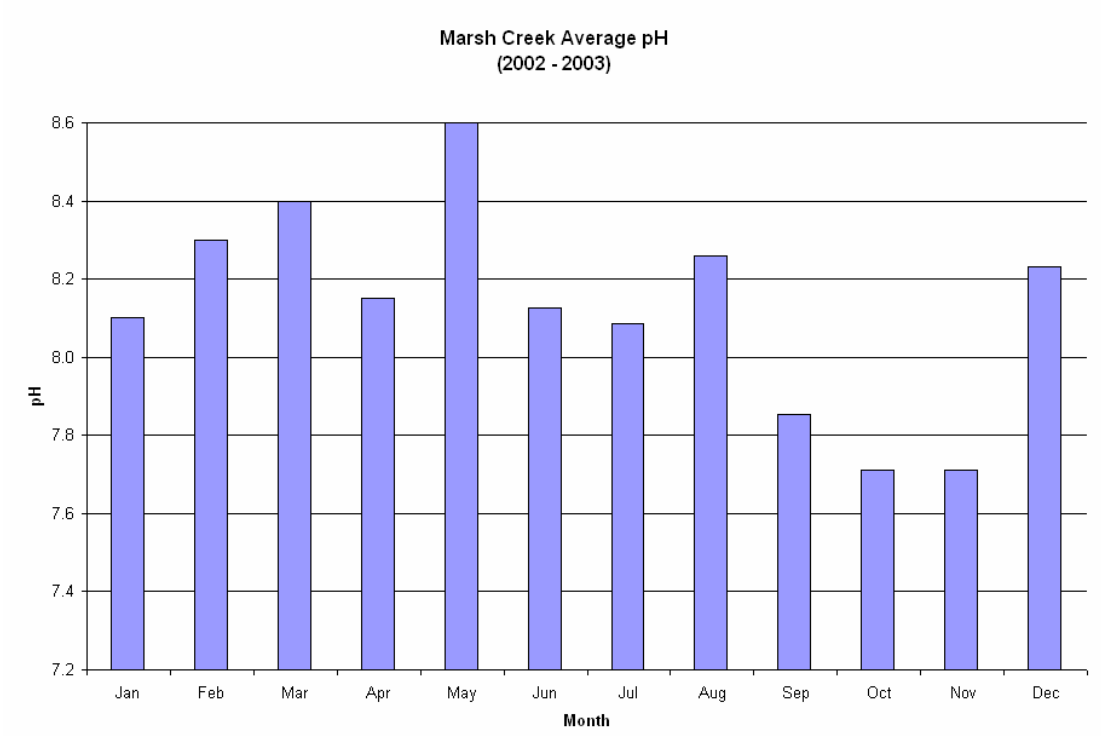
USGS. USGS National Water Information Systems Real-Time Streamflow Data (http://waterdata.usgs.gov/nwis/rt)

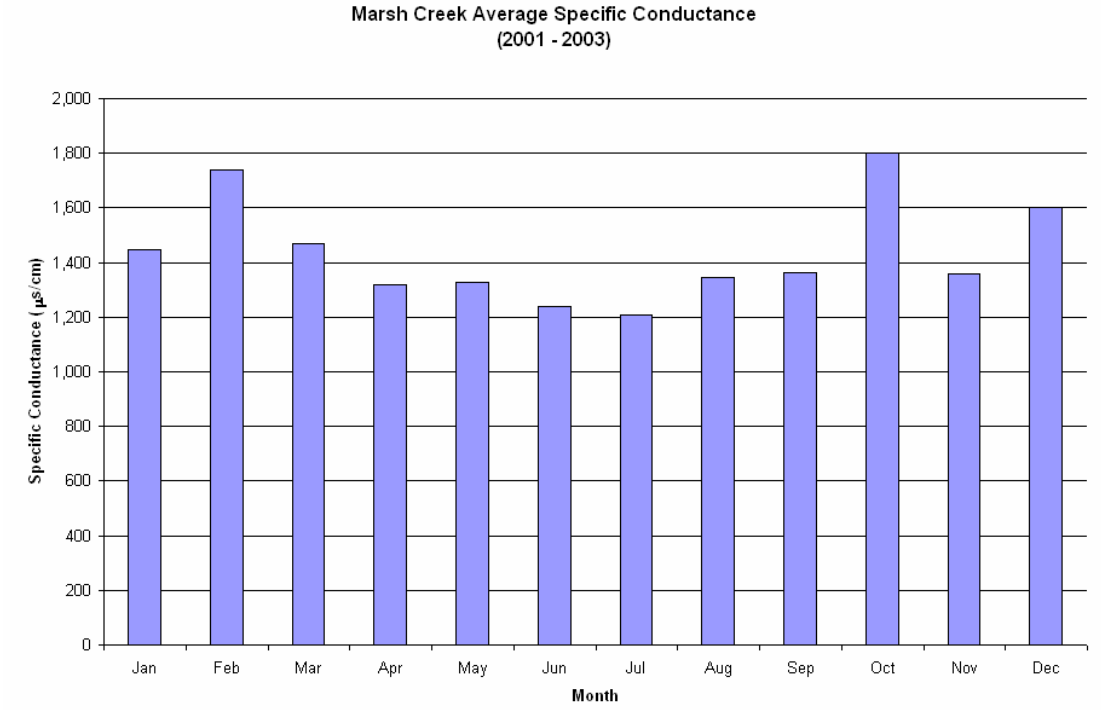
Ying, G.G., Kookana, R., and Waite, T.D. 2004. Australian Water Conservation and Reuse Research Program: Endocrine Disrupting Chemicals (EDCs) and Pharmaceuticals and Personal Care Products (PPCPs) in Reclaimed Water in Australia. Australian Water Association.

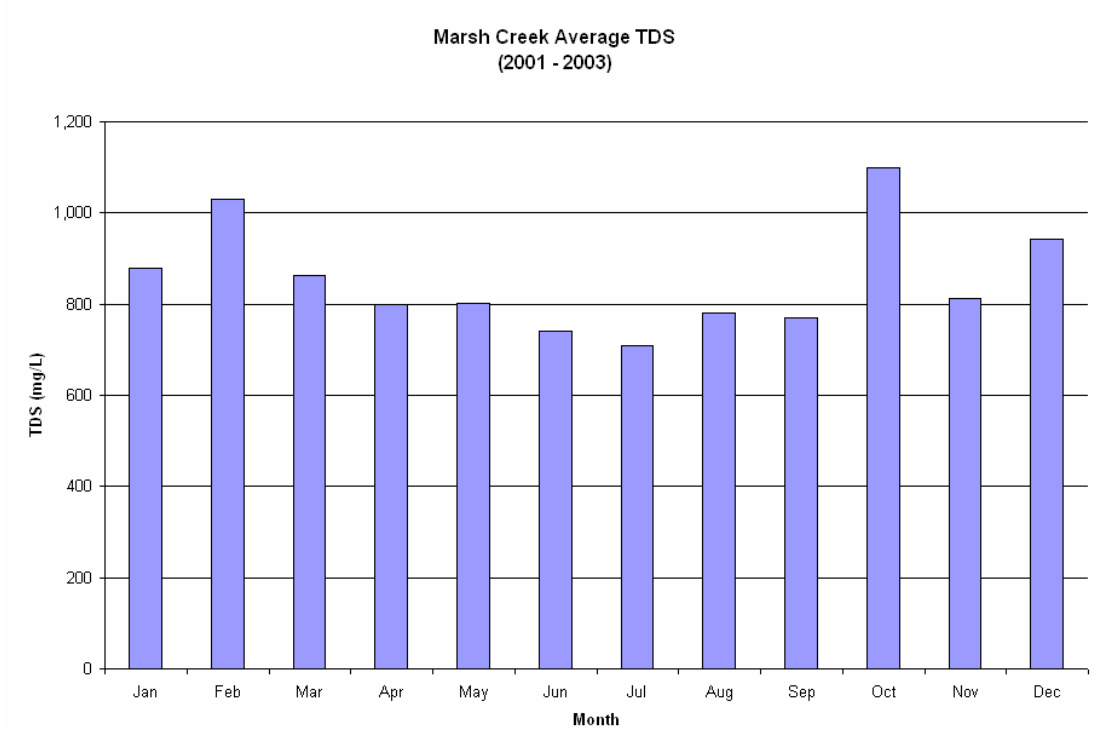
APPENDIX A

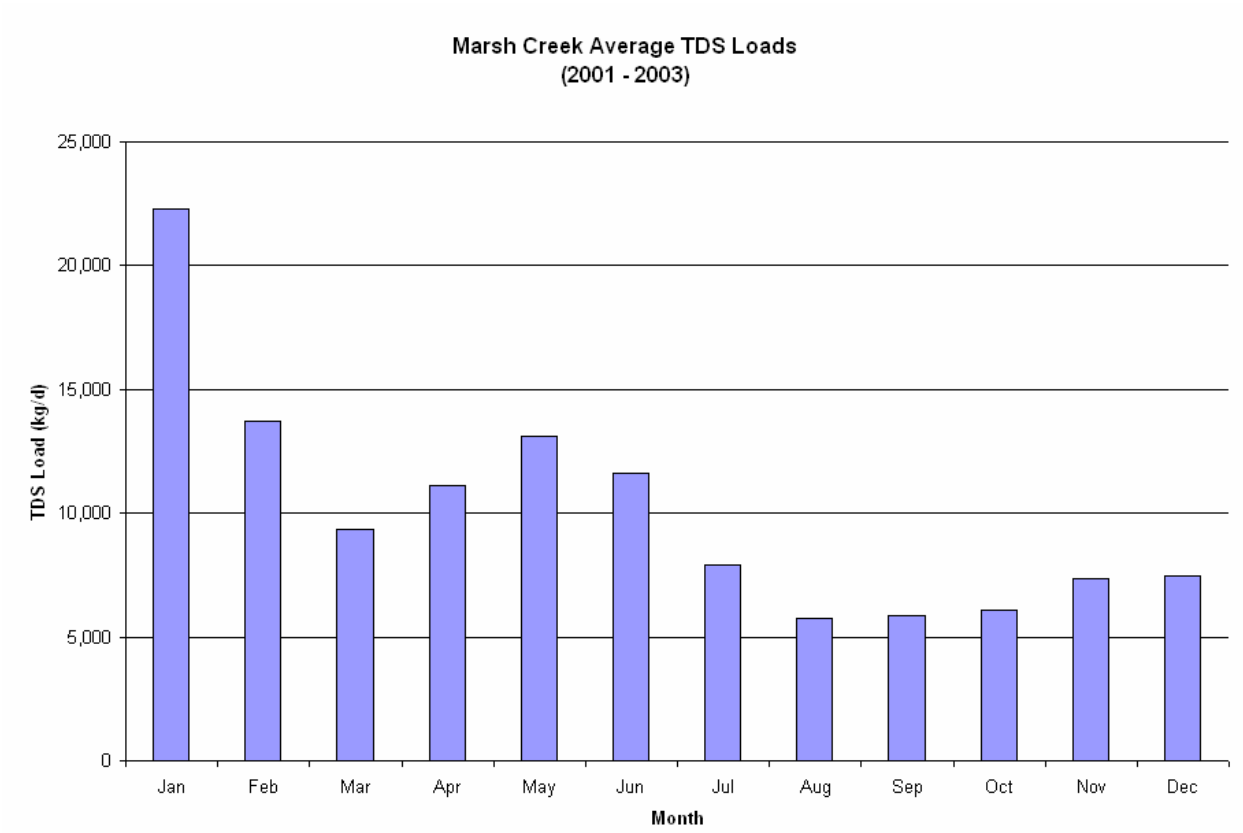
MARSH CREEK WATER QUALITY

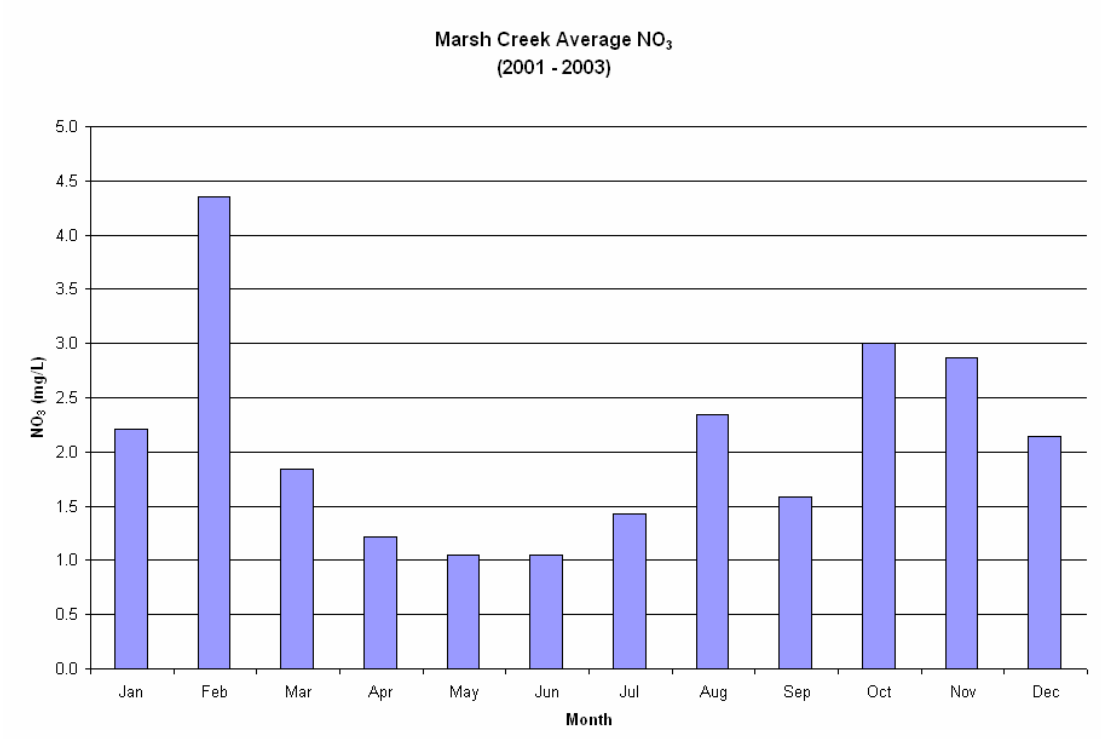
Data Source: Contra Costa Water District. Only November and December of 2001 were available for monthly average calculations. In some cases, only one monthly value (rather than two or three values) was available from 2001 – 2003.

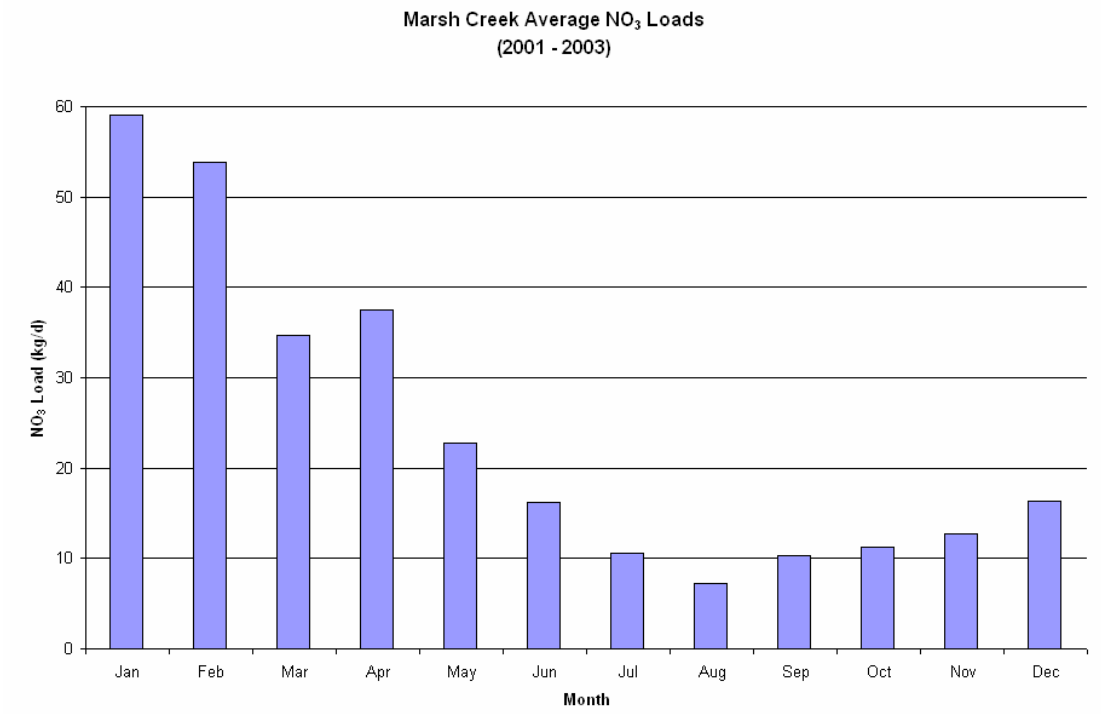


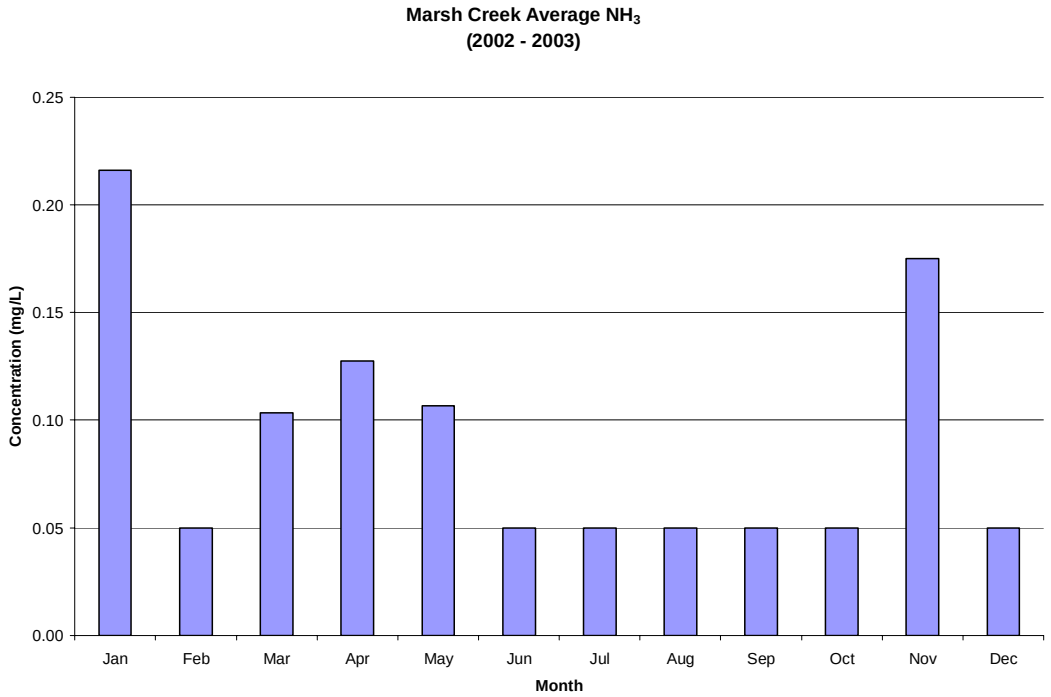



Marsh Creek Average TDS
(2001 - 2003)
TDS (mg/L)
1,200
1,000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Marsh Creek Average TDS Loads
(2001 - 2003)
TDS Load (kg/d)
25,000
20,000
15,000
10,000
5,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Marsh Creek Average NO_3
(2001 - 2003)
NO_3 (mg/L)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Marsh Creek Average NO_3 Loads
(2001 - 2003)
NO_3 Load (kg/d)
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month



Note: Most ammonia values were below the detection limit of 0.1 mg/L. Therefore, averages were calculated by representing below detection samples as 0.05 mg/L.

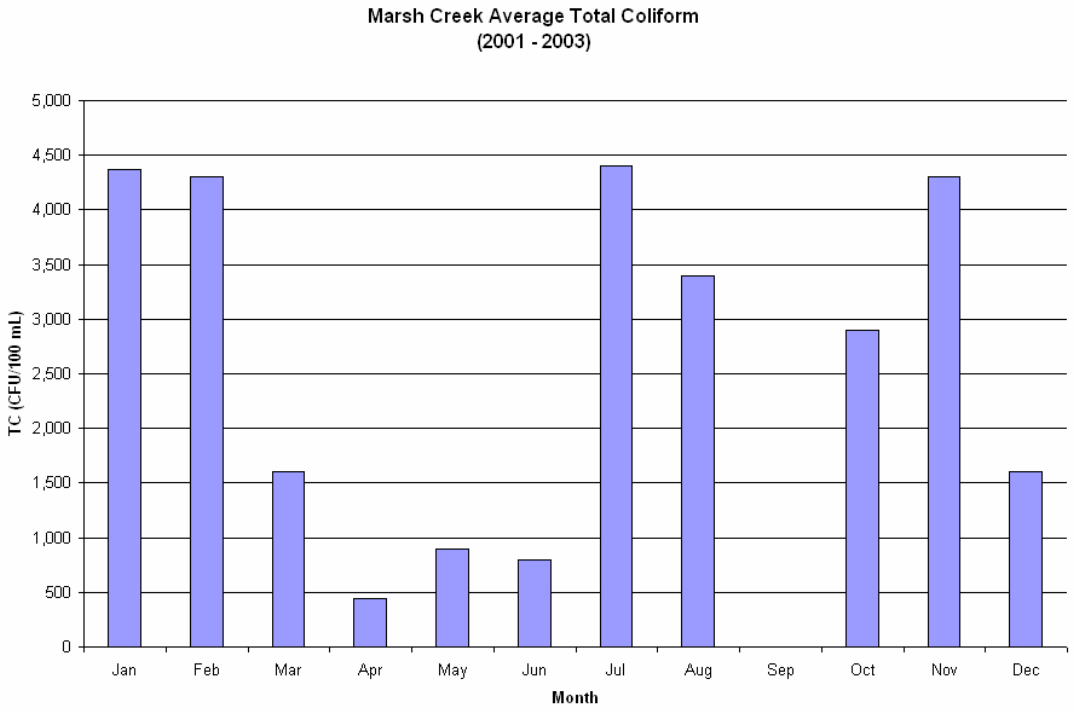


Table A-1. Big Break Data ((http://baydelta.ca.gov/)

1994-1995	Ammonia (as N)	Kjehdahl Nitrogen (as N)	NO3 + NO2-N	Ortho-P (as P)	Phosphorus, Total	Total Dissolved Solids	Total Suspended Solids	Turbidity
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(NTU)
Minimum	0.01	0.10	0.13	0.04	0.06	82	4	5
Maximum	0.16	0.80	1.10	0.14	0.20	1050	60	58
Median	0.04	0.40	0.34	0.06	0.10	191	7	10

APPENDIX C-2

Dutch Slough Water and Sediment Quality Monitoring Plan

TECHNICAL MEMORANDUM **128296-006**

April 20, 2006

TO: Nick Garrity, Phillip Williams and Associates

FROM: Michael Parenti, Brown and Caldwell
Laura Marshall, Brown and Caldwell
Sabre Duren, Brown and Caldwell

SUBJECT: DUTCH SLOUGH WATER AND SEDIMENT QUALITY MONITORING PLAN

1.0 INTRODUCTION

BACKGROUND

The proposed Dutch Slough restoration site (Project Site) is in Oakley, CA and is located in the Sacramento-San Joaquin Bay Delta. This site is bordered on the north by Dutch Slough, on the south by Contra Costa Canal, on the East by Jersey Island Road, and on the west by Marsh Creek. At the northwest corner of the site Marsh Creek empties into Big Break. The site is approximately 1166 acres and is composed of 3 separate parcels (Emerson, Gilbert, and Burroughs parcels). The three parcels are divided by two sloughs, Little Dutch Slough and Emerson Slough. These two sloughs will provide tidal source water to the Project Site. Marsh Creek, if diverted onto the site, would provide fluvial source of water to the Project Site. The site was historically a tidal marsh until it was drained for agriculture during the late 1800's. The proposed restoration would return the site to a mixture of open water and tidal wetland habitat by breaching levees in selected locations along the sloughs.

OBJECTIVES

This monitoring plan describes a program to collect and evaluate water and sediment quality data to assess baseline conditions at the Project Site, inform the restoration planning and design and provide data necessary to adaptively manage the Project Site. Brown and Caldwell (BC) prepared a Water Quality Assessment section of the Dutch Slough Conceptual Plan & Feasibility Report in which data gaps were identified. Data collected as part of this monitoring program will address these data gaps. Data obtained will also be useful in refining initial load estimates from the source water (tidal and fluvial) to the proposed tidal wetland. Data will also aid in determining the water quality impacts and feasibility of diverting Marsh Creek into the proposed tidal wetland. The data will support NEPA/CEQA analyses and water and sediment quality permitting requirements.

OVERVIEW

Water quality data will be collected from surface water bodies that would potentially provide source water to the Project Site, including Marsh Creek, and Emerson Slough, and Little Dutch Slough. In addition, two sample locations are proposed in Dutch Slough to the east and west of the Project Site. Sampling Dutch Slough will enable quantification of the total effect the tidal wetland has on water chemistry in the surrounding Delta water system. In addition, soil samples will be collected on the three parcels. Sediment data will be collected at one location in Emerson Slough and Little Dutch Slough and along a longitudinal gradient in Marsh Creek.

This plan addresses constituents of concern for organisms as well as drinking water quality because three drinking water intakes are located in relatively close proximity to the Dutch Slough site (Contra Costa Rock Slough and Old River Intakes, and Harvey O'Banks intake). The plan focuses on organic carbon and mercury, because wetlands have been shown to sometimes increase levels of these constituents of concern. Mercury is a concern because of toxicity to organisms in the environment and the potential for methylation. Organic carbon is believed to affect the solubilization and transport of mercury and is also a drinking water concern because of the formation of disinfection byproducts during the treatment process.

Laboratory analyses for water samples will include dissolve organic carbon (DOC), total organic carbon (TOC), UV 254, bromide, total mercury, dissolved mercury, methylmercury (MeHg), nitrate, ammonia, total kjeldahl nitrogen (TKN), orthophosphate, total phosphorus, zinc, arsenic, copper, cadmium, chromium, lead, nickel, selenium, iron, aluminum, manganese, alkalinity, total dissolved solids (TDS), total coliform, fecal coliform, *e. coli*, and total suspended sediment (TSS).

Slough bed sediment samples will be analyzed for MeHg, total mercury, dissolved mercury, total sulfide, iron, manganese, polychlorinated biphenols (PCBs), and organochloride pesticides. Marsh Creek sediment samples will be analyzed for total mercury. Soil samples collected to meet the requirements of the Beneficial Reuse of Dredged Sediments will be analyzed for total mercury, MeHg, an organic carbon surrogate, metals, organochlorine pesticides/PCBs, and PAHs.

Field parameters will be collected at all sites and include GPS coordinates, flow, dissolved oxygen (DO), temperature, pH, conductivity, turbidity. In addition, oxidation reduction potential (ORP) and DO will be measured along the vertical profile of the sloughs.

BC field staff will be mobilized for each of the sampling events. Each sampling event will require one day to collect and record water column and sediment samples, measure field parameters, prepare samples for transport, and coordinate transport to the laboratory. The sampling effort will begin in October 2005 and will continue through September 2006. Water samples will be taken monthly at all sample locations. In addition to monthly samples, flow and DOC will be monitored continuously year-round and mercury concentrations and speciation will be monitored during six 24-hour synoptic events at four main slough stations. Frequency of sampling events may be adapted to changing water quality conditions, as appropriate.

The locations and frequency of sampling events are described in Section 2. Based on the field conditions, the program may be modified by the project team during the sampling event to provide for field safety and make the collection accurate and thorough. Section 3 of this monitoring plan outlines the steps to be followed for surface water, sediment, and soil sampling and analysis. Procedures and methodologies for organic carbon, mercury, metals, nutrients, pathogens, flow, and field data are included in Section 3. Quality Control standards are outlined in Section 4.

2.0 SAMPLING LOCATIONS AND SCHEDULE

This section details the locations for water quality sampling and the scheduled timing and frequency of sampling events. As the project progresses, there may be a need to add or remove sampling sites and to adjust the timing or frequency of the sampling events. This monitoring plan will be updated with changes to the locations and schedule as needed.

2.1 Sampling Locations

Water quality data will be collected from all surface water bodies that would provide source water to the Project Site (Figure 1). Marsh Creek will be sampled at one location, just upstream of the proposed diversion onto the restoration site. Dutch Slough provides water to Little Dutch Slough and Emerson Slough and will be sampled at two locations, one just east of the Project Site and one just west of the site. Samples at these two locations will establish baseline conditions from which the effects of the restoration can be assessed. These locations allow an overall view of water quality being exported from the entire restoration and its effects on surrounding water bodies. Emerson Slough and Little Dutch Slough will be sampled at one location each. The sample location will be immediately prior to the confluence with Dutch Slough and the northernmost levee break in that slough (Figure 1). This should allow adequate mixing to occur within the slough before it is sampled. This will establish sample locations that account for all water flowing off the proposed marsh, so that comparisons can be made with pre- and post- wetland restoration water quality.

The sample locations in Dutch Slough provide an overall view of the restoration effects, the sample locations in Emerson and Little Dutch Slough provide an understanding of what is occurring within the Project Site. These are the primary sample locations where scientific knowledge and adaptive management insights can be gained as a result of the restoration. Since one of the primary goals of the restoration is to learn about wetland restoration within the Delta, various sections of the Project Site will be designed differently to test certain hypotheses. The Emerson and Little Dutch Slough locations will provide the information necessary for analysis of these variations in restoration design to adaptively manage the Project Site.

Sediment samples will be collected at all locations, with the exception of Dutch Slough. Sediment and water samples will be taken at the same location at all sample sites. A more detailed longitudinal sediment profile will be collected along Marsh Creek from below the Marsh Creek reservoir to the proposed diversion location. This will provide the data necessary to assess potential mercury provided by suspended and bed load transport.

Figure 1. Monitoring Station Locations

Soil samples will be taken from each of the three parcels, focusing on areas that may be excavated as part of the restoration efforts, as well as other areas that would be in contact with marsh waters. Final site selection will be made after additional site reconnaissance and analysis by BC. The number of samples will be determined based on a proposed excavation volume in accordance with the May 2000 Draft Staff Report from the San Francisco Bay Regional Water Quality Control Board – Beneficial Reuse of Dredged Materials: Sediment Screening and Testing Guidelines.

Soil samples will also be taken from the former mouth of Marsh Creek along the northern edge of the Emerson parcel. Performing soil analysis of the former channel would enable quantification of the mercury concentrations prior to when Marsh Creek breached into Big Break in the 1970s.

Urban drainage outfalls and the Brentwood Wastewater Treatment Plant (WWTP) discharge location will not be monitored as part of this monitoring plan. The water quality effects of these discharges will be represented in the Marsh Creek sampling location where it would be diverted onto the restoration site.

2.2 Sampling Team

The monthly sampling team will be composed of two BC staff that will collect samples, measure field parameters, and take flow measurements. Brown and Caldwell personnel implementing field sampling will be a combination (dependant on availability) of Sabre Duren, Laura Marshall, and Rhys McDonald. Moss Landing Marine Lab (MLML) will likely be involved in more specialized Hg sampling. The United States Geological Survey (USGS) will also likely be involved in specialized continuous organic carbon and flow measurement stations. MLML and USGS field personnel are to be determined, however the work would be coordinated with Mark Stephenson at MLML, and Brian Bergamaschi and Jon Burau at the USGS.

2.3 Timing and Scheduling

Sampling in Marsh Creek will occur on a monthly basis for one year. Sampling for one year will allow seasonality (dry weather and wet-weather conditions) to be monitored. Concentrations are often lower during high flow seasons due to dilution. However due to the increased flows, wet weather periods can produce the greatest load. During dry weather periods, concentrations are typically higher because pollutants are less diluted. It is anticipated that three of the Marsh Creek sampling events will be taken during storm events. Storm events need to be sampled because they can produce different water quality than is seen during non-storm event times. Storm events typically produce the maximum loads of many constituents and provide information relative to urban runoff discharges which is not being sampled directly as part of this plan. Runoff from storm events often results in brief concentration increases of some constituents. In order to adequately capture the significant variations described above, it is necessary to obtain data over the entire year.

Tidally influenced areas, such as the sloughs, have large variations in chemical concentrations on a small timescale. Due to these continuous fluctuations in concentrations, it is advantageous to have high frequency monitoring to more effectively quantify concentrations as well as changes over time. DOC and flow measurements will be collected continuously using real-time *in-situ* sampling at the four slough stations. Mercury data in the sloughs will be collected every hour during 24-hour sampling events. There will be six mercury sampling events, with a minimum of one during each season, as well as two spring tide sampling events on the outgoing low tide. Sampling during a spring low tide often represents the worst case scenario for MeHg concentrations.

Sampling after the restoration will occur on the outgoing tide to measure export water quality. It may be useful to sample the flood tide as well after the restoration is implemented. This would allow an analysis of how the water quality changed between the incoming water to and the export waterfrom the Project Site. It is preferable to sample during regular tides as opposed to spring or neap tides to represent the average case. Another option would be to sample during spring tides, which may represent the worst case scenario. Maintaining consistency in the timing of sampling with respect to the tidal cycle will enable all sampling events to be comparable during data analysis. The exact dates of each monthly sampling event will be determined once the monitoring plan is implemented, and will be based on the above factors. Sampling events will generally require one full day to complete.

Samples for sediments and soils will only be taken once. Sediment and soil concentrations do not typically have as significant variations on short timescales, and therefore do not need to be monitored on a frequent basis.

3.0 SAMPLING PROCEDURES AND ANALYSIS

3.1 Sample Collection

Marsh Creek Sampling. The location of the sampling site will be determined during site reconnaissance prior to the initial sampling event and coordinates will be recorded using a GPS unit. Water samples will be collected from the channel thalweg area using an isokinetic D-77 composite water sampler. Prior to sample collection, the sampler will be rinsed three times with site water. Chemical laboratory sample bottles will be filled from the composite water sampler. The sampler will be swirled to keep the water well mixed before filling each sample bottle. Bed sediment samples will be collected using a Wildco 77256 hand core sediment sampler at the same location as water samples. Water samples for mercury analysis will be collected following the EPA 1669 "clean hands-dirty hands" method. This method involves using a "clean hands" sampler to handle contact with the sample bottle and a "dirty hands" sampler to handle all other activities not associated with sample bottle contact. All sample bottles collected in the field will be labeled and placed immediately in a cooler with ice for transit to the appropriate laboratory.

Slough Sampling. GPS coordinates for the four slough locations (Figure 1) will be determined prior to the initial sampling event. Representative samples will be collected by boat to obtain water at the center of sloughs. Samples will always be taken at the same time during the tidal cycle to enable accurate comparison between sampling events. Composite water samples will be collected vertically in the middle of the slough cross-section at a representative deep location. Sediment samples will be collected using a bottom dredge sampler. Chemical laboratory sample bottles will be filled from the composite water sampler. The sampler will be swirled to keep the water well mixed before filling each sample bottle. Mercury samples during the six 24 hour synoptic events will be collected by MLML with a specialized in-situ monitoring instrument. In addition to monthly grab samples, continuous flow and DOC monitoring stations will be located at the four slough monitoring sites (See Section 3.2 below). All sample bottles collected in the field will be labeled and placed immediately in a cooler with ice for transit to the appropriate laboratory.

Emerson, Gilbert, and Burroughs Land Parcel and Marsh Creek Historic Streambed Soil Sampling. GPS coordinates for these locations will be determined prior to the initial sampling event. Samples will be collected by hand auger to the maximum depth that can be augered. Soil samples for each location will be a composite of a maximum of four samples from various depths. Suggested depths to sample are: just below the surface, 1.5', 3', and 5'. Depths may be adjusted as necessary in the field due to sample recovery. The hand auger will be cleaned between sample locations to remove all remaining soil. All sample containers collected in the field will be labeled and placed immediately in a cooler with ice for transit to the appropriate laboratory.

3.2 Flow Measurements and Continuous Monitoring Stations.

Accurate flow measurements in Marsh Creek, Emerson Slough, Little Dutch Slough, and Dutch Slough are important in estimating constituent loads to and from the restoration site. For Marsh Creek, flow will be determined by using data from the USGS stream gage on Marsh Creek. Measuring flow in tidally-influenced sloughs is inherently more complex than measuring flow in fluvial systems as the flow fluctuates with the 25-hour tidal cycle. Water may move upstream on a flowing tide and downstream on the ebbing tide, rendering a discrete field measurement inaccurate. The flow measurement methods for both Marsh Creek and the two tidal sloughs are discussed in more detail below.

Flow Measurement in Marsh Creek.

A USGS stream gage currently exists on Marsh Creek near the City of Brentwood and has been in operation since August 2000 (USGS gage 11337600). .The gage is located a few miles upstream of the restoration site, no significant sources of stream flow are known to exist between it and the restoration parcels (i.e. City of Brentwood WWTP is located upstream of the gage), and therefore flow measurements collected at the site of the gage accurately represent stream flow into the Project Site.

Flow and Monitoring Stations at Sloughs. Continuous flow and DOC concentrations will be measured at four slough stations shown in Figure 1:

1. Little Dutch Slough
2. Emerson Slough
3. West Dutch Slough
4. East Dutch Slough

As mentioned above, discrete flow measurements during sample collection at the tidally-influenced sloughs are inappropriate for understanding overall flow conditions. Continuous data is desirable to monitor both net flow through the sloughs and the fluctuating tidal flows upstream and downstream. Continuous monitoring will be accomplished using a horizontally mounted Acoustic Doppler Current Profiler (H-ADCP) with datalogging and telemetry capabilities. The H-ADCP uses acoustic signals to measure stream velocities at distinct intervals across a channel and, when combined with a measured cross-sectional stream depth profile, can accurately be used to measure stream flow. The project would require one H-ADCP unit to be installed at each monitoring station. With installation of continuous flow monitoring, the opportunity also exists to add other continuous sensors such as salinity, turbidity, pH, and temperature.

Flow validation measurements will be performed and a rating curves will be developed at each monitoring station after installation. These will be obtained using a boat-mounted bottom-tracking doppler velocity profiler system that measures velocities and depths while moving across the channel and calculates channel flow. Channel flows will be determined in this manner for direct comparison with the fixed station measurements over a wide range of flood and ebb tide conditions.

Corrections factors will be developed for different tide conditions to adjust fixed station flow measurements as needed.

DOC and other constituent concentrations are highly variable because of the tidal influence, varying over tidal and spring-neap cycles. Therefore, continuous monitoring is needed to ensure accurate estimates of constituent fluxes as well as variations in concentrations over time. Recent projects have successfully correlated the presence of the fluorescent fraction of natural dissolved organic material (fDOM) to DOC (Downing et al., 2004; Raymond et al., 2004). We propose to develop a continuous record of DOC concentration using a multiwavelength fluorescence sensor calibrated to DOC concentration under different tidal conditions. To establish which wavelengths should be monitored with the continuous sensor, prior to installing the sensor, grab samples will be collected using a D-77 integrated depth sampler from the stations during the wet and dry seasons. These samples will be characterized to identify the excitation and emission wavelengths that provide the best calibration to DOC under different conditions, as well as the best resolution of DOC sources. Recommended times for DOC grab sample collection are February, May or June, and August or September. The triplet sensor (Wetlabs) has the capability to simultaneously monitor fluorescence at three wavelengths as well as optical backscatterance. For accurate measurements, it is recommended the meter be serviced once per week to keep the lens clean.

3.3 Field Parameters

GPS coordinates will be obtained for all sampling locations. Field measurements of pH, DO, conductivity, oxidation reduction potential (ORP), turbidity, and temperature will be recorded using a portable in-stream meter (YSI 6920 or comparable) following EPA-approved standard techniques and equipment calibration procedures. Equipment calibration will be performed on the day of sampling before sample collection, and calibration will be recorded in the multi-meter (YSI) notebook. At Marsh Creek, field parameters will be measured directly in the water column at the midpoint of creek cross-sectional area and at mid-depth. Measurement of slough field parameters will take place directly in the water column at the center of the channel, at one meter depth intervals. All field sampling measurements along with sample date, time, location, sampler name, weather conditions, and any other pertinent information or visual observations will be noted in a bound field book.

3.4 Sampling Constituents and Analytical Methods

The sampling program focuses on five major constituent types: organic carbon, total and MeHg, nutrients, various metals, and pathogen indicators.

Organic Carbon. Organic carbon concentrations are of interest because of the role it plays in the methylation and transport of mercury. Organic carbon is also a concern to drinking water agencies that rely upon the Delta as a source of water. During the disinfection process, Depending on the nature of the organic carbon and the corresponding disinfection byproduct precursor potential, the organic carbon may form carcinogenic compounds such as trihalomethanes (THMs) and haloacetic acids (HAAs). The Contra Costa Water District's Rock Slough Intake is located less than 10 miles away from the restoration site, therefore it is useful to establish baseline DOC concentrations and

fluxes to evaluate and quantify possible changes in DOC concentrations and fluxes due to the restoration.

Mercury. Mercury in the Bay-Delta is a problem as a result of the region's early mining activities, including mercury mines and gold mines, which utilized a mercury-based process. MeHg is generated under anaerobic conditions often found in wetlands. Due to its hydrophobicity, mercury preferentially adsorbs to particulates. Therefore, mercury and MeHg will be measured in both filtered and unfiltered samples to characterize the dissolved and adsorbed fractions.

Nutrients. Excess nutrients, often stemming from agricultural fertilizers, can result in algae growth, eutrophication, and taste and odor problems for drinking water agencies. Wetlands often serve as a nitrogen sink, and it is useful to quantify pre-project loads of nitrogen to the site. Nutrients are an emerging concern for drinking water agencies and will be monitored in various forms of nitrogen (nitrate, nitrite, ammonia, and total kjeldahl nitrogen) and phosphorus (ortho-phosphate and total phosphorus).

Metals. Trace metals are important in aquatic ecosystems in dilute concentrations, but can become toxic at elevated concentrations and certain pH ranges. Samples will be collected for analysis of aluminum, arsenic, cadmium, chromium, copper, iron, manganese, nickel, lead, selenium, and zinc. Metals often adsorb to suspended sediment, therefore it is important to distinguish between the dissolved and adsorbed fractions.

Pathogen Indicators. Pathogen data within the Delta is sparse and knowledge of pathogen fate and transport is limited. Restoration projects often create habitat for wildlife, potentially contributing additional pathogen sources, but also may provide conditions for pathogen removal by natural processes. Pre-project monitoring will include total coliform, fecal coliform, and *Escherichia coli.*

Biological Tissue Sampling. Sampling of organisms to analyze concentrations of mercury in biological tissue is not a part of this monitoring plan. However, MLML is under a three-year contract with CalFed to perform fish tissue sampling for mercury concentrations, and the Dutch Slough area is one of the primary areas of the project. BC has begun coordinating with MLML on this project and will continue to do so. Therefore, it is anticipated that fish tissue data that is relevant to the Dutch Slough restoration site will be available.

Other.
Various other water quality parameters will be monitored, including bromide, alkalinity, total suspended solids (TSS), total dissolved solids (TDS), and sulfide. Bromide is of interest because of potential bromate formation, which is carcinogenic, during the drinking water treatment process. Accurate TSS measurements are important for determining the adsorbed fractions of the mercury and trace metals.

Sediment.
A variety of biological processes occur at the sediment-water interface including mercury methylation. The first 2 centimeters of sediment will be analyzed for total mercury, MeHg, and loss

on ignition (LOI), a surrogate for organic carbon. Analysis of sediment conditions will assist in determining the extent of mercury methylation. Additional sediment data that would be beneficial includes: iron, manganese, sulfide, and chlorinated pesticides/PCBs.

Soils. Soils on the restoration site will be sampled for constituents consistent with those outlined in the Beneficial Reuse of Dredged Materials: Sediment Screening and Testing Guidelines document. They will be analyzed for metals, organochlorine pesticides/PCBs, and PAHs. In addition, soil samples will be analyzed for total mercury, MeHg, and LOI.

The constituents list may be changed as appropriate during the sampling program. For example, if a constituent is consistently non-detect over multiple sampling events, including dry weather and wet weather, it may not be necessary to continue to sample for it.

3.5 Costs.

Grab Sampling Costs. The grab sampling program includes monthly collection of water quality samples for one year, a one-time collection of sediment samples at the Marsh Creek monitoring site, and two slough sampling sites (Little Dutch Slough and Emerson Slough). Table 3-1a and Table 3-1b provide a list of recommended constituents, analytical levels, detection levels and estimated cost of sample analysis. Based on the estimated costs in Table 3-1a water quality laboratory analysis costs are estimated to be $891 for each sampling event for an approximate 12 sample event cost of $10,686. Sediment quality laboratory analysis costs are estimated to be $2,647 based on analyzing 9 samples for sulfide, total mercury, methylmercury, iron, manganese, and three samples for chlorinated PCBs and pesticides (Table 3-1b). Costs for mobilization, instrument deployment, calibration, maintenance, sample collection and data analysis are estimated to be approximately $50,000 per site. Total grab sampling costs are presented in Table 3-2.

Table 3-1a. Water Quality Sampling Constituents, Analytical Methods, Detection Levels, and Estimated Cost of Sample Analysis

Constituent	Recommended Analytical Method	Detection Level	Estimated Lab Cost
DBP Precursors			
Total Organic Carbon	EPA 415.3 (or .2)	1 mg/L	$37.50
Dissolved Organic Carbon	EPA 415.3 (or .1, .2)	1 mg/L	$37.50
Bromide	EPA 300.0	0.1 mg/L	$12.50
Mercury			
Total Mercury in Unfiltered Water	EPA 1631	0.0002 ug/L	$75.00
Methylmercury in Unfiltered Water	EPA 1630	0.00002 ug/L	$125.00
Total Mercury in Filtered Water	EPA 1631	0.0002 ug/L	$75.00
Methylmercury in Filtered Water	EPA 1630	0.00002 ug/L	$125.00
Nutrients			
Nitrate & Nitrite	EPA 353.2 (300.0)	0.1 mg/L	$25.00
Ammonia	EPA 350.3 (or .2, .1)	0.08 mg/L	$15.00
Total Kjeldahl Nitrogen	EPA 351.1 (or .2), SM 4500	0.5 mg/L	$32.50
Total Phosphorus	EPA 365.1, .4 (365.3)	0.01 mg/L	$22.50
Ortho-phosphate	EPA 365.1 (300.0)	0.16 mg/L	$20.00
Metals (total fraction)			
Aluminum	EPA 200.8	5 ug/L	$15.00
Arsenic	EPA 200.8	1 ug/L	$15.00
Cadmium	EPA 200.8	0.25 ug/L	$15.00
Chromium	EPA 200.8	2 ug/L	$15.00
Copper	EPA 200.8	0.5 ug/L	$15.00
Iron	EPA 200.7	100 ug/L	$12.50
Manganese	EPA 200.8	5 ug/L	$15.00
Nickel	EPA 200.8	1 ug/L	$15.00
Lead	EPA 200.8	0.5 ug/L	$15.00
Selenium	EPA 200.8	1 ug/L	$15.00
Zinc	EPA 200.8	5 ug/L	$15.00
Pathogen Indicators			
Total Coliform	SM 9221 B&E or other	2 MPN/100ml	$19.34
Fecal Coliform	SM 9221 B&E or other	2 MPN/100ml	$19.33
E. coli	SM 9221 B&E or other	2 MPN/100ml	$19.33
Other			
Alkalinity	EPA 310.1	5 mg/L	$12.50
Total Suspended Solids	EPA 160.2	5 mg/L	$15.00
Total Dissolved Solids	EPA 160.1	5 mg/L	$15.00
Sulfide	EPA 376.1, SM 4500	1.0 mg/L	$25.00
Benthic Invertebrates	n/a	n/a	
	Total Cost for 1 Water Quality Sampling Event		**$891**

Table 3-1b. Sediment Quality Sampling Constituents, Analytical Methods, Detection Levels, and Estimated Cost of Sample Analysis

Sediment Analyses (0-2 cm depth)			
Sulfide	EPA 376.1, SM 4500	1.0 mg/L	$25.00
Total mercury in sediment	EPA 1631	0.0002 ug/L	$75.00
Methylmercury in sediment	EPA 1630	0.00002 ug/L	$125.00
Iron	EPA 200.7	100 ug/L	$12.50
Manganese	EPA 200.8	5 ug/L	$15.00
Chlorinated Pesticides/PCBs	EPA 508, 505	Various DLs	$125.00
		Total Cost for 1 Sediment Sampling Event	$2,647.50

Table 3-2. Grab Sampling Costs

Marsh Creek	
Sample Collection	$13,343
Sample Analysis	$50,000
Total	$63,343
Sloughs	
Emerson Slough	
Sample Collection	$13,343
Sample Analysis	$50,000
Total	$63,343
Little Dutch Slough	
Sample Collection	$13,343
Sample Analysis	$50,000
Total	$63,343

Continuous Monitoring Costs. Costs for the in-situ DOC monitoring includes mobilization, instrument deployment, calibration, maintenance, and data analysis for three stations (Little Dutch Slough, West Dutch Slough, and Emerson Slough). Data analysis includes rating curves for calibration of flow and DOC monitoring, flow decomposition analysis, and load calculations. Weekly grab samples will be necessary as part of the in-situ DOC monitoring.

Costs estimates for conducting annual continuous monitoring were obtained from the USGS and estimated by Brown and Caldwell. The USGS cost estimates for in-situ flow range is $100,000 per year for each station. The USGS annual cost is estimated to be $300,000 (Table 3-3). The Brown and Caldwell annual costs vary. The first year Brown and Caldwell cost is estimated at $477,345 (Table 3-2). Brown and Caldwell costs decrease after the first year because instrument purchase and installation costs are included in the first year costs. Annual operating costs for Brown and Caldwell are estimated at $150,000.

Moss Landing Marine Laboratory estimated costs for the mercury synoptic events. The cost for each 24-hour mercury sampling event is estimated at $20,000 per location which includes sample

collection and laboratory analysis. This does not include flow measurements which will be taken as part of the continuous DOC sampling. This cost can be reduced by an additional $4,000 to $5,000 by not analyzing every sample for filtered Hg and MeHg.

Table 3-3. Continuous Monitoring Costs

Continuous Monitoring in Sloughs	
USGS Annual Cost	$300,000
BC - First Year Cost	$477,345
BC - Continuing Operations	$150,000
Mercury Synoptic Events	$480,000

3.6 Standard Procedures

Sample Documentation and Delivery. Field sampling personnel will be responsible for collecting all water samples, completing all labeling, field notes, and chain of custody (COC) documentation, and coordinating the delivery of all samples to the appropriate analytical laboratory. Samples will be packaged on ice in coolers for transport immediately after sampling is completed.

Field Notebook. Field notes will be taken for all sampling sites and recorded in a bound field notebook. All observations and sampling methods will be recorded while at the sampling site to reduce confusion of conditions or unusual events at different sites. Information recorded will include: identification of the monitoring site; date and time of sampling; identity of the sampler(s); description of the type of samples taken; identification of QA/QC samples; method of sampling; results of any field analyses; description of the weather, including percent cloud cover and air temperature; description of the site appearance; and any unusual conditions observed.

Sample Bottle Labeling. Collected samples will be designated by sample location (e.g., MC1, ES1), which will be assigned after the site reconnaissance event. Each sample container will be individually labeled with the label affixed directly to the bottle itself and analysis to be performed printed on the label. Additional sampling information including date, time, location, sampling medium, and sampler initials, will also be written on the label with indelible ink.

Chain-of-Custody Documentation. COC documentation identifies sample containers, provides a complete inventory of all containers in a sample set, and provides an audit trail identifying the persons who have custody of a sample in order, and the exact date and time when custody was relinquished from one person to the next. COC forms will be obtained from the analytical laboratory with the sample bottles.

Sample Containment for Transport. All sample bottles collected in the field will be thoroughly labeled, double-bagged, and placed in a plastic re-useable cooler with double-bagged ice for transit to the appropriate laboratory. Samples will be kept chilled to approximately 4 degrees Celsius in a cooler from the time of collection through delivery to the analytical laboratory. Bubble wrap packing and/or air-filled bags will be used to fill the entire space in the cooler to minimize the chance for movement and damage of the sample bottles inside the cooler.

A completed chain-of-custody form will accompany each cooler, sealed in a plastic bag inside the cooler. All of the coolers for each sampling day will be hand-delivered to the laboratory or shipping company. Samples being shipped to a laboratory will be sent out the day of the sampling event to be delivered overnight. Delivery of samples will be coordinated with the analytical laboratory's work schedule to ensure that the samples can be properly received, logged in, and analyzed within the specified holding times.

The analytical laboratory will receive samples in a designated control area of the laboratory. The sample custodian will unpack the samples and check the shipping container to make sure that there are no broken bottles and that the samples remained cool during shipping. The sample custodian will verify the arrival of all samples against the COC record.
In addition, the sample custodian will make sure that the proper containers and preservatives for the parameters of interest have been used. The lab will immediately notify BC of any problems that may affect the sample integrity or any discrepancies between the samples and the COC record.

The laboratory will be instructed to retain all samples until the holding times have expired. This provides the opportunity to re-analyze samples if initial results seem anomalous and holding times have not been exceeded.

4.0 DATA QUALITY OBJECTIVES AND QUALITY CONTROL PROCEDURES

This section discusses how the specific quality objectives of precision, accuracy, representativeness, comparability, and completeness will be addressed in this study. Field QA/QC includes thorough sample collection, cleaning of sampling equipment, use of appropriate sample containers, and maintaining COC procedures. Detail of sampling procedures, including equipment cleaning and COC procedures, is discussed in Section 4. QA/QC measures are also followed by the contracted laboratories and include equipment blanks and spikes. QA/QC results will be provided by all laboratories.

4.1 Precision

Precision is a measure of the agreement between multiple measurements made on the same sample. Precision is determined by the characteristics of the instrument or method, and by the operator's technique. Precision is checked by evaluating multiple measurements at the same time and location (called duplicate samples), or performing multiple analyses on the same sample (called split samples)

Collected data will be analyzed for precision using duplicate samples. Duplicate field measurements of all parameters (temp, pH, conductivity, and DO) will be made at one of the sites during each sampling trip, representing a minimum10% replication.

In addition, duplicates of water samples are collected and analyzed for each analyte, for 10% of total samples collected. Field duplicates analyzed by the laboratories are labeled as separate samples to avoid confusion and to provide an unbiased blind evaluation. Duplicate QC samples are identified as D1, D2, etc., with the number designating the order in which duplicate samples were collected and will not represent the sample site location. Designation of the sampling location where the duplicate sample was taken is recorded in the bound field notebook for reference when reviewing sample results. Although the laboratory knows the sample is a duplicate, it does not know what sample has been duplicated and has no basis upon which to modify results.

4.2 Accuracy

Accuracy is a measure of the error between the reported value and the true value. Accuracy is assured by proper instrument calibration. Over time, some instruments tend to drift away from their calibration. Different types of instruments are affected by drift to different degrees. In order to make sure that instruments are not drifting too far from their calibration, periodic accuracy checks are performed by observing the instrument reading solution of known concentration.

This study uses a system of frequent calibration and accuracy checks to insure the accuracy of the results. Frequent communication and ongoing data review insures that any deficiencies in accuracy are caught quickly so that the appropriate corrective action can be taken.

- The pH, DO, turbidity, and conductivity probes are calibrated before every sampling event, and accuracy checked upon returning from the field each day.
- Calibration and accuracy check data are recorded in logbooks kept with each instrument.

The recommended accuracy for field parameters is shown in Table 5-1.

4.3 Representativeness

Representativeness is a measure of how closely the sample reflects the actual site conditions. Representativeness is assured by choosing good sampling sites and using proper sampling technique.

Sampling sites and procedures used in this study have been designed to insure that the resulting data are representative of the conditions in Marsh Creek and the sloughs. Samples are taken from the center of the channel where possible, and where the water is well mixed. Stagnant areas such as eddies behind bridge abutments are avoided. To obtain samples that are also representative by depth, each sample will be a composite of several grab samples taken in the same location at varying depths.

4.4 Comparability

Comparability is a measure of how well data from one study are comparable to data in other studies and to applicable criteria. Comparability is assured by using standard sampling protocols.

The monitoring program for this project ensures comparability with similar projects by following the standardized sampling protocols developed by state agencies (e.g., Surface Water Ambient Monitoring Program), and by using high quality equipment.

4.5 Completeness

Completeness is a measure of the amount of data obtained compared to the amount of data that was expected to be obtained. Completeness is assured by planning ahead and using good sampling technique to avoid data loss.

This study insures completeness by anticipating and preparing for problems that could cause data loss. Frequent calibration, accuracy checks, and data review by sampling staff allows equipment malfunctions or procedural problems to be caught and corrected promptly in order to keep invalid data to a minimum. Despite these preparations, there are some circumstances such as weather events or safety issues that may prevent sampling.

4.6 Data Validation Procedures

Data validation procedures are used to review laboratory reports and field notebooks to ensure that the data are complete, consistent, and correct. Proper data validation helps to identify errors and allow for correction of any problems in data collection and analysis for future sample collection. Data are checked by the designated quality control review person at Brown and Caldwell upon receipt from the laboratories. The review person will fill out a QA/QC Checklist for each laboratory report within a week of receipt of the report. If there are problems with the report, they will be resolved as soon as possible. Field notebooks and COCs are checked to confirm that the field notes reflect the proper date, time, and sample identification noted on the COC and in the laboratory report. The notebooks and laboratory reports are also compared to confirm that duplicates are identified and analyzed as indicated in the field notebook.

4.7 Reporting

For data validation and storage, analytical data and field parameters will be transferred to a computerized database after being validated. This facilitates data validation, reporting, graphic demonstration, and statistical analysis.

APPENDIX A
MEETING SUMMARIES

<u>Chris Foe</u> – Regional Water Quality Control Board (RWQCB)
April 28, 2005
Phone Conversation

The RWQCB is working on a Basin Plan Amendment, which may result in new permit requirements. As part of this amendment, they are going to propose that there be no net increase in loads of MeHg from newly created marshes. This is based on loads and not concentrations, therefore a marsh could be in violation if the flow increases but the concentration stays the same. Marsh restoration projects will need to sample for MeHg both before and after restoration. If the marsh is causing an increase, studies will be required to determine how this effect can be minimized. Mitigation elsewhere will also be required. Chris Foe noted that this is what is being proposed for the amendment, and it may or may not be approved.

<u>Mark Stephenson</u> – Department of Fish and Game (DFG) / Moss Landing Marine Laboratories (MLML)
May 26, 2005
Meeting at MLML

Mark Stephenson has been studying the amounts of MeHg coming off varying types of marshes within the Delta. His preliminary data indicates that some marshes are a source of MeHg, while some are a sink. Extensive site specific data is usually necessary to make this determination. The primary factors affecting mercury methylation are: dissolved oxygen levels, circulation, and presence of organic matter. MLML has the ability to monitor mercury levels on a 24 hour time-scale, which will likely be useful in the implementation of this monitoring plan. Discussion items included an overview of the Dutch Slough site and proposed restoration, components of the monitoring plan, and marsh restoration design factors affecting mercury methylation. MLML facilities were toured, with a focus on those lab facilities used for analyzing mercury samples.

<u>Brian Bergamaschi</u>, <u>Jacob Fleck</u>, <u>Jon Barau</u> – United States Geological Survey (USGS)
June 22, 2005
Meeting at USGS

Brian, Jacob, and Jon have extensive knowledge and research experience in both organic carbon and MeHg. They have been involved in multiple projects in the Delta quantifying amounts of DOC and MeHg coming off of various ecosystem types, especially wetlands. The primary factors affecting water quality are: residence time, water exchange through peat soils, algal production, and the soils in contact with the water. Brian suggests that some microcosm studies to study water quality in the site specific setting may be helpful. USGS staff stressed the importance of continuous sampling, since concentrations can vary significantly on a daily basis due to multiple factors. The USGS has in-situ real time DOC sensors which will likely be useful in the implementation of this monitoring

plan. USGS staff also mentioned that DOC supports 75% of the productivity in the estuary, and therefore increased DOC levels may have a beneficial effect, particularly since it is possible that low organic carbon levels may be limiting production in the estuary. Sample locations were discussed, including locations in Dutch Slough, Emerson Slough, and Little Dutch Slough. The USGS is currently monitoring flow at one nearby location in Dutch Slough. This location would make a good sampling point, especially since useful flow data is already being collected. Other discussion items included an overview of the Dutch Slough site and proposed restoration, as well as restoration design considerations. Brian suggests it will be important to involve a chemist team in the design. One design idea resulting from the meeting is to implement tidal gates, which only release water from the wetland during ebb tides. This would result in wetland outflow flowing away from existing drinking water intakes and towards Big Break.

APPENDIX C-3

Reconnaissance-Level Assessment of Pollutant Sources

TECHNICAL MEMORANDUM **128296-900**

August 22, 2005

TO: NICK GARRITY, PHILLIP WILLIAMS AND ASSOCIATES

FROM: MICHAEL PARENTI, BROWN AND CALDWELL
LAURA MARSHALL, BROWN AND CALDWELL
SABRE DUREN, BROWN AND CALDWELL

SUBJECT: RECONNAISSANCE-LEVEL ASSESSMENT OF POLLUTANT SOURCES

1. INTRODUCTION

1.1 Overview

In order to gain a better understanding of the pollutant sources within the watershed that drains to the Dutch Slough Restoration site (Project Site) Brown and Caldwell (BC) contacted agencies associated with local water quality control programs and conducted a field reconnaissance of the Project Site, conveyances (irrigation drainage channels) and water bodies (fluvial and tidal) that could potentially provide tidal exchange and freshwater flows to the Project Site.

1.2 Process and Objectives

BC contacted Allen Bourgeois of the City of Oakley and Jeff Cowling of the City of Brentwood. The City of Oakley provided a land use map for the 2020 General Plan and a figure showing Oakley development projects. In addition, Laura Marshall took a brief tour with Mr. Bourgeois of the area surrounding the proposed restoration, Marsh Creek, and nearby development. The City of Brentwood provided information regarding development in Marsh Creek watershed, additional contacts for Marsh Creek data, and a map showing Marsh Creek, outfalls, and developments. BC also contacted Aspen Madrone with Contra Costa County and Sarah Beamish Puckett with the Natural Heritage Institute (NHI). Contra Costa County provided some Marsh Creek data as well as a scientific paper titled Marsh Creek Watershed, 1995 Mercury Assessment Project by Slotten, Ayers, and Reuter. NHI also provided some Marsh Creek data and was instrumental in planning BC's site visit to the proposed restoration location.

Michael Parenti, Laura Marshall, and Sabre Duren conducted a field reconnaissance of the Project Site and Marsh Creek on May 25, 2005. Tom Hall, Staff Environmental Scientist with the Department of Water Resources (DWR), is very familiar with the proposed restoration site and served as an escort and knowledgeable source of

information while visiting the Project Site. The objectives of the field reconnaissance were:

- Overview of the Project Site including location of existing and historical land uses
- Review of Marsh Creek and existing water sampling locations
- Location and condition of conveyances that drain into the Project Site
- Proposed locations for storm water discharge to Emerson and Little Dutch Slough from residential development
- Soil conditions and properties
- Identification of potential monitoring and sampling locations.

2. FIELD RECONNAISANCE

2.1 Site Locations

The reconnaissance of the Project Site began at the Emerson Parcel (Figure 1 - Dutch Slough Project Site) and proceeded to the mouth of Marsh Creek near Big Break (Photos 1 – 4). From there the site visit went along Dutch Slough until the confluence with Emerson Slough (Photos 5-10). The visit then followed Emerson slough south to it terminus, then back out to Dutch Slough (Photos 11-13 and 15-17). BC staff also viewed the length of Little Dutch Slough (Photos 23 and 25). Several agricultural drainage ditches were viewed as well as an irrigation canal (Photos 18 – 22). Toe drains were also observed alongside the levees (Photo 24).

After the site visit, two locations along Marsh Creek upstream of the site were visited by BC staff (Figure 2). The first location was at the intersection of Brentwood Boulevard and Sunset Court, where two storm water outfalls discharge into Marsh Creek (Photos 26 – 30). This location is upstream of the Brentwood wastewater treatment plant (WWTP). The second location was where Marsh Creek crosses Delta Rd (Photos 31 – 32). This location is located downstream of the WWTP. The site visit and photos show that the flow downstream of the WWTP is more significant than the flow upstream of the WWTP.

2.2 Summary of Observations

The site reconnaissance provided valuable information not only as a general orientation, but also to identify potential sampling locations and assess the feasibility of Monitoring Plan implementation. Information on current, past, and future land uses was obtained. A historical dairy farm is located on site. The site is currently not being actively farmed, and therefore associated water quality impacts should be minimal compared to actively farmed sites. The land on the Project Site is subsided, but an elevation gradient, including some unique dunes, is present to allow various habitat types within the proposed restoration. A general sense was gained for the current general water quality of the sloughs and Marsh Creek. Extensive algae growth was observed in Emerson Slough

and Little Dutch Slough. This suggests high nutrient loads and a tendency for anaerobic conditions. Anaerobic conditions are an important factor to consider when evaluating the potential for mercury methylation at a site, which is one of the primary water quality concerns for the proposed restoration.

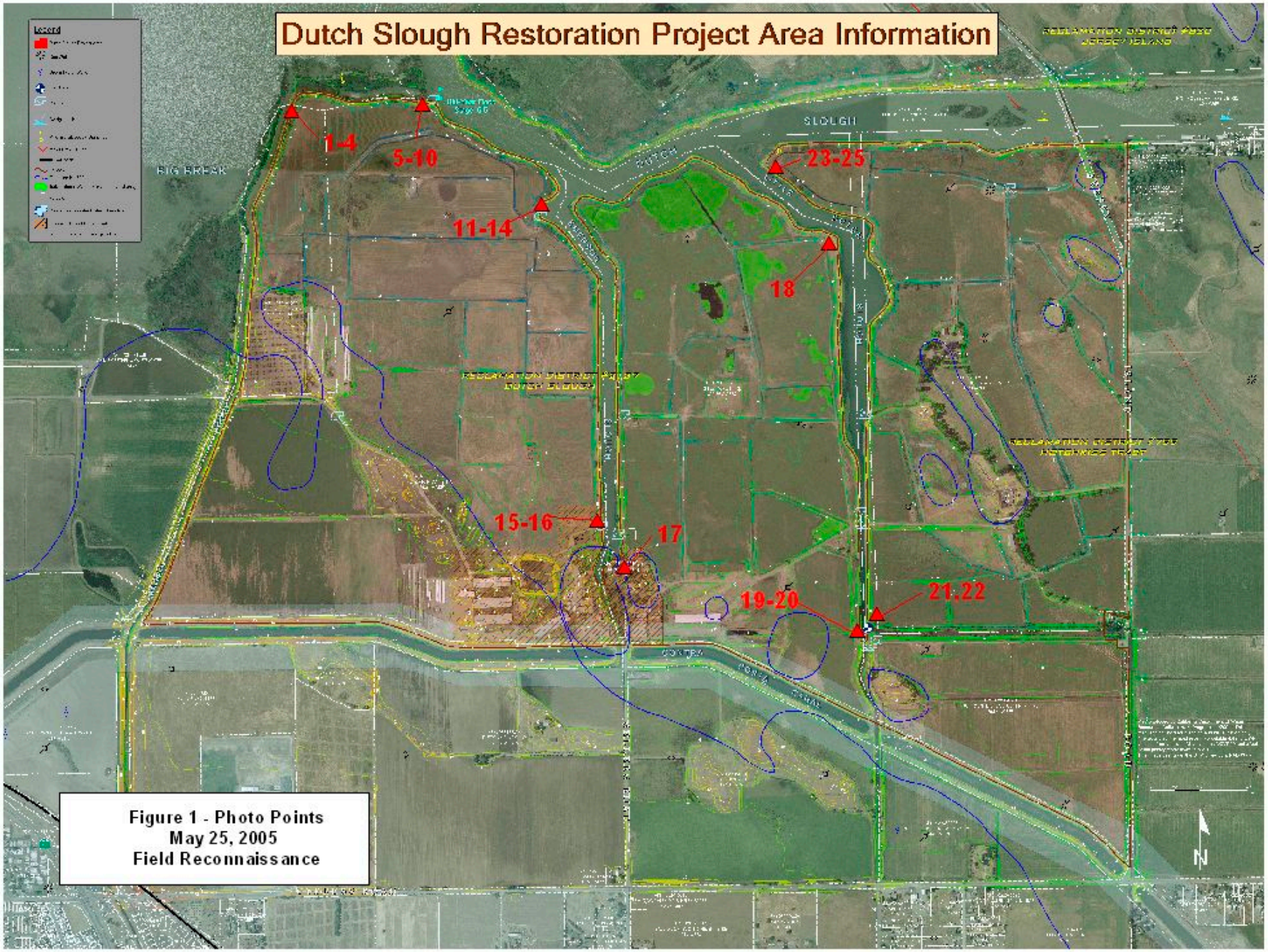


Figure 1 - Photo Points
May 25, 2005
Field Reconnaissance

Photo 1: Mouth of Marsh Creek looking NW

Photo 2: Mouth of Marsh Creek looking North

Photo 3: Mouth of Marsh Creek looking SW upstream

Photo 4: Emerson Parcel from Mouth of Marsh Creek

Photo 5: Dutch Slough

Photo 6: Dutch Slough at historic mouth of Marsh Creek

Photo 7: Dutch Slough from Emerson Parcel

Photo 8: Dutch Slough

Photo 9: Dutch Slough aquatic vegetation

Photo 10: Dutch Slough

Photo 11: Emerson Slough

Photo 12: Aquatic vegetation in Emerson Slough

Photo 13: Close-up of Emerson Slough aquatic vegetation

Photo 14: Dutch Slough

Photo 15: Emerson Slough

Photo 16: Aquatic vegetation Emerson Slough

Photo 17: Emerson Slough at terminus

Photo 18: Agricultural drainage ditch near Little Dutch Slough

Photo 19: Irrigation canal receiving water from Little Dutch Slough

Photo 20: Irrigation canal receiving water from Little Dutch Slough

Photo 21: Flap gate location on Little Dutch Slough intake for irrigation canal in Photos 19 and 20

Photo 22: Outlet for flap gate in Photo 21

Photo 23: Little Dutch Slough

Photo 24: Levee toe drain

Photo 25: Dutch Slough

Photo 26: Marsh Creek storm water outfall Brentwood Boulevard at Sunset Court

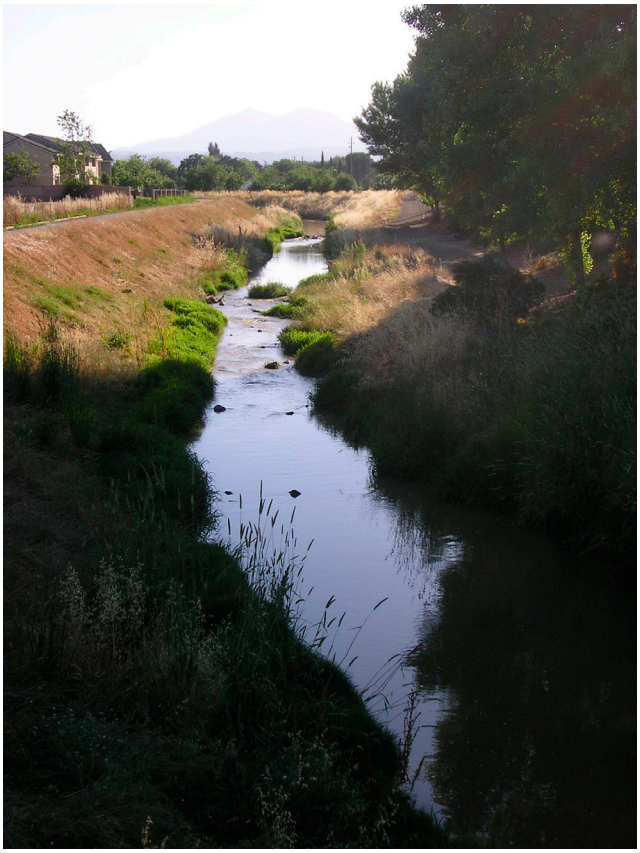


Photo 27: Marsh Creek upstream of Brentwood Boulevard

Photo 28: Marsh Creek at Brentwood Boulevard

Photo 29: Storm water outfalls Marsh Creek at Sunset Boulevard

Photo 30: Marsh Creek near Brentwood Boulevard

Photo 31: Marsh Creek at Delta Road downstream of Waste Water Treatment Plant

Photo 32: Marsh Creek at Delta Road looking north

APPENDIX D

Existing Conditions

D-1. Mercury
D-2. Special Status Species With Potential to Occur on the Dutch Slough Restoration Area
D-3. Description of Public Use in the Delta Region

APPENDIX D-1

Mercury

APPENDIX D-1: Mercury

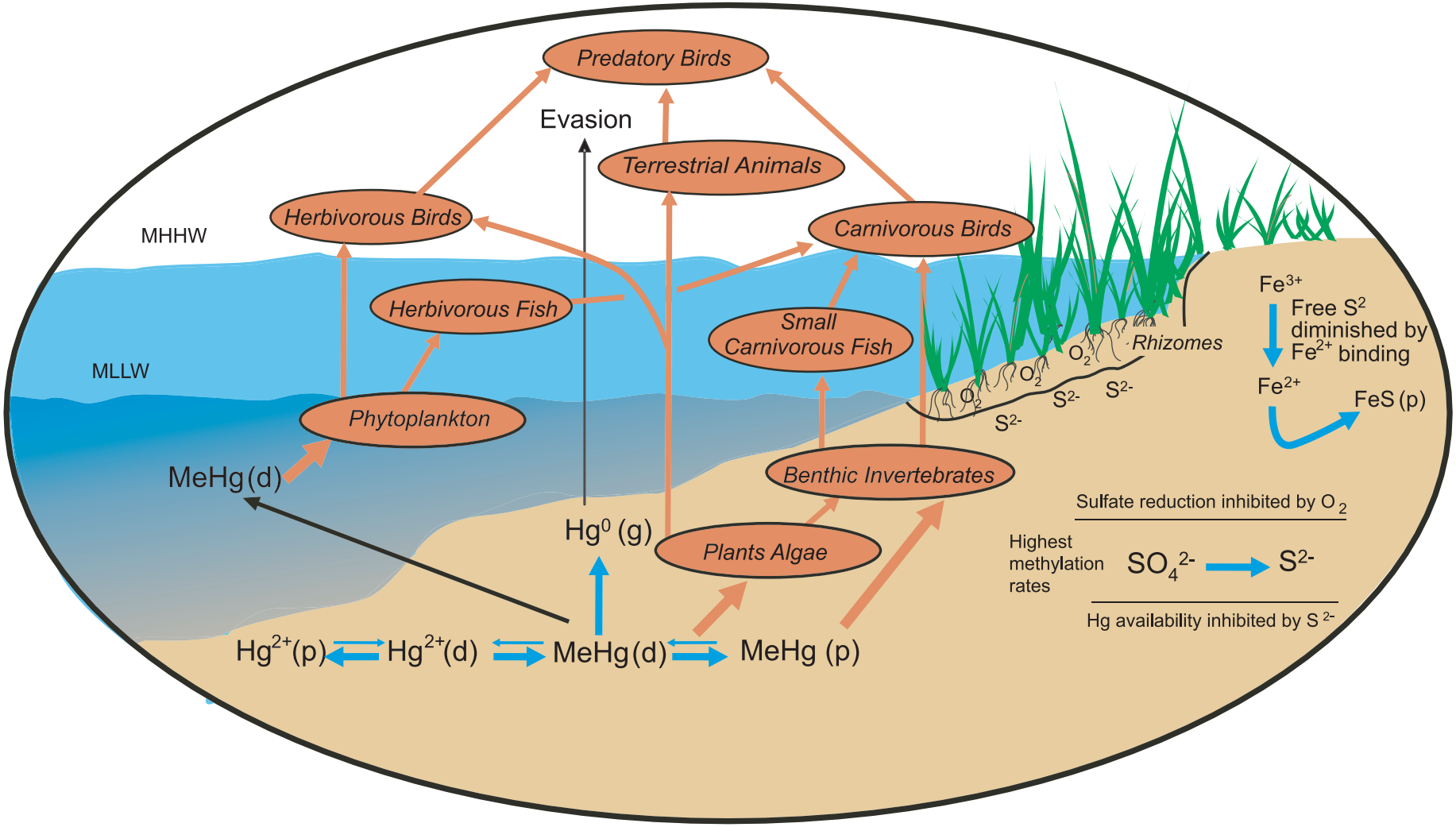
Mercury Conceptual Models

The South Bay Salt Ponds (SBSP) Mercury Technical Memorandum (BC, 2004) discusses several conceptual models for mercury cycling through various wetland ecosystems. Figure D-1 presents the conceptual model for a tidal marsh environment. Although the Dutch Slough Tidal Marsh Restoration Project will be performed in a less saline environment than the SBSP, many aspects of this model are still applicable. The SBSP model focuses on methylation and bioaccumulation processes. The science involved in these processes is still being developed. However, some of the key factors controlling methylation that have been identified are vegetation, dissolved oxygen, sulfide, salinity and dissolved organic carbon. Professor David Sedlack's conceptual model for the cycling of mercury within the Dutch Slough project area is presented in Figure D-2. These models present opportunities to apply and test adaptive management practices that could mitigate methylmercury production and/or bioaccumulation within the restored Dutch Slough wetlands.

Marsh Creek Watershed

The principal source of mercury loads within the Marsh Creek watershed is the historic Mt. Diablo Mercury Mine located on Dunn Creek, with additional sources coming from agricultural and urban runoff. It is estimated that this mine accounts for 95% of the mercury load within the watershed (Slotton et al 1998). A review of aerial photographs and geologic maps of this watershed indicate that sediment loads were historically deposited to the east of the project area, towards Discovery Bay, and that it was not until 1962 when Marsh Creek flood control measures were implemented that the current configuration of Marsh Creek discharging adjacent to the project area was established (NHI, 2004). The National Heritage Institute (NHI) hypothesized that it is unlikely that sediment loads carried through the existing Marsh Creek channel entered the project area since this area is surrounded by an elevated levee/dike system. Reviews of recent aerial photographs indicate that sediment loads are being discharged from Marsh Creek to Big Break, adjacent to the project area (NHI, 2004).

The Marsh Creek Watershed Mercury Assessment Project investigated the distribution of mercury loads throughout Marsh Creek. This assessment divided the creek into six general sections: upstream of the Mt. Diablo Mine, downstream of the Mt. Diablo Mine within Dunn Creek, the reach between the confluence of Dunn Creek/Marsh Creek and the Marsh Creek Reservoir, the Marsh Creek Reservoir itself, immediately downstream of the reservoir, and far downstream of the Reservoir. The results of this assessment indicate that elevated mercury loads originate in Dunn Creek and have also impacted the reach between the Dunn Creek/Marsh Creek confluence and the Marsh Creek Reservoir. The assessment concluded that it is likely the reservoir captures sediment and prevents the majority of the mercury load from being transported



Source: Beutel et al., 2004

Notes: MHHW = Mean Higher High Water; MLLW = Mean Lower Low Water; Hg= Mercury; HgMe = Methylmercury; S = Sulfur; O = Oxygen; Fe = Iron; (p) = precipitate; (d) = dissolved; (g) = gas.

figure D-1

Dutch Slough Tidal Marsh Restoration Feasibility Report

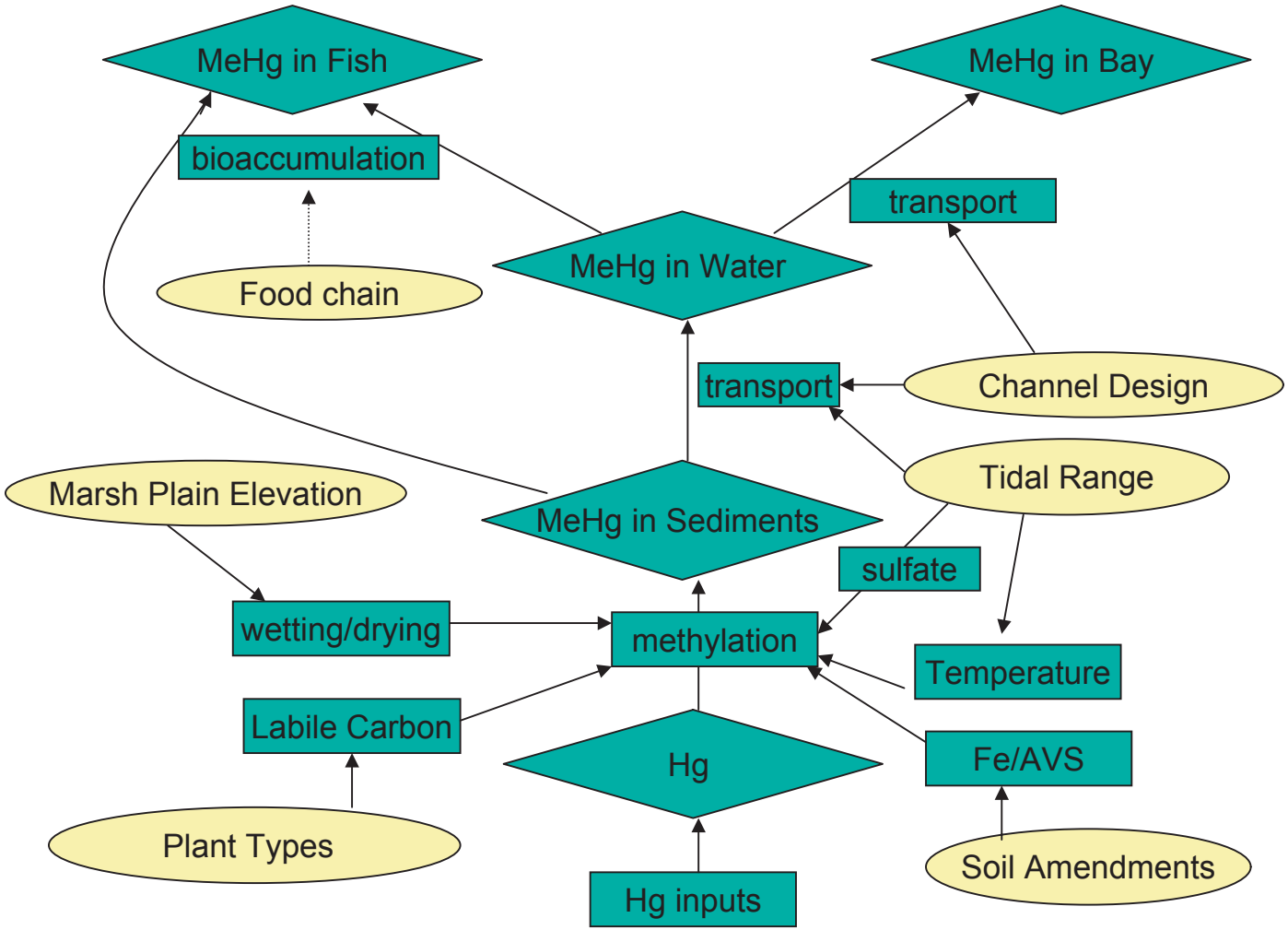
Mercury Cycling within a Tidal Marsh- Overview

PWA BROWN AND CALDWELL

further downstream. Since this reservoir was constructed in 1963, the project area received only one year of direct mercury sediment loads originating from the Mt. Diablo Mine (i.e., in 1962 the creek discharged adjacent to the project area).

Bay-Delta Mercury Studies

Currently, CALFED is funding several investigations related to mercury issues within the Bay-Delta ecosystem. One such investigation being conducted Mark Marvin-DiPasquale of the United States Geological Survey (USGS) is the *Evaluation of Mercury Transformation and Trophic Transfer in the San Francisco Bay/Delta: Identifying Critical Processes for the Ecosystem Restoration Program*. The objective of this study is to determine what effect the tidal inundation process and vegetative types have on methylmercury production in various wetland sub-habitats. Specifically, the project is examining the wetting/drying cycle within wetlands and the various submerging versus emergent tidal marsh vegetations. Additional methylmercury related projects within the Bay-Delta are planned to commence in early 2005. These include the San Francisco Estuary Institute (SFEI) sponsored *Mercury and Methylmercury Processes in North San Francisco Bay Tidal Wetland Ecosystems*, and other CALFED funded projects headed by Roger Fujii, who is with the USGS and a member of the Dutch Slough Adaptive Management Work Group.



Source: David Sedlak, 2004

figure D-2

Dutch Slough Tidal Marsh Restoration Feasibility Report

Mercury Cycling Within A Tidal Marsh- Methylation Detail

PWA BROWN AND CALDWELL

APPENDIX D-2

Special Status Species with Potential to Occur at Dutch Slough

Species		LiSting Status 1			Species Information			
Scientific Name	Common Name	USFWS (Federal)	CDFG (State)	CNPS	Flowering Period	General Habitat	Microhabitat	Dutch Slough Occurrence
Amphibian								
Ambystoma californiense	California tiger salamander	T	SSC			POPULATIONS IN SANTA BARBARA & SONOMA COUNTIES CURRENTLY LISTED AS ENDANGERED. PROPOSAL TO LIST AS THREATENED STATEWIDE.	NEED UNDERGROUND REFUGES, ESPECIALLY GROUND SQUIRREL BURROWS & VERNAL POOLS OR OTHER SEASONAL WATER SOURCES FOR BREEDING	NOT OBSERVED
Rana aurora draytonii	California red-legged frog	T	SSC			LOWLANDS & FOOTHILLS IN OR NEAR PERMANENT SOURCES OF DEEP WATER WITH DENSE, SHRUBBY OR EMERGENT RIPARIAN VEGETATION.	REQUIRES 11-20 WEEKS OF PERMANENT WATER FOR LARVAL DEVELOPMENT. MUST HAVE ACCESS TO ESTIVATION HABITAT.	NOT OBSERVED
Spea (=Scaphiopus) hammondii	western spadefoot toad	SC				OCCURS PRIMARILY IN GRASSLAND HABITATS, BUT CAN BE FOUND IN VALLEY-FOOTHILL HARDWOOD WOODLANDS.		NOT OBSERVED
Reptile								
Anniella pulchra pulchra	silvery legless lizard	SC	SSC			SANDY OR LOOSE LOAMY SOILS UNDER SPARSE VEGETATION.	SOIL MOISTURE IS ESSENTIAL. THEY PREFER SOILS WITH A HIGH MOISTURE CONTENT.	NOT OBSERVED
Emys (=Clemmys) marmorata	western pond turtle		SSC			A THOROUGHLY AQUATIC TURTLE OF PONDS, MARSHES, RIVERS, STREAMS & IRRIGATION DITCHES WITH AQUATIC VEGETATION.	NEED BASKING SITES AND SUITABLE (SANDY BANKS OR GRASSY OPEN FIELDS) UPLAND HABITAT FOR EGG-LAYING.	REPRODUCING POPULATIONS OBSERVED BY DWR (2004) IN AQUATIC HABITATS OF DITCHES ONSITE
Masticophis flagellum ruddocki	San Joaquin whipsnake	SC	SSC			OPEN, DRY HABITATS WITH LITTLE OR NO TREE COVER. FOUND IN VALLEY GRASSLAND & SALTBUSH SCRUB IN THE SAN JOQUIN VALLEY.	NEEDS MAMMAL BURROWS FOR REFUGE AND OVIPOSITION SITES.	NOT OBSERVED
Phrynosoma coronatum (frontale)	Coast (California) horned lizard	SC	SSC			FREQUENTS A WIDE VARIETY OF HABITATS, MOST COMMON IN LOWLANDS ALONG SANDY WASHES WITH SCATTERED LOW BUSHES.	OPEN AREAS FOR SUNNING, BUSHES FOR COVER, PATCHES OF LOOSE SOIL FOR BURIAL, & ABUNDANT SUPPLY OF ANTS & OTHER INSECTS.	NOT OBSERVED
Thamnophis gigas	giant garter snake	T	T			PREFERS FRESHWATER MARSH AND LOW GRADIENT STREAMS. HAS ADAPTED TO DRAINAGE CANALS & IRRIGATION DITCHES.	THIS IS THE MOST AQUATIC OF THE GARTER SNAKES IN CALIFORNIA.	NOT OBSERVED
Birds								
Accipiter cooperii	Cooper's hawk		SSC			(NESTING) WOODLAND, CHIEFLY OF OPEN, INTERRUPTED OR MARGINAL TYPE.	NEST SITES MAINLY IN RIPARIAN GROWTHS OF DECIDUOUS TREES, AS IN CANYON BOTTOMS ON RIVER FLOOD-PLAINS; ALSO, LIVE OAKS.	NOT OBSERVED
Agelaius tricolor	tricolored blackbird	SC	SSC			(NESTING COLONY) HIGHLY COLONIAL SPECIES, MOST NUMBEROUS IN CENTRAL VALLEY & VICINITY. LARGELY ENDEMIC TO CALIFORNIA.	REQUIRES OPEN WATER, PROTECTED NESTING SUBSTRATE, & FORAGING AREA WITH INSECT PREY WITHIN A FEW KM OF THE COLONY.	NOT OBSERVED

Species		LiSting Status 1			Species Information			
Scientific Name	Common Name	USFWS (Federal)	CDFG (State)	CNPS	Flowering Period	General Habitat	Microhabitat	Dutch Slough Occurrence
Aquila chrysaetos	golden eagle		SSC			(NESTING & WINTERING) ROLLING FOOTHILLS MOUNTAIN AREAS, SAGE-JUNIPER FLATS, DESERT.	CLIFF-WALLED CANYONS PROVIDE NESTING HABITAT IN MOST PARTS OF RANGE; ALSO, LARGE TREES IN OPEN AREAS.	NOT OBSERVED
Asio flammeus	short-eared owl		SSC			(NESTING) FOUND IN SWAMP LANDS, BOTH FRESH AND SALT; LOWLAND MEADOWS; IRRIGATED ALFALFA FIELDS.	TULE PATCHES/TALL GRASS NEEDED FOR NESTING/DAYTIME SECLUSION. NESTS ON DRY GROUND IN DEPRESSION CONCEALED IN VEGETATION.	NOT OBSERVED
Athene cunicularia	burrowing owl	SC	SSC			(BURROW SITES) OPEN, DRY ANNUAL OR PERENIAL GRASSLANDS, DESERTS & SCRUBLANDS CHARACTERIZED BY LOW-GROWING VEGETATION.	SUBTERRANEAN NESTER, DEPENDENT UPON BURROWING MAMMALS, MOST NOTABLY, THE CALIFORNIA GROUND SQUIRREL.	NOT OBSERVED
Buteo regalis	ferruginous hawk	SC	SSC			(WINTERING) OPEN GRASSLANDS, SAGEBRUSH FLATS, DESERT SCRUB, LOW FOOTHILLS & FRINGES OF PINYON-JUNIPER HABITATS.		NOT OBSERVED
Buteo swainsoni	Swainson's hawk	SC	T			(NESTING) BREEDS IN STANDS WITH FEW TREES IN JUNIPER-SAGE FLATS, RIPARIAN AREAS AND IN OAK SAVANNAH.	REQUIRES ADJACENT SUITABLE FORAGING AREAS SUCH AS GRASSLANDS, OR ALFALFA OR GRAIN FIELDS SUPPORTING RODENT POPULATIONS.	OBSERVED ON SITE (EDAW 2005), POSSIBLY NESTING IN RIPARIAN WOODLAND
Charadrius alexandrinus nivosus	western snowy plover	T				SANDY BEACHES, SALT POND LEVEES & SHORES OF LARGE ALKALI LAKES. NEEDS SANDY, GRAVELLY OR FRIABLE SOILS FOR NESTING.		NOT OBSERVED
Chlidonias niger	black tern	SC				(NESTING COLONY) FRESHWATER LAKES, PONDS, MARSHES & FLOODED AG FIELDS. AT COASTAL LAGOONS & ESTUARIES DURING MIGRATION.		NOT OBSERVED
Circus cyaneus	northern harrier		SSC			(NESTING) COASTAL SALT & FRESH-WATER MARSH. NEST & FORAGE IN GRASSLANDS, FROM SALT GRASS IN DESERT SINK TO MTN CIENAGAS.	NESTS ON GROUND IN SHRUBBY VEGETATION, USUALLY AT MARSH EDGE; NEST BUILT OF A LARGE MOUND OF STICKS IN WET AREAS.	OBSERVED FORAGING IN FRESHWATER MARSH ONSITE (EDAW 2005)
Dendroica petechia brewsteri	yellow warbler		SSC			(NESTING) RIPARIAN PLANT ASSOCIATIONS. PREFERS WILLOWS, COTTONWOODS, ASPENS, SYCAMORES, & ALDERS FOR NESTING & FORAGING		NOT OBSERVED
Egretta thula	snowy egret	SC				(ROOKERY) COLONIAL NESTER, WITH NEST SITES SITUATED IN PROTECTED BEDS OF DENSE TULES.	ROOKERY SITES SITUATED CLOSE TO FORAGING AREAS: MARSHES, TIDAL-FLATS, STREAMS, WET MEADOWS, AND BORDERS OF LAKES.	NOT OBSERVED

Species		LiSting Status 1			Species Information			
Scientific Name	Common Name	USFWS (Federal)	CDFG (State)	CNPS	Flowering Period	General Habitat	Microhabitat	Dutch Slough Occurrence
Elanus leucurus	white-tailed kite	SC				(NESTING) ROLLING FOOTHILLS/VALLEY MARGINS W/SCATTERED OAKS & RIVER BOTTOMLANDS OR MARSHES NEXT TO DECIDUOUS WOODLAND	OPEN GRASSLANDS, MEADOWS, OR MARSHES FOR FORAGING CLOSE TO ISOLATED, DENSE-TOPPED TREES FOR NESTING AND PERCHING.	NOT OBSERVED
Eremophila alpestris actia	California horned lark		SSC			COASTAL REGIONS, CHIEFLY FROM SONOMA CO. TO SAN DIEGO CO. ALSO MAIN PART OF SAN JOAQUIN VALLEY & EAST TO FOOTHILLS.	SHORT-GRASS PRAIRIE, "BALD" HILLS, MOUNTAIN MEADOWS, OPEN COASTAL PLAINS, FALLOW GRAIN FIELDS, ALKALI FLATS.	NOT OBSERVED
Falco columbarius	merlin		SSC			(WINTERING) SEACOAST, TIDAL ESTUARIES, OPEN WOODLANDS, SAVANNAHS, EDGES OF GRASSLANDS & DESERTS, FARMS & RANCHES.		NOT OBSERVED
Falco mexicanus	prairie falcon		SSC			(NESTING) INHABITS DRY, OPEN TERRAIN, EITHER LEVEL OR HILLY, BREEDING SITES LOCATED ON CLIFFS. FORAGES FAR AFIELD, EVEN TO MARSHLANDS AND OCEAN SHORES.		NOT OBSERVED
Falco peregrinus anatum	American peregrine falcon	SC	E			(NESTING) NEAR WETLANDS, LAKES, RIVERS, OR OTHER WATER; ON CLIFFS, BANKS, DUNES, MOUNDS; ALSO, HUMAN-MADE STRUCTURES.		NOT OBSERVED
Grus canadensis tabida	greater sandhill crane		T			(NESTING & WINTERING) NESTS IN WETLAND HABITATS IN NORTHEASTERN CALIFORNIA; WINTERS IN THE CENTRAL VALLEY.		NOT OBSERVED
Haliaeetus leucocephalus	bald eagle	T	E			(NESTING & WINTERING) OCEAN SHORE, LAKE MARGINS, & RIVERS FOR BOTH NESTING & WINTERING. MOST NESTS WITHIN 1 MI OF WATER.		NOT OBSERVED
Icteria virens	yellow-breasted chat		SSC			(NESTING) SUMMER RESIDENT; INHABITS RIPARIAN THICKETS OF WILLOW & OTHER BRUSHY TANGLES NEAR WATERCOURSES.		NOT OBSERVED
Ixobrychus exilis (ssp hesperis?)	least bittern		SSC			COLONIAL NESTER IN MARSHLANDS AND BORDERS OF PONDS AND RESERVOIRS WHICH PROVIDE AMPLE COVER.		NOT OBSERVED
Lanius ludovicianus	loggerhead shrike	SC	SSC			(NESTING) BROKEN WOODLANDS, SAVANNAH, PINYON-JUNIPER, JOSHUA TREE, & RIPARIAN WOODLANDS, DESERT OASES, SCRUB & WASHES.	PREFERS OPEN COUNTRY FOR HUNTING, WITH PERCHES FOR SCANNING, AND FAIRLY DENSE SHRUBS AND BRUSH FOR NESTING.	NOT OBSERVED

Species		LiSting Status 1			Species Information			
Scientific Name	**Common Name**	**USFWS (Federal)**	**CDFG (State)**	**CNPS**	**Flowering Period**	**General Habitat**	**Microhabitat**	**Dutch Slough Occurrence**
Laterallus jamaicensis coturniculus	California black rail	SC	T			MAINLY INHABITS SALT-MARSHES BORDERING LARGER BAYS.	OCCURS IN TIDAL SALT MARSH HEAVILY GROWN TO PICKLEWEED; ALSO IN FRESH-WATER AND BRACKISH MARSHES, ALL AT LOW ELEVATION.	OCCURS IN TIDAL MARSHES ADJACENT TO PROPERTY (NHI 2004)
Melospiza melodia maxillaris	Suisun song sparrow	SC	SSC			RESIDENT OF BRACKISH-WATER MARSHES SURROUNDING SUISUN BAY.	INHABITS CATTAILS, TULES AND OTHER SEDGES, AND SALICORNIA; ALSO KNOWN TO FREQUENT TANGLES BORDERING SLOUGHS.	OBSERVED IN FRESHWATER MARSH ON PROPERTY (EDAW 2005)
Numenius americanus	long-billed curlew	SC				(NESTING) BREEDS IN UPLAND SHORTGRASS PRAIRIES & WET MEADOWS IN NORTHEASTERN CALIFORNIA.		NOT OBSERVED
Nycticorax nycticorax	black-crowned night heron					(ROOKERY) COLONIAL NESTER, USUALLY IN TREES, OCCASIONALLY IN TULE PATCHES.	ROOKERY SITES LOCATED ADJACENT TO FORAGING AREAS: LAKE MARGINS, MUD-BORDERED BAYS, MARSHY SPOTS.	NOT OBSERVED
Phalacrocorax auritus	double-crested cormorant		SSC			(ROOKERY SITE) COLONIAL NESTER ON COASTAL CLIFFS, OFFSHORE ISLANDS, & ALONG LAKE MARGINS IN THE INTERIOR OF THE STATE.	NESTS ALONG COAST ON SEQUESTERED ISLETS, USUALLY ON GROUND WITH SLOPING SURFACE, OR IN TALL TREES ALONG LAKE MARGINS.	NOT OBSERVED
Rallus longirostris obsoletus	California clapper rail	E	E			SALT-WATER & BRACKISH MARSHES TRAVERSED BY TIDAL SLOUGHS IN THE VICINITY OF SAN FRANCISCO BAY.	ASSOCIATED WITH ABUNDANT GROWTHS OF PICKLEWEED, BUT FEEDS AWAY FROM COVER ON INVERTEBRATES FROM MUD-BOTTOMED SLOUGHS.	NOT OBSERVED
Sterna antillarum browni	California least tern	E	E			(NESTING COLONY) NESTS ALONG THE COAST FROM SAN FRANCISCO BAY SOUTH TO NORTHERN BAJA CALIFORNIA.	COLONIAL BREEDER ON BARE OR SPARSELY VEGETATED, FLAT SUBSTRATES: SAND BEACHES, ALKALI FLATS, LAND FILLS, OR PAVED AREAS.	NOT OBSERVED
Sterna caspia	Caspian tern					(NESTING COLONY) NESTS IN SMALL COLONIES INLAND AND ALONG THE COAST.	INLAND FRESH-WATER LAKES AND MARSHES; ALSO, BRACKISH OR SALT WATERS OF ESTUARIES AND BAYS.	NOT OBSERVED
FISH								
Archoplites interruptus	Sacramento perch	SC	SSC			HISTORICALLY FOUND IN THE SLOUGHS, SLOW-MOVING RIVERS, AND LAKES OF THE CENTRAL VALLEY.	PREFER WARM WATER. AQUATIC VEGETATION IS ESSENTAL FOR YOUNG. TOLERATE WIDE RANGE OF PHYSICO-CHEMICAL WATER CONDITIONS.	
Eucyclogobius newberryi	tidewater goby	E				BRACKISH WATER HABITATS ALONG THE CALIF COAST FROM AGUA HEDIONDA LAGOON, SAN DIEGO CO. TO THE MOUTH OF THE SMITH RIVER.		

Species		LiSting Status 1			Species Information			
Scientific Name	Common Name	USFWS (Federal)	CDFG (State)	CNPS	Flowering Period	General Habitat	Microhabitat	Dutch Slough Occurrence
Hypomesus transpacificus	Delta smelt	T	T			SACRAMENTO-SAN JOAQUIN DELTA. SEASONALLY IN SUISUN BAY, CARQUINEZ STRAIT & SAN PABLO BAY.		
Lampetra ayresi	river lamprey	SC	SSC			LOWER SACRAMENTO RIVER, SAN JOAQUIN RIVER & RUSSIAN RIVER. MAY OCCUR IN COASTAL STREAMS NORTH OF SAN FRANCISCO BAY.		
Lampetra tridentata	Pacific lamprey	SC	SSC			anadromous		
Oncorhynchus mykiss irideus	steelhead - Central Valley esu	T				POPULATIONS IN THE SACRAMENTO AND SAN JOAQUIN RIVERS AND THEIR TRIBUTARIES		
Oncorhynchus tshawytscha winter run	chinook salmon winter run	E	E			SACRAMENTO RIVER BELOW KESWICK DAM. SPAWNS IN THE SACRAMENTO RIVER BUT NOT IN TRIBUTARY STREAMS.		
Pogonichthys macrolepidotus	Sacramento splittail		SSC			ENDEMIC TO THE LAKES AND RIVERS OF THE CENTRAL VALLEY, BUT NOW CONFINED TO THE DELTA, SUISUN BAY & ASSOCIATED MARSHES.		
Spirinchus thaleichthys	longfin smelt	SC	SSC			EURYHALINE, NEKTONIC & ANADROMOUS. FOUND IN OPEN WATERS OF ESTUARIES, MOSTLY IN MIDDLE OR BOTTOM OF WATER COLUMN.		
MAMMAL								
Corynorhinus townsendii townsendii	Townsend's western big-eared bat	SC				HUMID COASTAL REGIONS OF NORTHERN & CENTRAL CALIFORNIA. ROOST IN LIMESTONE CAVES, LAVA TUBES, MINES, BUILDINGS ETC.		NOT OBSERVED
Microtus californicus sanpabloensis	San Pablo vole		SSC			SALTMARSHES OF SAN PABLO CREEK, ON THE SOUTH SHORE OF SAN PABLO BAY.	CONSTRUCTS BURROW IN SOFT SOIL. FEEDS ON GRASSES, SEDGES AND HERBS. FORMS A NETWORK OF RUNWAYS LEADING FROM THE BURROW	NOT OBSERVED
Perognathus inornatus inornatus	San Joaquin pocket mouse	SC				TYPICALLY FOUND IN GRASSLANDS AND BLUE OAK SAVANNAS.	NEEDS FRIABLE SOILS.	NOT OBSERVED
Vulpes macrotis mutica	San Joaquin kit fox	E	T			ANNUAL GRASSLANDS OR GRASSY OPEN STAGES WITH SCATTERED SHRUBBY VEGETATION.	NEED LOOSE-TEXTURED SANDY SOILS FOR BURROWING, AND SUITABLE PREY BASE.	NOT OBSERVED
Invertebrates								
Anthicus antiochensis	Antioch Dunes anthicid beetle	SC				KNOWN ONLY FROM THE ANTIOCH DUNES.		
Coelus globosus	globose dune beetle	SC				INHABITANT OF COASTAL SAND DUNE HABITAT, FROM BODEGA HEAD IN SONOMA COUNTY SOUTH TO ENSENADA, MEXICO.		

Species		LiSting Status 1			Species Information			
Scientific Name	Common Name	USFWS (Federal)	CDFG (State)	CNPS	Flowering Period	General Habitat	Microhabitat	Dutch Slough Occurrence
Cophura hurdi	Antioch cophuran robberfly					ONLY SPECIMEN KNOWN COLLECTED IN ANTIOCH.		
Desmocerus californicus dimorphus	valley elderberry longhorn beetle	T				OCCURS ONLY IN THE CENTRAL VALLEY OF CALIFORNIA, IN ASSOCIATION WITH BLUE ELDERBERRY (SAMBUCUS MEXICANA).		
Efferia antiochi	Antioch efferian robberfly	SC				KNOWN ONLY FROM CONTRA COSTA COUNTY (ANTIOCH) AND FRESNO COUNTY (FRESNO).		
Eucerceris ruficeps	redheaded sphecid wasp					CENTRAL CALIFORNIA INTERIOR DUNES.		
*Hydrochara ricksecker*i	Ricksecker's water scavenger beetle	SC				AQUATIC; KNOWN FROM THE SAN FRANCISCO BAY AREA.		
Perdita hirticeps luteocincta	yellow-banded andrenid bee					ANTIOCH DUNES.		
Philanthus nasalis	Antioch specid wasp					KNOWN ONLY FROM THE ANTIOCH DUNES OF THE SACRAMENTO-SAN JOAQUIN DELTA AREA, IN THE VICINITY OF ANTIOCH, CONTRA COSTA CO.		
Apodemia mormo langei	Lange's metalmark butterfly	E				INHABITS STABILIZED DUNES ALONG THE SAN JOAQUIN RIVER. ENDEMIC TO ANTIOCH DUNES, CONTRA COSTA COUNTY.	PRIMARY HOST PLANT IS ERIOGONUM NUDUM VAR AURICULATUM; FEEDS ON NECTAR OF OTHER WILDFLOWERS, AS WELL AS HOST PLANT.	
Branchinecta longiantenna	longhorn fairy shrimp	E				ENDEMIC TO THE EASTERN MARGIN OF THE CENTRAL COAST MTNS IN SEASONALLY ASTATIC GRASSLAND VERNAL POOLS.	INHABIT SMALL, CLEAR-WATER DEPRESSIONS IN SANDSTONE AND CLEAR-TO-TURBID CLAY/GRASS-BOTTOMED POOLS IN SHALLOW SWALES.	
Branchinecta lynchi	vernal pool fairy shrimp	T				ENDEMIC TO THE GRASSLANDS OF THE CENTRAL VALLEY, CENTRAL COAST MTNS, AND SOUTH COAST MTNS, IN ASTATIC RAIN-FILLED POOLS.	INHABIT SMALL, CLEAR-WATER SANDSTONE-DEPRESSION POOLS AND GRASSED SWALE, EARTH SLUMP, OR BASALT-FLOW DEPRESSION POOLS.	
Branchinecta mesovallensis	midvalley fairy shrimp	SC				VERNAL POOLS IN THE CENTRAL VALLEY		
Coelus gracilis	San Joaquin dune beetle	SC				INHABITS FOSSIL DUNES ALONG THE WESTERN EDGE OF SAN JOAQUIN VALLEY; EXTIRPATED FROM ANTIOCH DUNES (TYPE LOCALITY).	INHABITS SITES CONTAINING SANDY SUBSTRATES.	
Danaus plexippus	monarch butterfly					WINTER ROOST SITES EXTEND ALONG THE COAST FROM NORTHERN MENDOCINO TO BAJA CALIFORNIA, MEXICO.	ROOSTS LOCATED IN WIND-PROTECTED TREE GROVES (EUCALYPTUS, MONTEREY PINE, CYPRESS), WITH NECTAR AND WATER SOURCES NEARBY.	

Species		LiSting Status 1			Species Information			
Scientific Name	**Common Name**	**USFWS (Federal)**	**CDFG (State)**	**CNPS**	**Flowering Period**	**General Habitat**	**Microhabitat**	**Dutch Slough Occurrence**
Efferia antiochi	Antioch efferian robberfly	SC				KNOWN ONLY FROM CONTRA COSTA COUNTY (ANTIOCH) AND FRESNO COUNTY (FRESNO).		
Euphydryas editha bayensis	Bay checkerspot butterfly	T				RESTRICTED TO NATIVE GRASSLANDS ON OUTCROPS OF SERPENTINE SOIL IN THE VICINITY OF SAN FRANCISCO BAY.	PLANTAGO ERECTA IS THE PRIMARY HOST PLANT; ORTHOCARPUS DENSIFLORUS & O. PURPURSCENS ARE THE SECONDARY HOST PLANTS.	
Helminthoglypta nickliniana bridgesi	Bridges' coast range shoulderband (snail)	SC				INHABITS OPEN HILLSIDES OF ALAMEDA AND CONTRA COSTA COUNTIES.	TENDS TO COLONIZE UNDER TALL GRASSES AND WEEDS.	
Hygrotus curvipes	curved-foot hygrotus diving beetle	SC				AQUATIC; KNOWN ONLY FROM ALAMEDA & CONTRA COSTA COUNTIES.		
Idiostatus middlekaufi	Middlekauf's shieldback katydid	SC				ANTIOCH DUNES.		
Linderiella occidentalis	California linderiella	SC				SEASONAL POOLS IN UNPLOWED GRASSLANDS WITH OLD ALLUVIAL SOILS UNDERLAIN BY HARDPAN OR IN SANDSTONE DEPRESSIONS.	WATER IN THE POOLS HAS VERY LOW ALKALINITY, CONDUCTIVITY, AND TDS.	
Lytta molesta	molestan blister beetle	SC				INHABITS THE CENTRAL VALLEY OF CALIFORNIA, FROM CONTRA COSTA TO KERN AND TULARE COUNTIES.		
Myrmosula pacifica	Antioch multilid wasp	SC				ANTIOCH DUNES.		
Perdita scituta antiochensis	Antioch andrenid bee	SC				ANTIOCH DUNES.	VISITS FLOWERS OF ERIOGONUM, GUTIERREZIA CALIFORNICA, HETEROTHECA GRANDIFLORA, LESSINGIA GLANDULIFERA.	
Plants								
Aster lentus	Suisun Marsh aster	SC		1B	May-Nov	MARSHES AND SWAMPS (BRACKISH AND FRESHWATER). ENDEMIC TO THE SAC/SAN JOAQUIN RIVER DELTA.	MOST OFTEN SEEN ALONG SLOUGHS WITH PHRAGMITES, SCIRPUS, BLACKBERRY, TYPHA, ETC. 0-3M.	TIDAL FRESHWATER MARSH, OBSERVED IN EMERSON SLOUGH AND MARSH CREEK
Astragalus tener var. tener	alkali milk-vetch	SC		1B	Mar-Jun	ALKALI PLAYA, VALLEY AND FOOTHILL GRASSLAND, VERNAL POOLS.	LOW GROUND, ALKALI FLATS, AND FLOODED LANDS; IN ANNUAL GRASSLAND OR IN PLAYAS OR VERNAL POOLS. 1-170M.	NOT OBSERVED
Atriplex cordulata	heartscale	SC		1B	May-Oct	CHENOPOD SCRUB, VALLEY AND FOOTHILL GRASSLAND, MEADOWS.		NOT OBSERVED
Atriplex coronata var. coronata	crownscale			4	Apr-Oct	CHENOPOD SCRUB?, VALLEY AND FOOTHILL GRASSLAND, VERNAL POOLS		NOT OBSERVED
Atriplex depressa	brittlescale	SC		1B	May-Oct	CHENOPOD SCRUB, MEADOWS, PLAYAS, VALLEY AND FOOTHILL GRASSLAND, VERNAL POOLS.	USUALLY IN ALKALI SCALDS OR ALK. CLAY IN MEADOWS OR ANNUAL GRASSLND; RARELY ASSOC W/RIPARIAN, MARSHES, OR V.P'S. 1-320M.	NOT OBSERVED

Species		LiSting Status 1			Species Information			
Scientific Name	Common Name	USFWS (Federal)	CDFG (State)	CNPS	Flowering Period	General Habitat	Microhabitat	Dutch Slough Occurrence
Atriplex joaquiniana	San Joaquin saltbush	SC		1B	April-Sept	CHENOPOD SCRUB, ALKALI MEADOW, VALLEY AND FOOTHILL GRASSLAND.	IN SEASONAL ALKALI WETLANDS OR ALKALI SINK SCRUB WITH DISTICHLIS SPICATA, FRANKENIA, ETC. 1-250M.	NOT OBSERVED
Calystegia purpurata ssp. saxicola	coastal bluff morning-glory	SC		1B		COASTAL DUNES, COASTAL SCRUB.	15-105M.	NOT OBSERVED
Carex comosa	bristly sedge			2	May-Sep	MARSHES AND SWAMPS. FAIRLY WIDELY DISTRIBUTED, BUT APPARENTLY RARELY COLLECTED.	LAKE MARGINS, WET PLACES; SITE BELOW SEA LEVEL IS ON A DELTA ISLAND. -5-1005M.	NOT OBSERVED
Centromadia parryi ssp. congdonii	Congdon's tarplant	SC		1B		VALLEY AND FOOTHILL GRASSLAND.	ALKALINE SOILS, SOMETIMES DESCRIBED AS HEAVY WHITE CLAY. 1-230M.	NOT OBSERVED
Cirsium crassicaule	slough thistle	SC		1b	May-Aug	chenopod scrub, marshes and swamps, sloughs, riparian		NOT OBSERVED
Cirsium hydrophilum var. hydrophilum	Suisun thistle	C		1B	July-Sep	salt marshes		NOT OBSERVED
Cordylanthus mollis ssp. mollis	soft bird's-beak	E	R	1B	July-Sep	COASTAL SALT MARSH.	IN COASTAL SALT MARSH WITH DISTICHLIS, SALICORNIA, FRANKENIA, ETC. 0-3M.	NOT OBSERVED
Eleocharis parvula	small spikerush			4	Jun-Sep	MARSHES AND SWAMPS.		NOT OBSERVED
Eryngium racemosum	Delta button-celery	SC	E	1B		RIPARIAN SCRUB. EXTANT IN CAL AND MER COUNTIES; HISTORICAL FROM SJQ AND STA COUNTIES.	SEASONALLY INUNDATED FLOODPLAIN ON CLAY. 3-75M.	NOT OBSERVED
Erysimum capitatum ssp. angustatum	Contra Costa wallflower	E	E	1B	Mar-July	INLAND DUNES. ENDEMIC TO CONTRA COSTA COUNTY.	STABILIZED DUNES OF SAND AND CLAY NEAR ANTIOCH ALONG THE SAN JOAQUIN RIVER. 3-20M.	NOT OBSERVED
Gratiola heterosepala	Boggs Lake hedge-hyssop	SC	E	1B	Apr-Aug	MARSHES AND SWAMPS (FRESHWATER), VERNAL POOLS.		NOT OBSERVED
Hibiscus lasiocarpus	rose-mallow			2	Jun-Sep	MARSHES AND SWAMPS (FRESHWATER).	MOIST, FRESHWATER-SOAKED RIVER BANKS & LOW PEAT ISLANDS IN SLOUGHS; IN CALIF., KNOWN FROM THE DELTA WATERSHED. 0-150M.	NOT OBSERVED
Holocarpha macradenia	Santa Cruz tarplant	T	E	1B		COASTAL PRAIRIE, VALLEY AND FOOTHILL GRASSLAND.	LIGHT, SANDY SOIL OR SANDY CLAY; OFTEN WITH NONNATIVES. 10-260M.	NOT OBSERVED
Lathyrus jepsonii var. jepsonii	Delta tule pea	SC		1B	May-Sep	FRESHWATER AND BRACKISH MARSHES. MOST OF DISTRIBUTION RESTRICTED TO THE SACRAMENTO/SAN JOAQUIN RIVER DELTA.	OFTEN FOUND W/TYPHA, ASTER LENTUS, ROSA CALIF., JUNCUS SPP., SCIRPUS, ETC. USUALLY ON MARSH AND SLOUGH EDGES.	NOT OBSERVED
Lilaeopsis masonii	Mason's lilaeopsis	SC	R	1B	April-Oct	FRESHWATER AND BRACKISH MARSHES, RIPARIAN SCRUB.	TIDAL ZONES, IN MUDDY OR SILTY SOIL FORMED THROUGH RIVER DEPOSITION OR RIVER BANK EROSION. 0-10M.	NOT OBSERVED
Limosella subulata	Delta mudwort			2	May-Aug	RIPARIAN SCRUB, FRESHWATER MARSH, BRACKISH MARSH. PROBABLY THE RAREST OF THE SUITE OF DELTA RARE PLANTS.	USUALLY ON MUD BANKS OF THE DELTA IN MARSHY OR SCRUBBY RIPARIAN ASSOCIATIONS; OFTEN WITH LILAEOPSIS MASONII. 0-3M.	NOT OBSERVED

Species		LiSting Status 1			Species Information			
Scientific Name	**Common Name**	**USFWS (Federal)**	**CDFG (State)**	**CNPS**	**Flowering Period**	**General Habitat**	**Microhabitat**	**Dutch Slough Occurrence**
Oenothera deltoides ssp. howellii	Antioch Dunes evening-primrose	E	E	1B	Mar-Sep	INTERIOR DUNES. KNOWN ONLY FROM CONTRA COSTA AND SACRAMENTO COUNTIES.	REMNANT RIVER BLUFFS AND SAND DUNES EAST OF ANTIOCH. 0-30M.	NOT OBSERVED
Plagiobothrys glaber	hairless popcorn-flower	SC		1A	Apr-May	MEADOWS AND SEEPS, MARSHES AND SWAMPS		NOT OBSERVED
Plagiobothrys hystriculus	bearded popcorn flower			1A	Apr-May	VERNAL POOLS, VALLEY AND FOOTHILL GRASSLAND. KNOWN ONLY FROM A HISTORICAL COLLECTION IN SOLANO COUNTY.		NOT OBSERVED
Polygonum marinense	Marin knotweed	SC		3	Jun-Aug	MARSHES AND SWAMPS.		NOT OBSERVED
Potamogeton filiformis	slender-leaved pondweed			2		MARSHES AND SWAMPS.	SHALLOW, CLEAR WATER OF LAKES AND DRAINAGE CHANNELS. 15-2310M.	NOT OBSERVED
Potamogeton zosteriformis	eel-grass pondweed			2		MARSHES AND SWAMPS.	PONDS, LAKES, STREAMS. 0-1860M.	NOT OBSERVED
Sagittaria sanfordii	Sanford's arrowhead	SC		1b	may-august flowering	freshwater marshes and swamps		NOT OBSERVED
Scutellaria galericulata	marsh skullcap			2		MARSHES AND SWAMPS, LOWER MONTANE CONIFEROUS FOREST, MEADOWS AND SEEPS.	SWAMPS AND WET PLACES. 0-2100M.	NOT OBSERVED
Scutellaria lateriflora	blue skullcap			2		MEADOWS AND SEEPS, MARSHES AND SWAMPS.	WET MEADOWS AND MARSHES. -3-500M.	NOT OBSERVED
Suaeda californica	California seablite	E		1B		MARSHES AND SWAMPS.	MARGINS OF COASTAL SALT MARSHES. 0-5M.	NOT OBSERVED
Trichocoronis wrightii var. wrightii	Wright's trichocoronis			2	May-Sept	meadows, marshes, swamps, riparian forests, alkaline vernal pools		NOT OBSERVED
Habitat								
Stabilized Interior Dunes	Stabilized Interior Dunes							REMNANTS ONLY
Northern Maritime Chaparral	Northern Maritime Chaparral							NOT PRESENT ONSITE
Valley Sink Scrub	Valley Sink Scrub							NOT PRESENT ONSITE
Alkali Meadow	Alkali Meadow							OCCUR ONSITE
Alkali Seep	Alkali Seep							NOT PRESENT ONSITE
Northern Claypan Vernal Pool	Northern Claypan Vernal Pool							NOT PRESENT ONSITE
Serpentine Bunchgrass	Serpentine Bunchgrass							NOT PRESENT ONSITE
Valley Needlegrass Grassland	Valley Needlegrass Grassland							NOT PRESENT ONSITE
Cismontane Alkali Marsh	Cismontane Alkali Marsh							NOT PRESENT ONSITE
Coastal and Valley Freshwater Marsh	Coastal and Valley Freshwater Marsh							OCCUR ONSITE
Coastal Brackish Marsh	Coastal Brackish Marsh							NOT PRESENT ONSITE
Northern Coastal Salt Marsh	Northern Coastal Salt Marsh							NOT PRESENT ONSITE

Species		LiSting Status 1			Species Information			
Scientific Name	Common Name	USFWS (Federal)	CDFG (State)	CNPS	Flowering Period	General Habitat	Microhabitat	Dutch Slough Occurrence

Source: EDAw 2004

* Habitat based on Jepson Manual, (Hickman 1993)

[1] Legal Status Definitions

[2] Habitats sensus California Native Plant Society Online Electronic Inventory

U.S. Fish and wildlife Service Federal Listing	**California Department of Fish and Game State Listing Categories**
E Endangered (legally protected)	E Endangered (legally protected)
T Threatened (legally protected)	T Threatened (legally protected)
PT proposed for Threatened Status	R Rare (legally protected)
FC Candidate for listing as threatened or endangered (no Formal	FP Fully protected (legally protected, no take allowed)
FSC Federal Species of Concern (no formal	CSC California Species of Concern (no formal protection)
	S Sensitive
CDFG = California Department of Fish and Game	**California native plant Society Categories**
CNPS = California Native Plant Society	1A presumed extinct in California
	1B plant species considered rare or endangered in California and elsewhere (but not legally protected under ESA or CESA)
	2 plant species considered rare or endangered in California but more common elsewhere (but not legally protected under ESA or CESA)
	3 More information is needed to define status (Currently on Review List)
	4 Limited Distribution (Currently on watch List)

APPENDIX D-3

Description of Public Use in the Delta Region

Appendix D-3. Description of Public Use in the Delta Region

1. EXISTING USE AND SUPPLY

Within the Delta, water skiing, general boating and sailing comprise 30 percent of total recreation use. Shore fishing and boat fishing comprised 24 and 15 percent of all recreation use, respectively (DPC 1997).

Boating

Three private boat launch facilities are located approximately one mile to the east along Dutch Slough. There are a number of private marinas within one to five miles. The nearest public boat launch is approximately ten miles to the west near Antioch (DPC 2004). Boats are permitted to navigate the sloughs that border the site: Dutch Slough, Marsh Creek, Emerson Slough, and Little Dutch Slough. Fishing is allowed wherever there is boating access (T. Hall, per. comm.). The nearest windsurfing access sites are approximately 5 miles to the northwest from the Dutch Slough site along the Sacramento River (DPC 2004). Wildlife viewing is usually a secondary form of recreation that may take place while visitors and recreationists are boating.

Fishing

There are several nearby opportunities for pier fishing and lake fishing close to the City of Oakley, which shares its northern border with the regional shoreline. In cooperation with East Bay Regional Parks District, the City is exploring ways to preserve the open space and ensure access for citizens (City of Oakley, 2004).

Vehicular Access

Vehicular access on roads within the site is limited to DWR and lessees who are authorized by DWR to access their parcels for farming and ranching. Public visitors are able to drive as far as the end of Sellers Avenue to the locked gate but there is no recreational opportunity provided (T. Hall, per. comm.).

Hunting

Hunting is not permitted on-site. California Department of Fish and Game does not consider hunting to be compatible with existing livestock activities. Some illegal hunting may be taking place as there are duck and other species in the vicinity (T. Hall, per. comm.). There are three authorized hunting access areas within approximately five to ten miles of the project site (DPC, 2004).

Camping

There is no camping allowed within the Dutch Slough site. The nearest private camping and pump-out facilities are available on Bethel Island approximately one mile to the east. There are no nearby public camping areas (DPC, 2004).

Trails

The Marsh Creek and Delta de Anza regional trails run through the City of Oakley, providing paved, multi-use trailways for walkers, runners, bicyclists and equestrians. In addition to providing exercise and recreational opportunities, these trails offer an alternative to using automobiles for light errands, traveling to and from neighborhood parks, and for children to get to schools located on or near the trails (City of Oakley, 2004). There are no other nearby trail access points (DPC, 2004).

Regional Parks

There are several regional parks and open space areas near the site with viewpoints of the Delta and surrounding bay, the valleys to the east, and the hills to the west. These parks offer hiking trails, picnic areas, and historic monuments. Round Valley Preserve, Contra Loma Regional Reservoir, Black Diamond Mines, and Briones Regional Park are all located in Contra Costa County. The East Bay Regional Park District (EBRPD) provides and manages the Regional Parks for Alameda and Contra Costa counties including Big Break. The regional park system includes 55 parks and over 1,000 miles of trails (Oakley, 2004).

State Parks

Brannan Island State Park is located a few miles north of Oakley over the Antioch Bridge. Besides camping, there is access to the delta for sailing, boating and kayaking. Mt. Diablo State Park just west of Oakley offers hiking, picnicking, and bicycling (Oakley, 2004).

2. EXISTING CAPACITY AND SUITABILITY

Capacity for recreation facilities and activities within the site is potentially limited by four factors: ecological, spatial, facility and social constraints. Ecological capacity refers to the degree to which an area may be suitable for development while taking into account ecological factors. Ecologically, areas within the site that are the most suitable for recreation development are those that have already been significantly altered and/or are identified as being of lower ecological value than other sites, such as the proposed park site. Spatial capacity refers to the limits of space on a given site for constructing facilities. Existing facilities (such as a parking lot or campground) have a designated capacity established during design. Social capacity indicates the level of crowdedness that visitors can accept. Other factors to consider regarding recreation suitability include slope, micro-climates, shoreline access, and sufficient area for potential development.

The 55-acre site designated for a potential future City of Oakley park was originally developed as a dairy production facility. This site has high suitability with the potential to provide park space and multiple

visitor facilities, and to improve ecological diversity. The site has the potential to provide sufficient space for a variety of facility types and the potential for shoreline access to Emerson Slough. Due to the presence of well developed riparian woodland habitat at the southern end of the Emerson Slough, public shoreline access may need to be limited to other areas.

While there are currently no visitor facilities at the site, existing buildings provide the potential to be transformed, for example, into a community center and/or a visitor center. Existing barns may also be converted for visitor use into facilities such as a greenhouse or an educational biological research center. Currently, there are no recreation social capacity issues such as user group conflicts. However, the degree to which the community is supportive of the project could determine the future degree of social acceptance and maximization of social capacity within the site (if needed).

3. EXISTING AND LATENT DEMAND

Demand for public access within the site has not specifically been studied. Recreation trends regarding the Delta overall would likely apply to the Dutch Slough area. All of the activities offered in the Delta are projected to continue to rise in demand (DPC, 1994).

While population changes do not necessarily create an equally distributed increase among various activities, it is still an important factor in projecting future demand. Contra Costa and nearby counties including Alameda, Sacramento, San Joaquin and Stanislaus County are all projected to grow significantly in the next 50 years. San Francisco County is projected to grow less significantly through 2020 with no projected growth beyond 2020 (CDF, 2004). These population increases will likely increase demand on the Delta.

APPENDIX E

Dutch Slough Tidal Marsh Restoration Conceptual Model

PWA
PHILIP WILLIAMS & ASSOCIATES
CONSULTANTS IN HYDROLOGY
720 CALIFORNIA ST., 6TH FLOOR, SAN FRANCISCO, CA 94108
TEL 415.262.2300 FAX 415.262.2303
SFO@PWA-LTD.COM

MEMORANDUM

TO: Dutch Slough Restoration Project Management Team

FROM: Nick Garrity, Michelle Orr, and Philip Williams; PWA (Philip Williams & Associates)
With Bruce Herbold, EPA, and Charles Simenstad, University of Washington

DATE: May 4, 2006

RE: **Dutch Slough Tidal Marsh Restoration Conceptual Model**

---

1. SUMMARY

This memorandum documents the Dutch Slough Tidal Marsh Restoration Conceptual Model and describes how the conceptual model informs large-scale adaptive management experiments in the Dutch Slough Tidal Wetland Restoration project. The memorandum describes the adaptive management context for the restoration project (Section 3), the conceptual model for freshwater tidal marsh restoration (Section 4), key uncertainties identified in the conceptual model (Section 5), hypotheses for the large-scale experiments for marshplain elevation and marsh scale (Section 6), and experimental design considerations for these large-scale experiments (Section 7).

The large-scale adaptive management experiments for marshplain elevation and marsh scale are intended to test the response of special status native fish to different methods of wetland restoration and to inform restoration design, including cost-effectiveness, for future Delta restoration projects. The hypothesis for the marshplain elevation experiment is that lower elevation marshes produce greater prey resources for juvenile salmon and splittail than higher elevation marshes, and thus greater potential for feeding, growth, and survival. The hypothesis for marsh scale is that tidal channel networks in larger marshes provide greater refuge from predation than in smaller marshes, and thus greater survival opportunities for juvenile salmon and splittail.

The Dutch Slough project includes small-scale and water quality adaptive management experiments, which are not described in this memorandum. These additional experiments are planned as part of the Dutch Slough project and will be described in the Dutch Slough Tidal Marsh Adaptive Management and Monitoring Plan (NHI, in progress) or developed in future phases of the project.

2. INTRODUCTION

The Dutch Slough Tidal Marsh Restoration is being planned by the California Department of Water Resources (DWR), the State Coastal Conservancy (SCC), the City of Oakley, and the California Bay-Delta Authority (CBDA) (who collectively form the Dutch Slough Management Team). DWR is the land owner, having purchased the site in 2003 with funds from CBDA and the SCC. The SCC is leading the restoration planning with assistance from the Natural Heritage Institute (NHI) and the PWA (Philip

Williams & Associates) consultant team. The PWA consultant team developed the Dutch Slough Tidal Marsh Restoration Conceptual Plan and Feasibility Study (Conceptual Plan and Feasibility Study) (PWA and others, 2006). An Adaptive Management Work Group (AMWG) provided scientific input to the Dutch Slough conceptual restoration plan. AMWG members (listed in Section 8) include agency and university scientists and local restoration practitioners.

One of the goals of the Dutch Slough restoration project is to contribute to scientific understanding of ecological restoration by implementing the project under an adaptive management framework. The AMWG, Dutch Slough Management Team, and PWA consultant team developed the Dutch Slough Tidal Marsh Restoration Conceptual Model (Dutch Slough Conceptual Model) to guide the adaptive management process. NHI is coordinating the AMWG and is developing the Dutch Slough Tidal Marsh Restoration Adaptive Management and Monitoring Plan (Adaptive Management and Monitoring Plan) (NHI, in progress).

The Dutch Slough Conceptual Model is based on the CALFED (2000) adaptive management process and guidance on developing conceptual models. CALFED's Strategic Plan for Ecosystem Restoration describes conceptual models as follows:

> Many resource managers, scientists, and stakeholders interested in the restoration and management of the Bay-Delta ecosystem have implicit beliefs about how the ecosystem functions, how it has been altered or degraded, and how various actions might improve conditions in the system. That is, they have simplified mental illustrations about the most critical cause-and-effect pathways. Conceptual modeling is the process of articulating these implicit models to make them explicit. (CALFED, 2000)

This memorandum documents the Dutch Slough Conceptual Model in its current state of development. The conceptual model is expected to evolve with continued input from the AMWG and through the adaptive management process, and is therefore a working document. As described by CALFED (2000), "conceptual models are based on concepts that can and should change as monitoring, research, and adaptive probing provide new knowledge about the ecosystem."

The large-scale adaptive management experiments are designed to test hypotheses that predict the response of special status native fish to different methods of wetland restoration. Providing habitat for special status native fish species was the key objective of the adaptive management program that drove development of the large-scale adaptive management experiments. The conceptual model documented in this memorandum focuses on special status native fish species.

Conceptual models for other elements of habitat restoration (in addition to habitat for special status native fish) and for other project elements (e.g., bioaccumulation of methylmercury) were developed and discussed as part of project planning. These conceptual models will guide the Dutch Slough restoration adaptive management program for elements of the restoration other than improving conditions for special status native fish. These conceptual models will be documented in the Adaptive Management and Monitoring Plan.

The conceptual model for special status native fish was developed during a series of meetings between the AMWG, the Dutch Slough Management Team, and the PWA consultant team. The CALFED Ecosystem Restoration Program Science Board provided feedback on a preliminary version of the conceptual model and adaptive management framework in a May 2004 meeting, and the Dutch Slough Sub-committee of the Science Board provided additional input in a May 2005 meeting.

3. ADAPTIVE MANAGEMENT CONTEXT

Adaptive management is the process of learning from restoration and management actions, then using this knowledge to inform and adapt future actions. Typically, these actions modify parts of a restoration that have already been implemented. Figure 1 from CALFED (2000) illustrates the steps in the adaptive management process.

Within the context of the Dutch Slough restoration, adaptive management also refers to informing actions for future restoration projects. This second type of adaptive management is sometimes referred to as "adaptive learning." Lessons learned at Dutch Slough are primarily intended to inform future restoration projects anticipated in the Sacramento-San Joaquin River Delta, but may also influence management actions at Dutch Slough after tidal restoration is implemented. The project will test different methods of wetland restoration, monitor the physical and ecological responses, and make these results available.

The process of adaptive management input to the design is as follows:

1. Define measurable ecological objectives. (These are discussed in Section 3 of the Conceptual Plan and Feasibility Study).
2. Articulate a conceptual model (or models) of the process linkages that explain how the restoration actions address the ecological objectives.
3. Identify key uncertainties in the conceptual model(s).
4. Articulate hypotheses for each of the key uncertainties.
5. Design experiments to test the hypotheses. (These are described in Section 7 of the Conceptual Plan and Feasibility Study and will be detailed in the Adaptive Management and Monitoring Plan.)
6. Implement a monitoring and adaptive management plan for the experiments and the restoration project. (This is in progress and will be documented in the Adaptive Management and Monitoring Plan.)

Adaptive management is an iterative process. Once monitoring results are available (from Step 6), the adaptive management process circles back to reassess the objectives (Step 1) and conceptual models (Step 2), etc. Steps 2 – 4 are described in this memorandum. Experimental design considerations (related to Step 5) for the large-scale experiments are also discussed. The Dutch Slough adaptive management process embedded within the overall restoration plan is more fully described in a draft memorandum to the AMWG (Cain, 2004) and will be documented in the Adaptive Management and Monitoring Plan.

4. CONCEPTUAL MODEL

4.1 Overview

This memorandum documents the conceptual model for growth, survival, and spawning of three special status fish species identified as "tier 1" target species for the project: Sacramento splittail (*Pogonichthys acrolipidotus*), Chinook salmon (*Oncorhynchus tshawytscha*) and Delta smelt (*Hypomesus transpacificus*) (see Conceptual Plan and Feasibility Report Appendix A).

The Dutch Slough Conceptual Model used a previous conceptual model by the Delta Habitats Group (Attachment B) as a starting point and the structure of Level 3 of the PSNERP (2006) conceptual model, developed for use in Puget Sound. In the Dutch Slough Conceptual Model, restoration actions are linked to ecological outcomes in cause-and-effect relationships. The conceptual model focuses on controllable actions at Dutch Slough. Other factors not directly related to the Dutch Slough restoration also affect outcomes, such as freshwater flows, Delta pump operations, water contaminants, fisheries management, or new introduced species. For clarity and simplicity, however, these factors are not included in the Dutch Slough Conceptual Model.

The Dutch Slough Conceptual Model consists of an overarching general conceptual model and more detailed, operational conceptual models for the large-scale experiments. Elements of the general conceptual model are organized into the categories (Figure 2):

- Restoration Actions
- Physical and Vegetative Processes
- Habitat Structures
- Ecological Processes
- Functional Response
- External Factors

The AMWG articulated detailed linkages among different elements of the conceptual model (see Attachment A1). Many of the linkages between processes and categories in the conceptual model are self-explanatory. This memorandum does not provide detailed descriptions of each linkage. Rather, this memorandum focuses on the key linkages between restoration actions with habitat structures that received the most discussion in developing the conceptual model.

4.2 Restoration Actions

Restoration actions are required to recreate freshwater tidal marsh on leveed sites in the Delta that are presently subsided. These restoration actions allow physical and vegetative processes to occur and create habitat structures. Restoration actions are required because natural processes that formed ancient and

historic freshwater tidal marshes over the last 10,000 years in the Delta are not expected to restore marsh habitat structures on a restored (or restoring[1]) subsided site within the desired timeframe.

Restoration actions at Dutch Slough include: filling and grading marsh areas, excavating channels, managing or planting vegetation to favor native plant establishment (re-vegetation), diverting Marsh Creek, and breaching levees. Natural physical and vegetative processes include: sediment deposition and biomass accumulation (accretion), erosion, tidal inundation, vegetation colonization, and heating/cooling. Restoration actions and physical and vegetative processes create and interact with the following habitat structures: vegetated marshplain, tidal channels, subtidal open water, floodplain, riparian, upland and transition, soil profile and chemistry, and water chemistry. Key processes and habitat structures are discussed below.

4.3 Physical and Vegetative Processes

Generally, the physical processes part of the conceptual model predicts few significant geomorphic changes within several years to one or two decades after the site is constructed. Unlike its restoration counterparts in the more saline and sediment-rich parts of the estuary (San Francisco Bay) where sedimentation rates are higher, Dutch Slough is expected to experience slow rates of sedimentation in shallow subtidal and marshplain habitats, and likely limited formation of tidal channels through tidal scour. To achieve restoration and adaptive management goals within the planning horizon, it is therefore necessary to create restored marshes with features similar to equilibrium marshplain elevations and tidal channel networks, rather than relying on the evolution of equilibrium conditions through natural physical processes, in order to achieve the project goals within the planning horizons for restoration and adaptive management (50 years and from several years to one or two decades, respectively, as discussed in Section 7 of the Conceptual Plan and Feasibility Report). Constructed restoration features are expected to persist and evolve slowly over at least the next decade.

Physical and vegetative processes for the San Francisco Bay Estuary are generally described in Orr et al. (2003), Reed (2002), Simenstad et al. (2000), Atwater and Belknap (1980), and Atwater et al. (1979), and Gilbert (1917). Much of the discussion that follows is based on Orr and others (2003) and Simenstad and others (2000). The extensive freshwater tidal marshes of the Sacramento-San Joaquin River Delta formed gradually over the last 10,000 years as rising sea levels flooded former inland valleys at the mouth of the Sacramento and San Joaquin rivers (Atwater and others, 1979). Marshplain elevations kept pace with rising sea level (Atwater and Belknap 1980), building up peat and peaty mud through sediment deposition and biomass accumulation (peat formation). Minerogenic sedimentation was primarily in response to flood flows of the Sacramento and San Joaquin rivers and confined to the margins of their distributary channels. Distal from these internal deltas, organic-rich marshes began to accumulate (Atwater, 1982). These ancient and historic Delta freshwater tidal marshes are drained by intricate systems of sinuous and branching tidal channels. The predominant marsh vegetation type is tule *(Scirpus acutus, S. californicus,* and *S. americanu*s), with cattails *(Typha* sp.) and common reed *(Phragmite* sp.) (Atwater and Hedel 1976).

[1] The term “restoring” is sometimes used to indicate that restored marshes continually evolve.

Reclamation of delta wetlands – levee-building, ditching, and draining of lands primarily for agriculture – has caused subsidence through direct dewatering of the substrate and aerobic decomposition of organic material in marsh soils. Sediment supply to the delta has been highly modified by upstream activities, which include hydraulic mining, grazing, deforestation, marsh and floodplain reclamation, dam construction, and channel incision (Gilbert, 1917; Beeman and Krone, 1992; Wright and Schoellhamer, 2003 in Orr and others, 2003).

Accretion. Tidal marshplains sustain vertical growth (*i.e.,* accretion) through sediment deposition and organic biomass accumulation. Marshes in the Delta are sustained primarily by the accumulation of low density organic rich soils (typically 50% organic content) derived from surface vegetation growth (Atwater and Belknap, 1980; Atwater and others, 1979), and also fluvial and estuarine mudflat sediments, depending on the location within the Delta. Peat formation occurs as organic material is buried and accumulates beneath the water table, where decomposition is slowed under anaerobic conditions. Mineral sediments are transferred fairly efficiently through the system to Suisun and San Pablo bays.

Ancient and historic marshplain elevations kept pace with sea level rise at an equilibrium elevation of approximately MHHW through self-regulating accretionary processes (Atwater and others, 1979; Allen, 2000). Accretion above the MHHW elevation is limited by sea level rise and the decomposition of organic matter. Leveed former marshes such as the Dutch Slough site have subsided to elevations below mean sea level. When former leveed marshes are restored to tidal action by levee breaching, low elevation tidal areas are created where accretionary processes occur and are not limited by sea level rise. In subtidal areas below the vegetation colonization (see below), sediment deposition occurs; areas at intertidal elevations also accrete through biomass accumulation once vegetation is established.

Available empirical data on accretion in Delta marshes indicate that rates of sedimentation and biomass accumulation are slow compared to restoration timelines (Orr and others, 2003). Historic rates of accretion for natural (high elevation) marshes are limited by the rate of sea level rise (as high as 3 to 4 mm/yr at Brown's Island; Goman and Wells 2000). Limited data on long-term rates of accretion in restored (low elevation) marshes range from 9 – 18 mm/yr (at Sherman Lake, Lower Mandeville Tip, Mildred Island, and Frank's Tract; data from Reed, pers. comm., Simenstad and others 2000, and PWA unpublished). An ongoing study by the USGS to measure accretion in permanently flooded (managed) wetlands has found initial biomass accumulation rates of 26 mm yr -1 (with a wide variation) over a three-year period (Drexler and others, 2003); however, these rates are not expected to be representative of tidal conditions in restored marshes. Accretion rates may be limited by the extent of wave and current energy in exposed subtidal restored sites (Simenstad and others, 2000).

Vegetation colonization. Emergent vegetation colonization occurs in two ways: (1) pioneer colonization and (2) lateral expansion colonization. Pioneer colonization occurs by seed or deposition of vegetation fragments. Once vegetation becomes established, lateral expansion can extend lower in the tidal zone by extension of rhizomes. Higher elevation marshplains ("high marsh") are typically vegetated by a mix of plant species including common tule (*Scirpus acutus*), California bulrush (*Scirpus californicus*), common reed (*Phragmites communis*), spikerush (*Eleocharis* spp.), and narrowleaf cattail (*Typha angustifolia*);

whereas lower elevation marshplains ("low marsh") tend to be dominated by a monoculture of California bulrush (Simenstad et al, 2000; see Section 6.3 of the Conceptual Plan and Feasibility Report).

Note that while the terms "high" and "low" marsh are used here, the transition from high marsh to low marsh is not well defined. Morphologically-similar freshwater emergent marsh vegetation occurs over a range of intertidal elevations. Low marsh and high marsh are not generally-recognized habitat categories in the Delta, unlike in the more saline San Francisco Bay.

Vegetation colonization within the intertidal zone is expected to be rapid (Simenstad and others 2000, USFWS and USACE 1990). Areas below the vegetation colonization elevation are expected to remain as mudflats or to be colonized by non-native, invasive submerged aquatic vegetation (SAV). Limited data from Delta marshes show that tule vegetation becomes less dense in coverage with interspersed areas of mudflat and SAV within an elevation range between approximately +1 and -2 ft MLLW (Simenstad and others 2000; see Section 8.1.1 of the Conceptual Plan and Feasibility Study). In lower elevation zones near the bottom of this range, the extent of tule vegetation may be limited and SAV is expected to dominate plant communities (see Invasive SAV below). Subtidal areas below -12 ft mean tide level (MTL) are not expected to support SAV due to limited sunlight. At the marsh/channel edge, the lower limit of tules is expected to be similar in lower and higher elevation marshes. The quality of channel bank/marsh edge habitat is therefore also expected to be similar in different elevation marshes (see Figure 3 and Section 4.3).

Under non-tidal conditions (i.e., managed water or leveed conditions), the natural recruitment of tules can occur in response to periodic flooding and draw-down water levels. The natural recruitment of tules has occurred inadvertently in low areas of the leveed Dutch Slough site and other sites in the Delta. The USGS demonstration project at Twitchell Island has used flood irrigation to encourage natural recruitment as a technique for re-vegetation and biomass accretion. Water management can be used to grow tules in subsided sites at elevations below the range of tule colonization observed for tidal conditions; however, it is uncertain whether tules pre-established below this range will survive under tidal conditions if the site is breached.

Historically, natural channel levees formed along the banks of the fluvial distributary channels in some mature marshes (Atwater and Belknap, 1980; Simenstad and others, 2000; PWA, 2003). These natural levees were higher than the average elevation of the mature high marshplain and supported mature riparian vegetation, in contrast to the tule marshplain along tidal slough (non-distributary) channels. The natural channel levees decreased in elevation with both height and width with distance downstream in the Delta (Atwater and Belknap, 1980). They approached heights of 24 ft above MLLW near Sacramento and 14 ft above MLLW further downstream at the head of Grand and Sutter Islands (PWA, 2003). These levees were sustained by preferentially high sedimentation immediately adjacent to the distributary channels during flood flows. Vegetation-elevation transects surveyed by PWA at natural marshes along Lindsey Slough in the north Delta and Upper Mandeville Tip in the central Delta show that a subtle elevation difference of 0.5 ft between natural channel levees and the adjacent marshplain can support riparian vegetation along the levee (Simenstad and others, 2000; PWA, 2003).

In restored marshes, volunteer establishment of native woody and herbaceous riparian plants in higher elevation areas is expected to be limited to areas adjacent to existing native riparian plant communities, and would likely take decades to succeed beyond initial willow scrub phases to cottonwood-willow forests. Volunteer establishment is expected to be minimal in areas that lack adjacent existing native riparian plant communities to provide a source for colonization. Instead, there would be a high potential for establishment of invasive non-native species, including Himalayan blackberry, perennial pepperweed, Bermuda grass, milk thistle, Italian ryegrass, vetch, and curly dock.

Tidal channel morphology. The formation of channels through tidal scouring of the compacted agricultural field surface in restored marshes is expected to be limited, and is an area of high uncertainty (see Section 5 below). Tidal velocities may be high enough in the large channels (the sloughs) and near the breaches to scour, as they have at Donlon Island; however, velocities in the small channels are hypothesized to be too low to scour channels into the marshplain. There may be a minimum restored marsh scale or tidal prism for tidal channels to form through tidal scour. Below this minimum, channels may not form and tules may colonize the potential channel footprint. The potential for tidal channel scour was identified as an area of uncertainty (see Section 5 below). In restored marshes, tidal channels that are constructed similar to natural channels (as possible) – both in cross-section (depth, width, side slope) and plan form (density, sinuosity, bifurcation) – are hypothesized to be sustainable habitat structures over the life of the restoration.

In ancient and historic Delta marshes, tidal channel systems are sinuous and branching. In cross-section, tidal channels maintain unvegetated channel beds and steep-sloping channel banks with vegetated edges, which provide fish habitat (see Section 4.3 below). Tidal channel morphology is controlled both by marsh hydrology and vegetation. The volume of tidal flows (tidal prism) is related to the cross-sectional area, depth, and width of tidal channels, which can be correlated in hydraulic geometry relationships (PWA, 2003; Williams and others, 2002; Simenstad and others, 2000). The density of tidal channels in freshwater marshes is less than in more saline marshes (SFEI, 2004), presumably because freshwater vegetation assemblages grow lower within the tidal range. In freshwater marshes, smaller tidal channels with bed elevations in the intertidal zone are few in number because intertidal areas tend to be vegetated with tules. In some cases, these small first order channels are overgrown with tules to form subsurface drainage "pipes;" in other marsh areas, small intertidal channels are not present or are indistinguishable from the marshplain (PWA observations and unpublished data).

The planform and cross-sectional geometry of tidal channels are expected to vary with marshplain elevation and marsh scale. Limited data suggest that channels in lower elevation restored marshes are wider than channels that drain the same area of higher elevation (MHHW) mature marsh, but that channel depths may not differ significantly (Simenstad and others, 2000). Tidal channel formation in restored marshes may also be controlled by antecedant conditions (*e.g.*, agricultural field surface, ditches, etc) in addition to marshplain elevation. The number of channel bifurcations (channel order) in larger marsh areas will be greater than in smaller marsh areas. The main (higher order) channels in larger marsh areas will be larger and deeper than in smaller marsh areas. Larger marsh areas will have a greater range of channel sizes and depths. The range in channel depths is important for native juvenile fish habitat and refuge (see Section 4.3 below).

Heating and cooling. Temperature dynamics in tidal marshes are primary controlled by depths and frequency of inundation (i.e., wetting and drying or desiccation) and vegetation cover and shading. Generally, temperatures in deeper areas and shaded areas are less variable. Temperature variability is greatest during the day, especially when tide levels drop below the marshplain elevation and the marshplain is exposed to high temperatures. Temperatures in lower elevation marshplain environments are expected to be less variable, and therefore more benign, than higher elevation marshplains. The difference in heating the water column above vegetated marshplains with different elevations (high and low) is not expected to be significant (Garrity, 2004).

Invasive SAV establishment. Conditions affecting the establishment and survival of non-native SAV (e.g., *Egeria densa*) were the focus in conceptual model development because of SAV's perceived detriment to native fishes (see below). SAV can colonize tidal areas and grow at depths of up to 8 to 12 ft below MTL (-6.5 to -10.5 ft NGVD). Based on limited data, tt is not expected to be possible to control non-native SAV by designing for high velocities or selection of substrate (L. Anderson, USDA, pers. comm.). High velocities are expected to slow, but not prevent, the initial establishment of SAV. SAV is expected to establish in pockets in low velocity areas adjacent to high velocity areas. Once established, SAV is expected to eventually spread to higher velocity areas, forming a continuous coverage. Similarly, compacted soils or other unsuitable substrates are expected to slow, but not prevent, SAV colonization.

4.4 Habitat Structures, Ecological Processes, and Functional Response

Juveniles of many of fishes, including several species of concern, will preferentially occupy shallow water habitats in the Delta through transitory periods in their early life history (Moyle, 1976; Wang, 1986). The AMWG developed several simple conceptual models that illustrate how an adaptive management strategy can be used to identify and test functional relationships between fish performance and restored wetland structure, where structure includes composition, structure, and arrangement of various fish habitat elements (Attachments A2 and A3). Performance measures for this strategy consist of juvenile Chinook salmon survival and growth, although similar mechanisms are expected to affect other fish using the restored wetlands, particularly Sacramento splittail. Performance measures can be tracked using both fish that are volitionally entering and using the sites and with manipulative release experiments using hatchery-produced juvenile salmon. These conceptual models show the expected responses of fish to marshplain elevation, channel characteristics and invasive SAV, and some of the fundamental assumptions behind these responses.

Tidal marshplain habitat. A key feature of tidal marshes that influences juvenile salmon (and splittail) performance is the edge of vegetation along tidal channels. These fish feed predominantly at the marsh edge and are not expected to venture onto the vegetated marshplain. Therefore, the capacity of a marsh to support fish is more likely related to the complexity (e.g., channel length and density) of the tidal channels than it is related to total marshplain area.

Access to prey. The opportunity for fish to access prey resources along the vegetated channel edge, and thus fish feeding rate and growth, is related most directly to the amount of time the fish have to access the

channel edge over the tide cycle. Thus, assuming full tidal drainage, the quality of lower marsh and higher marsh channel bank habitats provide approximately equivalent benefits to fish feeding and growth if the lower edges of vegetation are comparable (Figure 3).

Prey productivity. Productivity, behavior and life history traits of juvenile salmon and splittail prey that occur along the marsh edge (i.e., dipteran fly larvae, pupae and adults; gammarid amphipods) may differ as a function of mean marshplain elevation (inversely related) because the duration of inundation will affect the amount of flooded habitat and the degree of elevation-associated stressors such as desiccation and elevated temperatures. It should be noted that other (generally less prominent) prey, such as planktonic cladocerans, do occur in the water column and in tidal channel mudflats and submerged and floating vegetation (e.g., gammarid amphipods).

Tidal channel habitat and refuge from predation. We make the fundamental assumption that short-term survival of juvenile salmon and splittail is greater in shallow subtidal channels than in either deep subtidal channels or intertidal channels. At low tide, shallow subtidal channels will provide refuge from predation by piscivorous birds for juvenile salmon and splittail, but will be too shallow to allow access for large, piscivorous fish predators. Predator fish are unable to access and forage channels with water depths of less than approximately 0.5 m because they will be exposed near or above the water surface (i.e., "their backs stick out of the water"). These predators will not enter shallow subtidal channels at low tide when channel depths are less than approximately 0.5 m, but will be confined to deeper subtidal channels (Figure 4). Piscivorous fish predators will enter the same channels during higher tide stages, when water depths are greater than 0.5 m, but they will likely enter these channels after small, juvenile fishes have followed the rising tide into smaller channels farther into the marsh. Tidal channels that dewater at low tides force even juvenile fish out into deeper sloughs and distributary channels, where they are presumably more vulnerable to piscivorous predators. We also assume that juvenile fish that are feeding and growing well will be less susceptible to predation due to their increased vigor.

Invasive SAV. In order for fish to take advantage of the feeding and refugia opportunities afforded by the Dutch Slough restoration effort, they must be able to find and enter the distributary channels. The greatest hindrance to access is expected to be growth of SAV in larger subtidal channels (Figure 5). Non-native SAV and also floating aquatic vegetation (*e.g.*, water hyacinth) lower dissolved oxygen levels under some conditions and may affect other water quality parameters, as well as create conditions that attract predators of native fish species. However, the times when out-migrating salmon are present and splittial are expected to spawn is in winter and early spring, when accumulated plant material may be flushed out of the western delta and before temperature and insolation have allowed regrowth.

4.5 External Factors

External factors – outside of the Dutch Slough site - have the potential to affect the ecological outcome of restoration actions. These factors cannot be controlled within the restoration design or adaptive management experiments. Examples of external factors include landscape factors such as regionally variable salinities and freshwater flows and other factors such as Delta pump operations, urban and agricultural pollutants, changes in fisheries management, and appearance of new invasive species. The

conceptual model does not describe the effects of external factors in detail. The affect of external factors within the adaptive management process and experimental design can be addressed with monitoring of baseline conditions and reference sites.

5. KEY UNCERTAINTIES

The AMWG identified uncertainties related to: geomorphic and vegetative processes, linkages between habitat structures and functional response, water quality (mercury methylation and bioaccumulation, dissolved organic carbon (DOC) production), and construction feasibility. The AMWG considered which uncertainties were most uncertain and most important to test. In addition to the level of importance and uncertainty, the AMWG used the following criteria to select key uncertainties:

- What variables/uncertainties have the greatest implications for the future cost and feasibility of marsh restoration at Dutch Slough and elsewhere in the Delta?
- What variables can we test at Dutch Slough?
- What variables can be just as easily tested elsewhere?
- What design feature variables will maximize the chances of seeing a response?
- What variables can be experimentally tested while still maximizing the restoration value of the project?
- What variables can be experimentally tested without significantly increasing the restoration costs (e.g., the amount of fill required)?
- How many variables can be tested within the experimental design?
- To what degree should the Dutch Slough site be partitioned to test different variables?
- How does diverting Marsh Creek on to the site affect the ability to test variables?

The uncertainties identified for testing at Dutch Slough are listed in Table 1. Key uncertainties are those that are considered most important (i.e., high potential to affect the outcome and cost-effectiveness of restoration) and most uncertain. The AMWG selected tidal marshplain elevation and marsh scale as the key uncertainties for large-scale large scale experimental testing (Table 2 and Section 6). Marshplain elevation is considered important to test because lower vegetated marshes require less fill, but the habitat value may differ from that of higher, natural marshes. Marsh scale (*i.e.*, size of the marsh drainage area) is considered important to test to guide the selection of future restoration sites. Small sites are generally more available for restoration than large sites, but may not offer the same benefits on a per-acre basis (*e.g.*, tidal channel complexity). Both parameters have implications for the cost-effectiveness and feasibility of restoration, as filling restored marshes to higher elevations and acquiring larger areas for restoration are typically more expensive. Other uncertainties were selected for testing at smaller spatial scales (one to two acres) (Table 2).

Table 1. Importance and Uncertainty of Parameters to Test in Adaptive Management Experiments

		Uncertainty	
		Low	High
Importance	Low		• Rate and extent of tidal channel formation through tidal scour • Vector control ponds
	High	• Subsidence reversal (e.g., biomass accumulation, addition of organic matter such as rice straw) • Maximum inundation regimes for emergent marsh vegetation survival and inundation regimes for minimization of invasive plants	• Tidal marshplain elevation • Marsh scale • Water quality (dissolved organic carbon production, mercury methylation and bioaccumulation)

Table 2. Summary of Adaptive Management Parameters and Experimental Scale

Experimental Scale	**Parameters**
Large scale	• Tidal marshplain elevation • Marsh scale
Small scale	• Dissolved organic carbon production • Mercury methylation and bioaccumulation • Maximum inundation regimes for emergent marsh vegetation survival and inundation regimes for minimization of invasive plants • Subsidence reversal techniques (e.g., biomass accumulation, addition of organic matter such as rice straw) • Vector control ponds • Rate and extent of formation of channels through tidal scour

Water quality processes of DOC production and mercury methylation and bioaccumulation are both uncertain and important (see Section 8.3.5 in the Feasibility Study). Small-scale experiments may be designed to specifically test these water quality parameters; however, these parameters will also be measured for the large-scale experiments to determine the affect of marshplain elevation and marsh scale on DOC production and mercury methylation. The Natural Heritage Institute (NHI) is developing experimental hypotheses and design for water quality parameters as part of the Adaptive Management and Monitoring Plan.

6. HYPOTHESES FOR MARSHPLAIN ELEVATION AND MARSH SCALE

Experimental hypotheses, detailed operational conceptual models, and assumptions are described below for the large-scale experiments for marshplain elevation and marsh scale.

6.1 Tidal Marshplain Elevation

The hypothesis related to marshplain elevation is:

There is greater production of prey resources for juvenile salmon and splittail in lower elevation marshes than in higher elevation marshes, and thus greater potential for feeding, growth, and survival

The rationale behind this hypothesis is that a lower marshplain is inundated for a longer part of each tide cycle. A longer marshplain inundation period is expected to provide a more productive environment for fish prey (i.e., dipteran fly larvae, pupae and adults; gammarid amphipods) because there is less stress (*i.e.*, less desiccation and exposure to high temperatures). Greater fine sediment and detritus accumulation in lower marshplain environments may also provide increased productivity.

Low and high marshplain habitat structures are hypothesized to have somewhat different linkages between physical/vegetative processes and ecological processes (Figure 5). Vegetation colonization of lower marshplains is expected to be more susceptible to the invasion of non-native SAV; however, the hypothesis assumes that revegetation techniques will be used to encourage equal extents of tule cover on restored low and high marshplains. The tidal inundation duration of lower marshplains will be significantly greater than higher marshplains, assuming that the difference between lower and higher marshplain elevations is large (i.e., at least half the tide range). The rise and fall of tide levels are not expected to differ significantly, assuming that tidal circulation is not limited by constricted conveyance from the tidal source through external sloughs, breaches, and/or the restored (constructed) channel systems (and that the restoration is designed to avoid this). Sedimentation rates in lower marshplain habitats is expected to be greater than for higher marshplain habitats due to the greater tidal inundation duration.

6.2 Marsh Scale

The hypothesis related to marsh scale is:

Tidal channel networks in larger marshes provide shallow water refuge from predation throughout the tide cycle, whereas smaller channel networks in smaller marshes do not. Thus, larger marshes are expected to provide greater survival opportunities for juvenile salmon and splittail than smaller marshes.

The rationales behind this hypothesis are that: (1) the size of the tidal channel network is related to marsh scale and (2) channels with shallow water depths at low tide limit predator access and provide refuge for juvenile salmon and splittail. In larger marshes, some portion of the channel network is expected to always have water depths suitable for refuge during low tide. In smaller marshes, channel depth at low tide is not expected to be sufficient to provide refuge for juvenile salmon and splittail, which will be "flushed" into deep subtidal Delta slough channels (external sloughs) that likely harbor predators. In addition, larger marshes are hypothesized to provide greater structural heterogeneity and diversity (*e.g.*, relief, vegetation assemblages and tidal channel sizes) and complexity (*e.g.*, larger tidal channel systems, greater tidal energy, more refugia) than smaller marshes, and thus greater refuge and survival opportunities.

Marsh scale influences the linkages between restoration actions and functional response for habitat structures (Figure 6). Marsh scale directly relates to the following habitat structures: length of marsh/channel edge and the range of channel sizes. Larger-scale marshes are expected to have a greater length of marsh/channel edge and a larger range of channel sizes and depths. As with different elevation marshplains, the rise and fall of tide levels in different scale marshes are expected to be similar, assuming the tidal circulation is not limited by the restored (constructed) channel systems, breaches, or external sloughs. Because most of the fish forage along the vegetated edge of the tidal channels, increased access to prey is presumed to result from increased length of marsh/channel edge. Larger marshes therefore provide greater access to prey than smaller marshes; however, on a per-acre basis, the length of channel edge (*i.e.* linear channel density) is expected to be similar in larger and smaller marshes (SFEI, 2004; PWA, 1995). Prey access is therefore expected to also be similar in larger and smaller marshes on a per-acre basis. Protection from both fish and bird predation is linked to refugia such as shallow water, narrow channels and overhanging vegetation. Channel size is also assumed to influence foraging on benthic and epibenthic prey because larger channels have more surface area of low gradient, unconsolidated sediments ("mudflats").

The habitat value of a smaller marsh area and channel network is expected to be less than a marsh area of the same size within a larger marsh area. Due to the dendritic nature of tidal channel systems, smaller-scale channel and marsh systems are nested within large-scale marshes. The range of channel sizes in larger marshes is expected to provide more refugia (e.g., greater range of channel depths suitable for native fish refuge for varying tide levels, more ponded areas in dewatered channel bottoms). In smaller marsh systems, the range of channel sizes will be entirely limited to smaller channels. The larger external sloughs that are adjacent to both large and small tidal systems are typically armored and lack the refuge provided by the marsh edge. Thus, while juvenile fish may usually find refugia at some position within a larger channel system, varying as a function of tidal stage, they will be completely forced out of small channel systems during most low tides.

7. EXPERIMENTAL DESIGN CONSIDERATIONS

The preferred restoration plan, including large-scale experiments to test the marshplain elevation and marsh scale hypotheses, are described in Sections 7 and 8 of the Conceptual Plan and Feasibility Report. The following considerations and assumptions are incorporated in the experimental design to allow testing of the adaptive management hypotheses.

7.1 Tidal Marshplain Elevation.

Note that "lower elevation" and "higher elevation" marshes may be treated as distinct for adaptive management purposes, but are morphologically similar and not generally-recognized as distinct habitat categories in the Delta as discussed in Section 4.3. For adaptive management purposes, the intent is to compare "lower" and "higher" marshplains that differ enough in elevation to show different ecological responses, while not making the "higher" marsh so high that it becomes fill-limited or cost prohibitive. Selection of the exact elevations to compare requires an application of judgment. The preferred restoration plan includes low marsh areas (average marshplain elevation at mean lower low water) and

mid marsh areas (average marshplain elevation at mean tide level) that differ in elevation by approximately two feet and have significantly different tidal inundation frequencies.

Revegetation methods (tule pre-establishment) will be used to encourage equal extents of vegetation cover on low and mid marshplains at the time of breaching, which is expected to aid the experimental comparison. Tule pre-establishment is expected to provide a somewhat greater probability of tule cover on low marshes than sites that undergo pioneer colonization under tidal conditions. Tule pre-establishment is also expected to aid in competition against invasive SAV.

Tidal channel systems in restored marsh areas will be constructed to be as similar to natural systems as possible, both in cross-section (depth, width, side slope) and plan form (density, sinuosity, bifurcation). Tidal channels are anticipated to be wider in low marshes to accommodate the larger tidal prism; however, the density and depth of channels are not expected to differ greatly from mid marshes. It is assumed that tidal channel systems in low and mid marshes with equal areas will be designed with similar channel densities and depths.

7.2 Marsh Scale

The large-scale experiment for marsh scale included in the Dutch Slough restoration plan will compare low marsh and mid marsh areas drained by large channel networks (approximately 80 – 90 acres), medium sized channel networks (approximately 30 – 40 acres), and small networks (approximately 10 – 15 acres). Paired sampling of low and mid marsh will allow for comparison between low and mid marsh at different scales. A very large area of low marsh on the Burroughs parcel (approximately 150 acres) will also be compared to the smaller paired-sample marsh areas. As discussed above, tidal channels will be excavated into the restored marshplain to ensure rapid tidal channel formation and provide fish habitat at the Dutch Slough restoration site.

The intent of the marsh scale experiment is to test the value of structural heterogeneity and tidal channel complexity with increasing marsh scale to special status native fish survival. The scale of the small marsh area and channel network is expected to approximate the minimum scale that will provide low tide refuge for target fish species. Limited data on the relationship between channel depth and marsh area in Delta marshes (Simenstad and others 2000) suggest that marsh areas from approximately 10 – 15 acres may provide sufficient channel depths for low tide refuge (Figure 7). The channel networks in these small-scale marshes are expected to be 3rd order channel systems, based on data from historic freshwater and brachish marshes in other regions of the San Francisco Bay-Estuary (SFEI 2004). Medium-scale marsh and channel networks are expected to transition from 3rd to 4th order channel systems, with the largest channels allowing predator access at low tide, but a greater number of intermediate and small channel sizes that provide low tide refuge. The large and very large marsh areas and channel networks are expected to be 4th and 5th order channel systems and are hypothesized to have the greatest structural heterogeneity, diversity, and complexity.

The scale of each marsh area and channel network may be refined in future design phases for the purpose of the adaptive management experiments. Additional data on tidal channel depth and plan form

relationships to marsh area would be required to reduce the uncertainty in designing and predicting fish response to tidal channel morphology.

The marsh scale hypothesis is that juvenile native fish in smaller marshes will be more likely to be exposed to predators in the external slough channels while juvenile native fish in larger marshes are expected to remain in the restored marsh for refuge. The adjacency of small- and large-scale marshes may constitute a confounding factor for the marsh scale adaptive management experiments when using fish access and abundance as the performance measure. This is because fish offered the option of entering a large and a small marsh in close proximity may select the large marsh because the larger channel will allow them earlier access in the tidal cycle and may not dewater to the extent that they must leave. We assume that the opportunity to enter the small marsh will occur somewhat later in the tidal cycle and the fish will typically be forced out of the small marsh on the ebbing tide. Because smaller marshes are separated from nearby larger marshes by the external slough, this adjacency is not expected to be a significant factor. In addition, while the density of fish might be affected by adjacency, the performance of fish in manipulative experiments (with fish releases) within the marshes would not be as vulnerable to any artifact introduced by adjacent marshes.

8. AMWG MEMBERS

The Dutch Slough Adaptive Management Work Group is:

Bruce Herbold, Ph.D., US EPA (Chair)
Peter Baye, Ph.D., Private Consultant
Joan Florsheim, Ph.D., UC Davis
Roger Fujii, Ph.D., USGS
David Sedlak , Ph.D., UC Berkeley
Stuart Siegel, Ph.D., Private Consultant
Mark Stacey, Ph.D., UC Berkeley
John Takekawa, Ph.D., USGS
Lars Anderson, Ph.D., USDA

9. REFERENCES

Allen, JRL. 2000. Morphodynamics of Holocene salt marshes: a review sketch from the Atlantic and southern North Sea coasts of Europe. Quaternary Science Review 19(12):1155-1231.

Anderson, Lars. U.S. Department of Agriculture. Personal communication.

Atwater BF. 1982. Geologic maps of the Sacramento-San Joaquin Delta, California. Menlo Park (CA): U.S. Geological Survey MF-1401.

Atwater BF, Belknap DF. 1980. Tidal-wetland deposits of the Sacramento-San Joaquin Delta, California. In: Field ME, Bouma AH, Colburn IP, Douglas RG and Ingle JC, editors. Quaternary depositional

environments of the Pacific Coast. Pacific Coast Paleogeography Symposium 4. Proceedings of the Society of Economic Paleontologists and Mineralogists. Los Angeles (CA): Society of Economic Paleontologists and Mineralogists. p 89-103.

Atwater BF, Conard SG, Dowden JN, Hedel CW, MacDonald RL, Savage W. 1979. History, landforms, and vegetation of the estuary's tidal marshes. In: Conomos TJ, Leviton AE, Berson M, editors. San Francisco Bay: the urbanized estuary. San Francisco (CA): Pacific Division, AAAS. p 347-385.

Atwater BF, Hedel CW. 1976. Distribution of seed plants with respect to the tide levels and water salinity in the natural tidal marshes of the northern San Francisco Bay estuary, California. Preliminary report. U.S. Geological Survey Open File Report 76-389.

Beeman and Krone. (Ogden Beeman & Associates, Inc., RB Krone & Associates, Inc.). 1992. Sediment budget study for San Francisco Bay. Final report. Prepared for the San Francisco District, U.S. Army Corps of Engineers. Located at: Ogden Beeman & Associates, Inc., Portland, OR. 25+ p.

Cain, John. 2004. Memorandum to Dutch Slough Adaptive Management Working Group candidates. Subject: Draft Memo on Adaptive Management Working Group. Revised March 30.

CALFED (CALFED Bay-Delta Program). 2000. Ecosystem restoration program plan final programmatic EIS/EIR. Sacramento (CA): CALFED Bay-Delta Program. Available from: http://calwater.ca.gov/CALFEDDocuments/Final_EIS_EIR.shtml.

Delta Habitats Group, 2002. Report of the Delta Habitats Group, CALFED ISB Adaptive Management Workshop, March 19-20, 2002. Prepared by Denise Reed, ISB Adaptive Management Subcommittee and Bruce DiGennaro, Kleinschmidt.

Drexler JZ, Fleck J, Wheeler G, Fujii R. 2003. Carbon storage and sediment accretion in restored wetlands on Twitchell Island in the Sacramento-San Joaquin Delta, California [abstract]. In: CALFED Science Conference 2003 Abstracts. CALFED Science Conference 14-16 Jan 2003, Sacramento Convention Center. Sacramento (CA): CALFED Bay-Delta Program. p 46.

Garrity NJ. 2004. Solar Heating and Temperature Dynamics of Over-Marsh Tides in Restored Marshes. U.C. Berkeley CEE209A Hydrologic Mixing Processes class project for Professor Mark Stacey. May 17.

Gilbert GK. 1917. Hydraulic mining in the Sierra Nevada. U.S. Geological Survey Professional Paper 105. Washington, DC: Government Printing Office.

Goman M, Wells L. 2000. Trends in river flow affecting the northeastern reach of the San Francisco Bay Estuary over the past 7000 years. Quaternary Research 54:206-217.

Moyle, PB. 1976. Inland fishes of California. University of California Press.

NHI (Natural Heritage Institute). In progress. Dutch Slough Tidal Marsh Restoration Adaptive Management and Monitoring Plan.

Orr MK, Crooks S, Williams PB. (2003). Will Restored Tidal Marshes Be Sustainable? *San Francisco Estuary and Watershed Science* **1**(1): Article 5.

PSNERP (Puget Sound Nearshore Ecosystem Restoration Project, Nearshore Science Team). 2006. Conceptual model for assessing restoration of Puget Sound Nearshore Ecosystems. Prepared by the Nearshore Science Team, Conceptual Model Working Group – C. Simenstad lead author, K. Fresh, M. Logsdon, J. Newton and H. Shipman. Olympia, WA. (in press)

PWA (Philip Williams & Associates, Ltd.). 2006. Dutch Slough Tidal Marsh Restoration Conceptual Plan and Feasibility Study. Prepared for The California State Coastal Conservancy; PWA Report 1714.

PWA (Philip Williams & Associates, Ltd.). 2003. Decker Island Phase II Restoration Project – Concept Design. Prepared for MBK Engineers and DWR. May 8, 2003 Memorandum from Michelle Orr, Nick Garrity, and Phil Williams, PWA to Gilbert Cosio and Don Trieu, MBK Engineers. PWA report#1666. Located at: PWA, San Francisco, CA. 10+ p.

PWA (Philip Williams & Associates, Ltd.), Pacific Estuarine Research Lab, and Louisiana Universities Marine Consortium. 1995. Design guidelines for tidal channels in coastal wetlands. Prepared for the U.S. Army Corps of Engineers Waterways Experiment Station. PWA report #934. Located at: PWA, San Francisco, CA. 46+ p.

Reed DJ. 2002. Sea-level rise and coastal marsh sustainability: geological and ecological factor in the Mississippi delta plain. Geomorphology 48:233-243.

SFEI (San Francisco Estuary Institute). 2004. Syntheses of Scientific Knowledge for Maintaining and Improving Functioning of the South Bay Ecosystem and Restoring Tidal Salt Marsh and Associated Habitats over the Next 50 Years at Pond and Pond-Complex Scales. Draft Final Report.

Simenstad C, Toft J, Higgins H, Cordell J, Orr M, Williams P, Grimaldo L, Hymanson Z, Reed D. 2000. Sacramento-San Joaquin Delta breached levee wetland study (BREACH). Preliminary report. Seattle (WA): Wetland Ecosystem Team, University of Washington, School of Fisheries. 46 p.

USFWS and USACE (U.S. Fish and Wildlife Service (Sacramento) and U.S. Army Corps of Engineers (Sacramento District)). 1990. Design and biological monitoring of wetland riparian habitats created with dredged materials. Final report. Deepwater Ship Channel monitoring program. Sacramento (CA): Sacramento District Corps of Engineers. 68 p.

Wang JCS. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

Williams PB, Orr M.K., Garrity NJ. 2002. Hydraulic geometry: a geomorphic design tool for tidal marsh channel evolution in wetland restoration projects. Restoration Ecology 10:577-590.

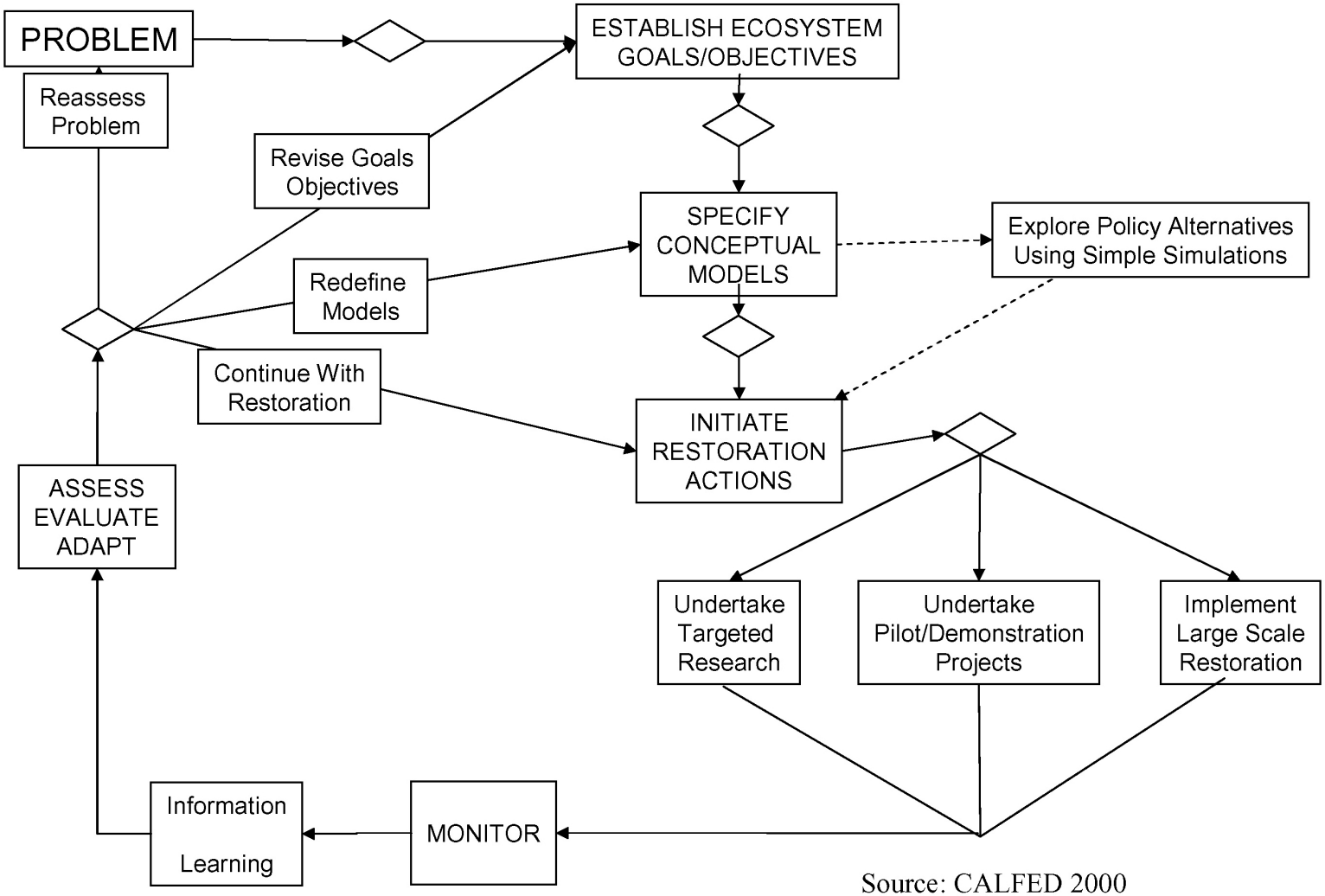
Wright SA, Schoellhamer DH. 2003. Trends in the sediment yield of the Sacramento River, 1957-2001 [abstract]. In: CALFED Science Conference 2003 Abstracts; 14-16 Jan 2003, Sacramento. Sacramento (CA): CALFED Bay-Delta Program. p 177.

FIGURES

Figure 1. Adaptive Management Plan Flow Diagram
Figure 2. General Conceptual Model
Figure 3. Tidal Marshplain Elevation Hypothesis
Figure 4. Marsh Scale Hypothesis
Figure 5. Tidal Marshplain Elevation Conceptual Model
Figure 6. Marsh Scale Conceptual Model
Figure 7. Channel Depth and Marsh Area Relationship

ATTACHMENTS

Attachment A. Initial Development of Dutch Slough Conceptual Model
Attachment B. Conceptual Model by the Delta Habitats Group



Source: CALFED 2000

Note: diamonds indicate decision points.

figure 1

Dutch Slough Conceptual Model

Adaptive Management Process Flow Diagram

Appendix E

PWA

PWA#: 1714 Append_E.cdr

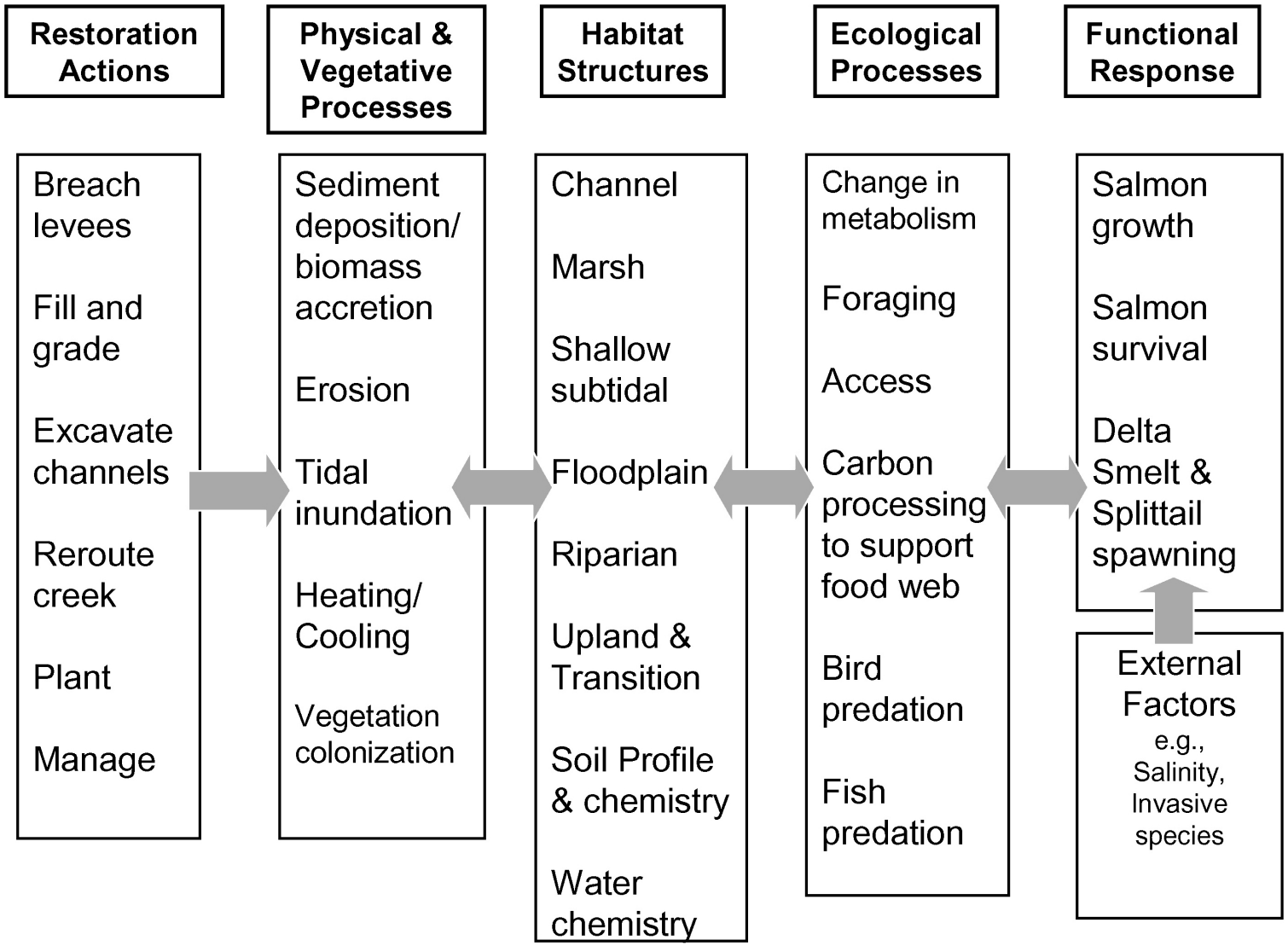


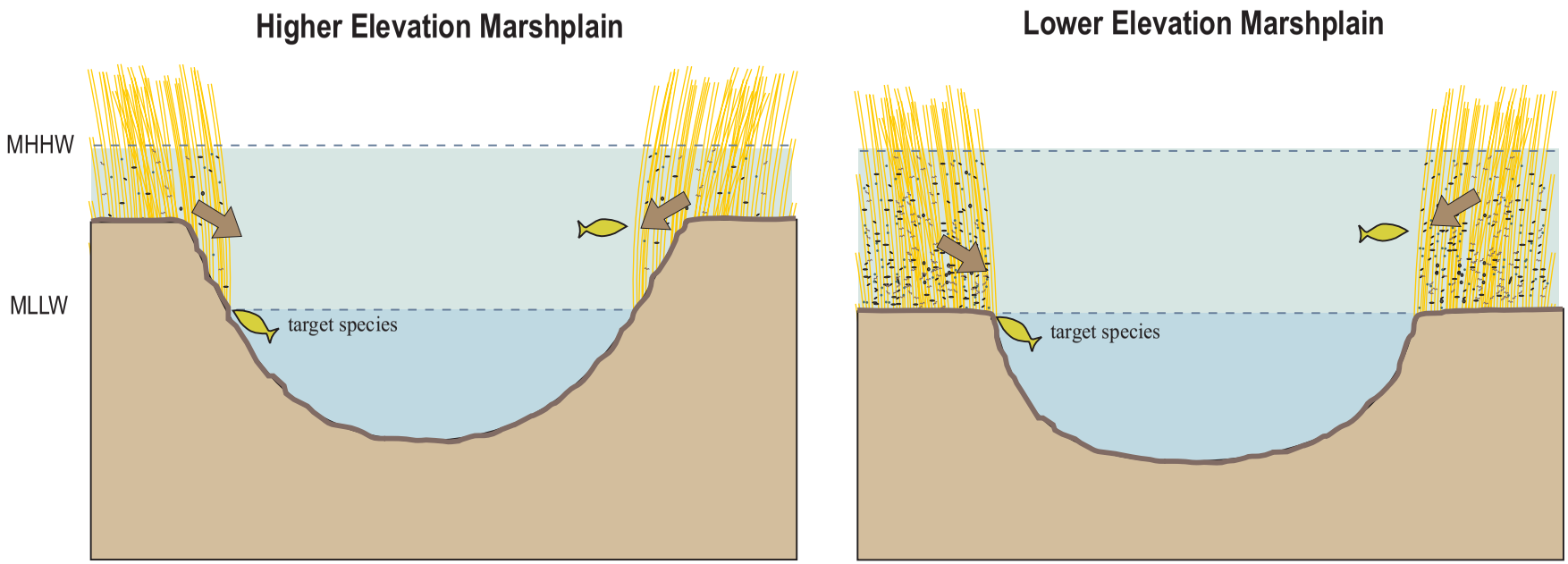
figure 2

Dutch Slough Conceptual Model

General Conceptual Model

PWA

PWA#: 1714 Append_E.cdr



Hypothesis

There is greater production of prey resources for juvenile salmon and splittail in lower elevation marshes than in higher elevation marshes, and thus greater potential for feeding, growth, and survival.

Legend

- tule vegetation
- prey
- delivery of prey to channel
- target special status native fish species (juvenile salmon and splittail)

Notes:
MHHW = mean higher high water
MLLW = mean lower low water
Not to scale

figure 3

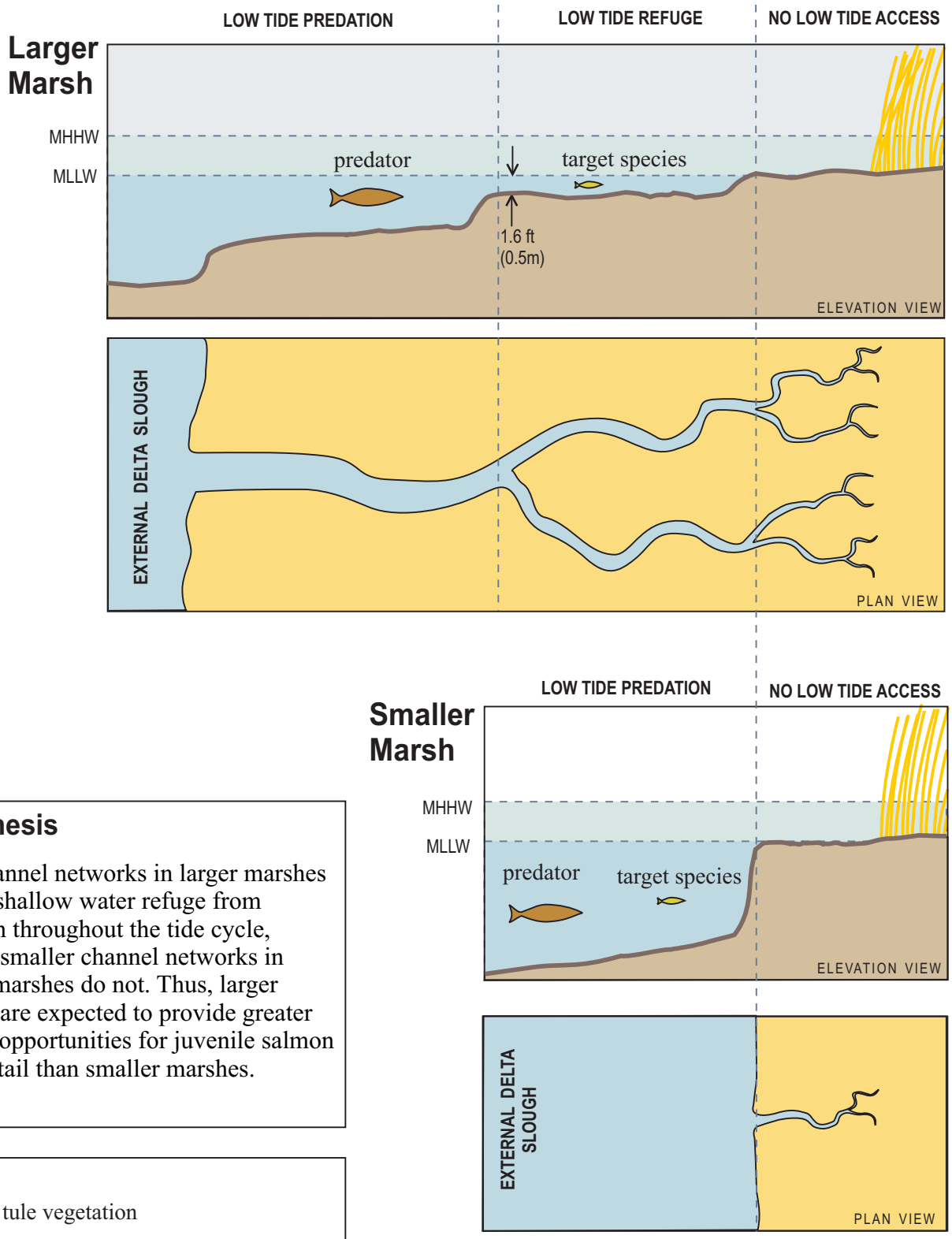
Dutch Slough Conceptual Model

Tidal Marsh Elevation Hypothesis

Appendix E

PWA

PWA Ref# 1714 AppendixE fig3 elevHypoth.cdr



Hypothesis

Tidal channel networks in larger marshes provide shallow water refuge from predation throughout the tide cycle, whereas smaller channel networks in smaller marshes do not. Thus, larger marshes are expected to provide greater survival opportunities for juvenile salmon and splittail than smaller marshes.

Legend

- tule vegetation
- predator fish species
- target special status native fish species (juvenile salmon and splittail)

Notes:
MHHW = mean higher high water
MLLW = mean lower low water
Not to scale

figure 4

Dutch Slough Conceptual Model

Marsh Scale Hypothesis

Appendix E

PWA

PWA Ref# 1714 AppendixE fig4 marshScale.cdr

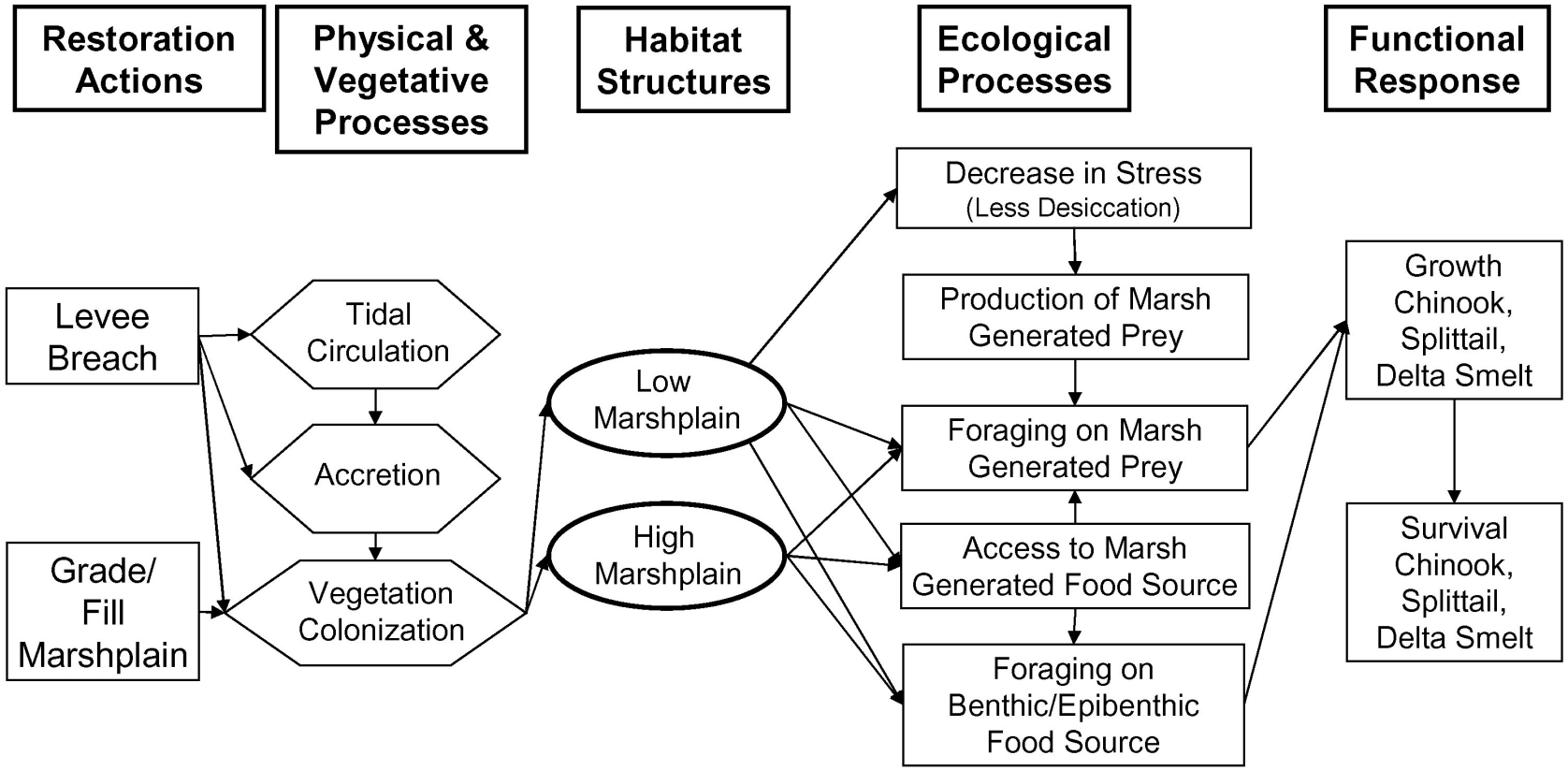


figure 5

Dutch Slough Conceptual Model

Tidal Marshplain Elevation Conceptual Model

Appendix E

PWA

PWA#: 1714 Append_E.cdr

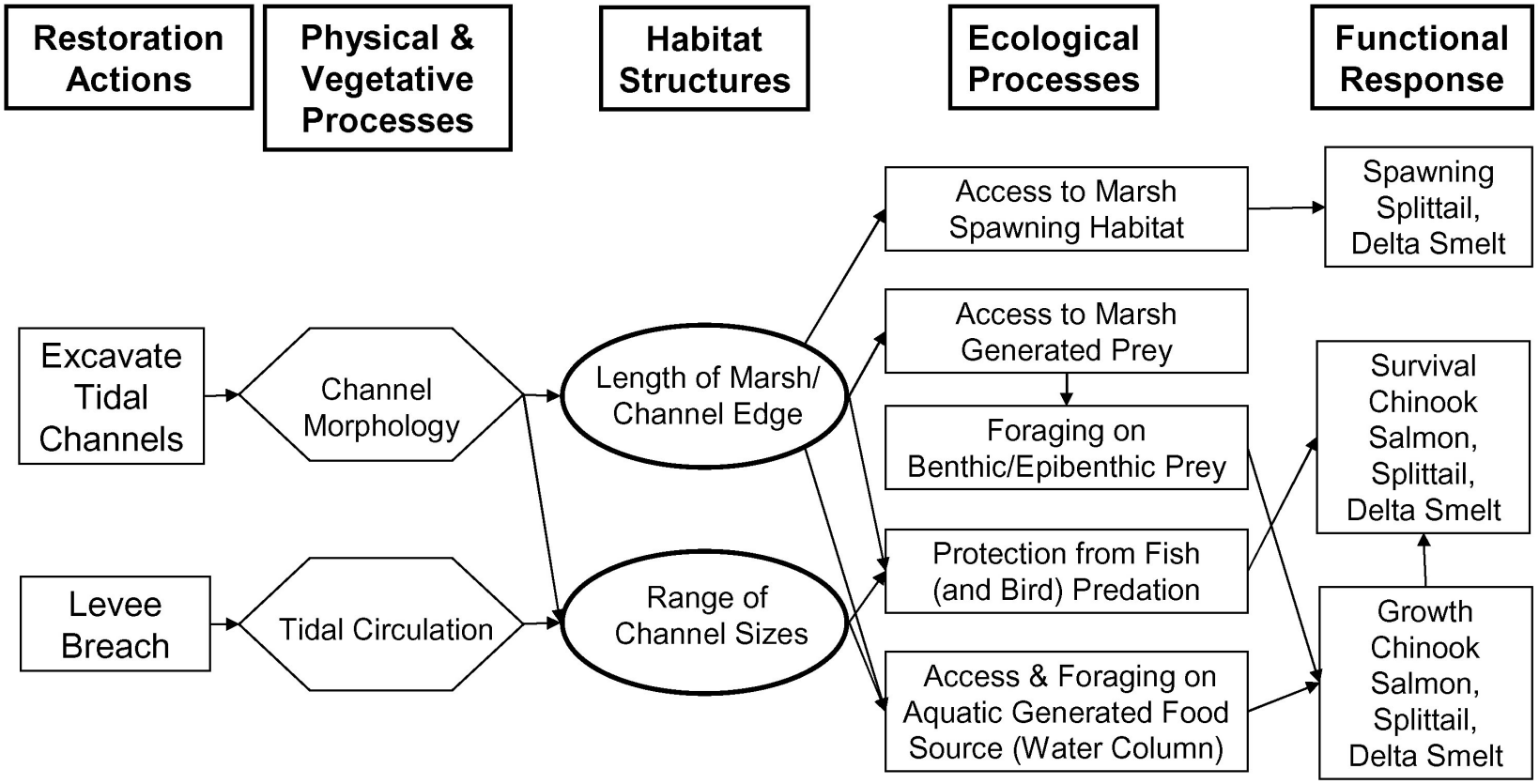


figure 6

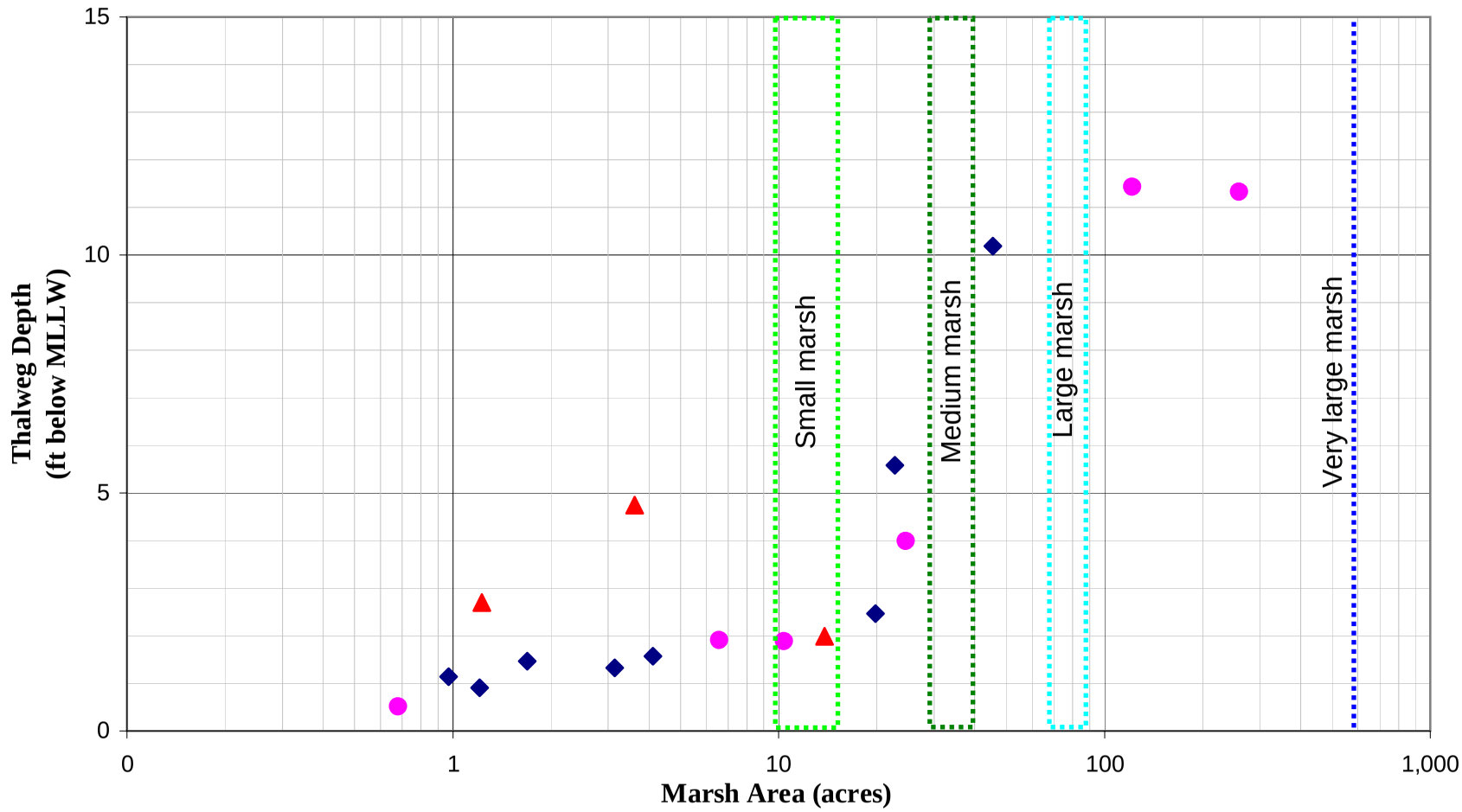
Dutch Slough Conceptual Model

Marsh Scale Conceptual Model

Appendix E

PWA

PWA#: 1714 Append_E.cdr



▲ Lower Mandeville Tip ◆ Sherman Island ● Browns Island

Source: Simenstad and others, 2000

figure 7

Dutch Slough Conceptual Model

Channel Depth and Marsh Area Relationship

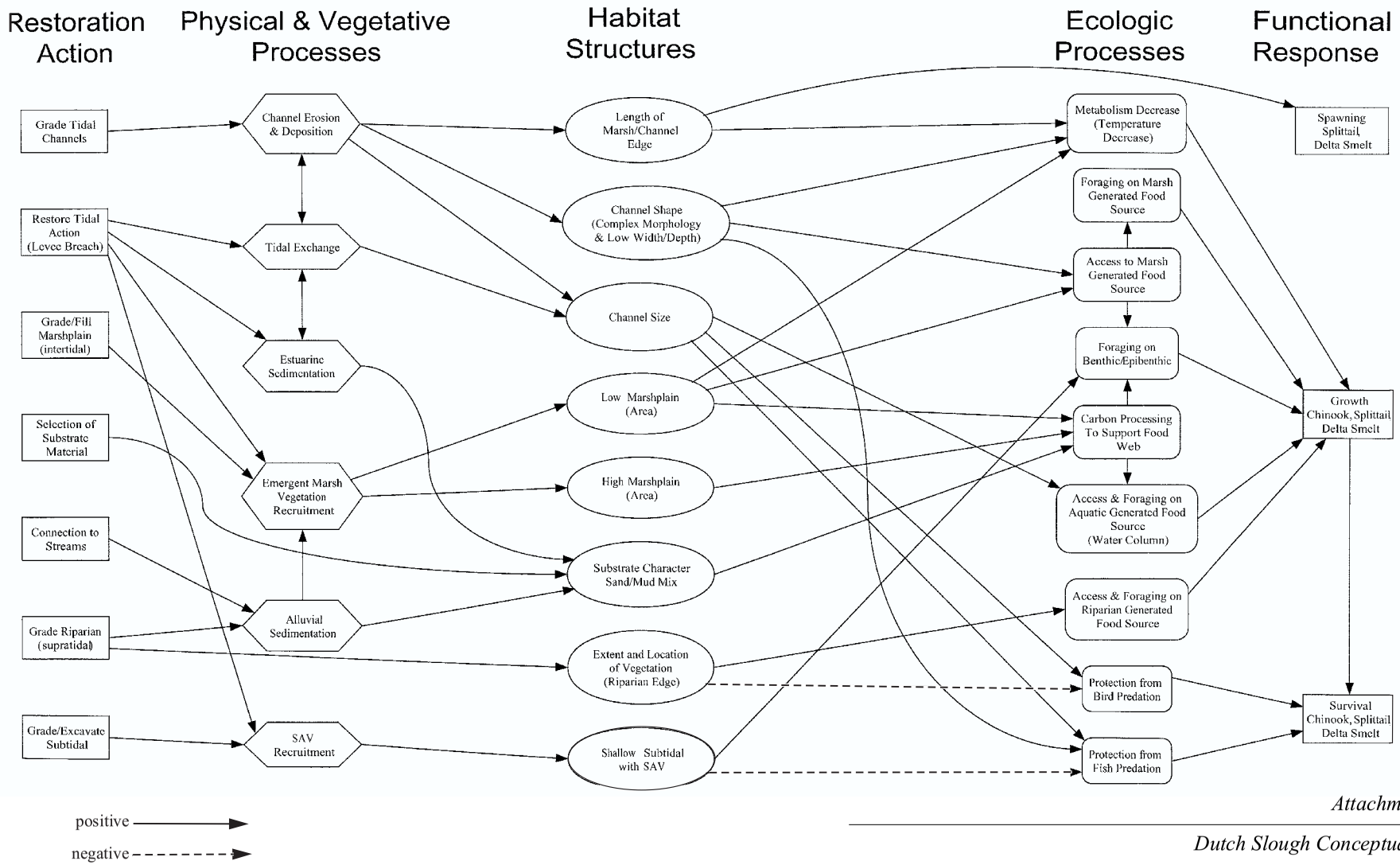
PWA#1714 **Appendix E**

PWA

Sept. 2004 DRAFT

Dutch Slough Conceptual Model

HOW TIDAL RESTORATION ACTIONS AFFECT DESIRED FUNCTIONAL RESPONSE ON SITE



Source: AMWG meeting discussion, PWA, and Simenstad

Attachment A1

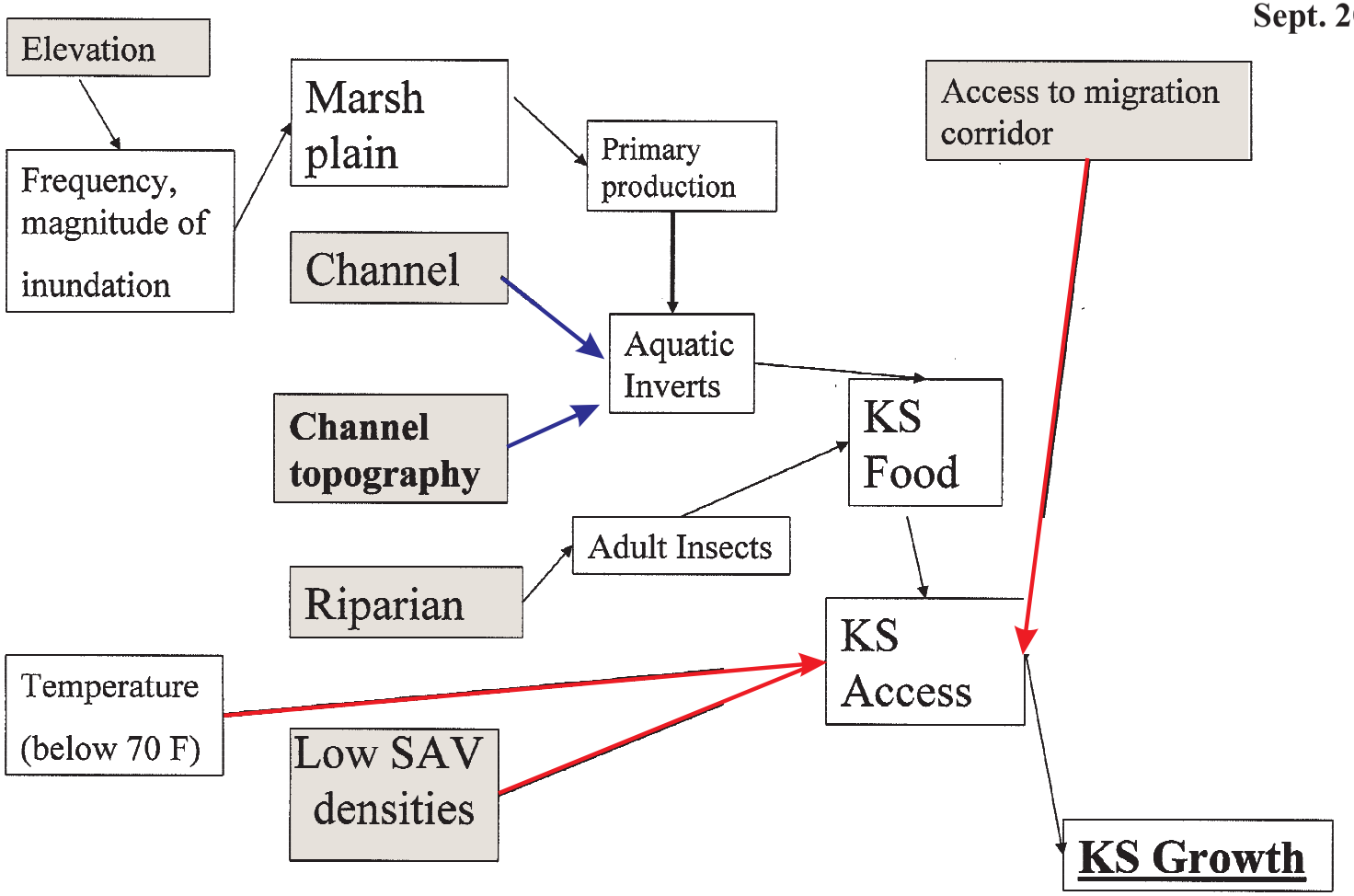
Dutch Slough Conceptual Model

Initial Detailed Conceptual Model

Appendix E

PWA

PWA#: 1714 Append_E.cdr



Note: blue arrows represent areas of high uncertainty, red arrow represent areas of high importance. Shaded boxes represent targets of restoration activities; implied within the shaded boxes are various possible configurations to maximize or minimize the effects represented by the arrows.

Attachment A2

Dutch Slough Conceptual Model

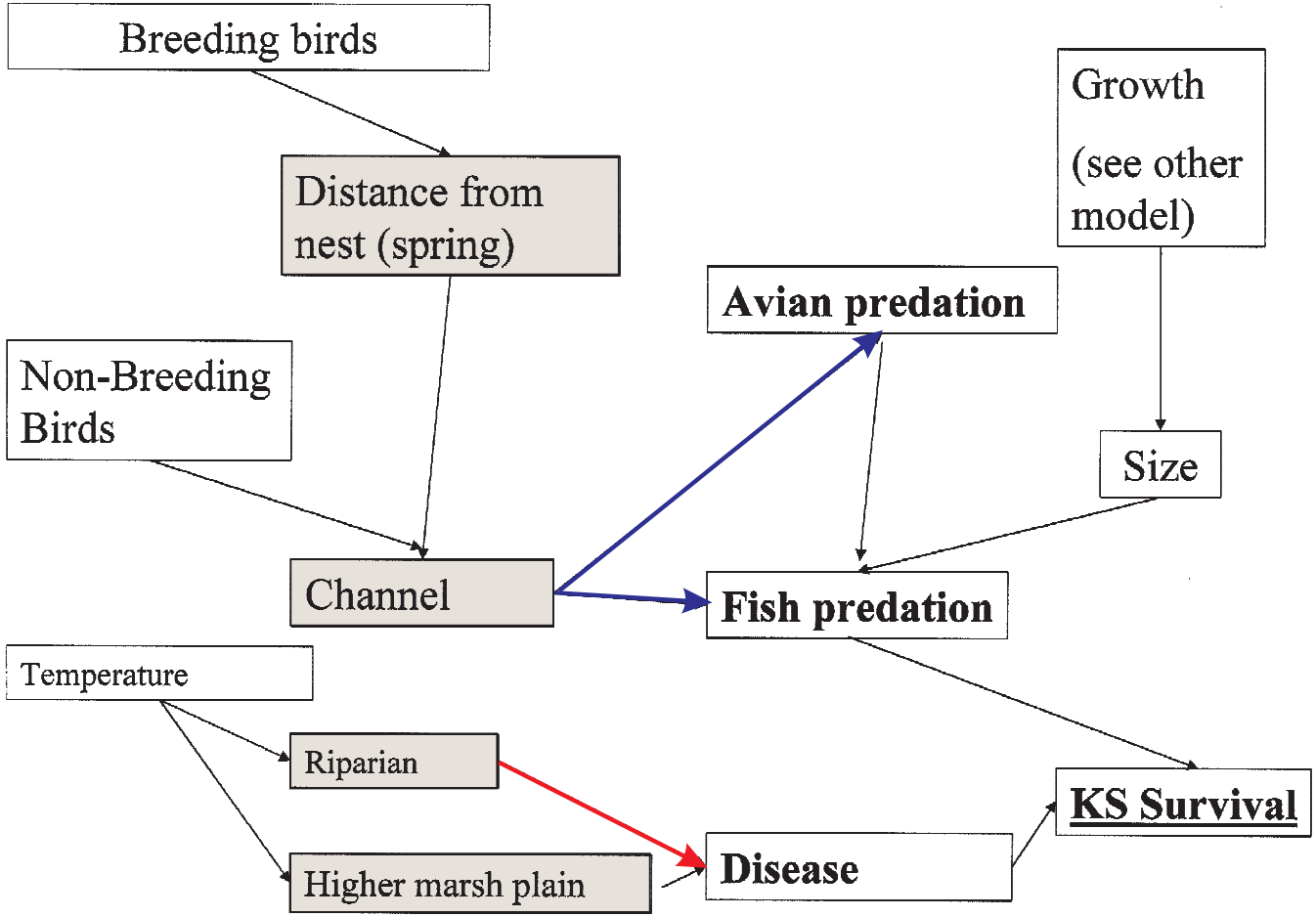
Initial Conceptual Model for Chinook Salmon Growth: Habitats, Processes and Attributes

Source: AMWG meeting discussion

Appendix E

PWA

Sept. 2004 DRAFT



Note: blue arrows represent areas of high uncertainty, red arrow represent areas of high importance. Shaded boxes represent targets of restoration activities; implied within the shaded boxes are various possible configurations to maximize or minimize the effects represented by the arrows.

Attachment A3

Dutch Slough Conceptual Model

Initial Conceptual Model for Chinook Salmon Survival: Habitats, Processes and Attributes

Source: AMWG meeting discussion

Appendix E

PWA

PWA#: 1714 Append_E.cdr

Appendix E.
Attachment B

Report of the Delta Habitats Group
CALFED ISB Adaptive Management Workshop
19-20 March, 2002

Prepared by
Denise Reed, ISB Adaptive Management Subcommittee
Bruce DiGennaro, Kleinschmidt

Introduction

The Delta Habitats Group was charged with developing an adaptive management experimental manipulation of delta habitat configurations. A large number of restoration actions are being taken or considered in the delta to restore or improve physical habitat, and many in the group had experience with design, construction or monitoring of these projects and the potential array of delta habitats.

The group began their deliberations with a brainstorming session on important types of delta habitats, their attributes and major uncertainties associated with their restoration. Suggestions for experimental habitat restoration were then put forward by individuals for discussion by the group. The three possible experiments considered were:

Concept 1. Provide floodplain habitat during dry season by opening all or part of Merritt,Sutter,or lower Grand Island,via gates or control structures,to allow inundation driven by tidal flow.

Concept 2. Create a large tidal marsh area by removing all or a significant portion of a delta island levee and grading the levee material onto the island.Material would be graded to create a gradual sloping land surface elevation from MLLW to something above EHHW at the opposite side of the island.The lower elevation (marsh)edge would front an active channel.

Concept 3. Provide dendritic tidal marsh habitat with attributes which will benefit native at-risk species,and discourage attributes (i.e.,non-native SAV)that do not,while exploring the most effective ways to create such habitat across deltaic gradients
The group broke into 3 sub-groups to develop these ideas further and the results were presented back to the group for discussion. Concepts 1 and 2 were thought to provide promising ideas for further consideration and brief descriptions have been developed.The consensus of the group was that Concept 3 should be developed in more detail as an experiment. The approach to developing the experiment from the concept was to follow the adaptive management approach described in Chapter 3 of the ERP Strategic Plan (Final EIS/EIR Technical Appendix 2002).

This report includes a description the detailed experiment developed for concept 3 which has been reviewed and revised by the group. Short descriptions of Concepts 1 and 2 were developed from the breakout session notes and were reviewed and modified by the concept ‘champions ’.

Delta Habitats Breakout Group

Bill Bennett,Bodega Marine Laboratory
Marina Brand,CA Department of Fish and Game
Jon Burau,U.S.Geological Survey
Larry Brown,U.S.Geological Survey
Gonzalo Castillo,US Fish and Wildlife Service
Mike Chotkowski,U.S.Bureau of Reclamation
Steve Culberson,CA Department of Water Resources
Michael Dege,CA Department of Fish and Game
Bruce DiGennaro,KleinSchmidt (Recorder)
Lenny Grimaldo,CA Department of Water Resources
Bruce Herbold,U.S.Environmental Protection Agency
Lisa Lucas,U.S.Geological Survey
Bill Martin,San Francisco State University
Mike McGowan,San Francisco State University
Doug Morrison,US Fish and Wildlife Service
Anke Mueller-Solger,CA Department of Water Resources
Matt Nobriga,CA Department of Water Resources
Anitra Pawley,The Bay Institute
Denise Reed,University of New Orleans (Facilitator)
Curt Schmutte,CA Department of Water Resources
Charles Simenstad,University of Washington
Michelle Stevens,CA Department of Water Resources
Bob Spies,Applied Marine Systems
Marc Vayssieres,CA Department of Water Resources
Phil Williams,Philip Williams and Associates

Constructing Tidal Marshes with Dendritic Channels to Benefit Native Fishes: an adaptive management experiment.

A product of the
CALFED ISB Adaptive Management Workshop
19-20 March,2002
Delta Habitats Group

Concept

One of the major underlying assumptions of many tidal marsh restoration projects is that shallow subtidal and intertidal habitat is a significant factor limiting at-risk species in the Sacramento-San Joaquin Delta.However,this assumption has not been tested for many of these species.In addition,there is uncertainty about whether tidal marsh restoration will result in even further intrusion of non-native submerged aquatic vegetation (SAV) that marginalize marsh function for fish and wildlife.This adaptive management experiment seeks to reduce uncertainty surrounding this issue by testing some hypotheses regarding the design and location of such habitat restoration,and by assessing species-specific responses.Specifically,this project addresses the development of tidal wetlands with minimal non-native submerged aquatic vegetation and the value of dendritic tidal channels as fish habitat.This experiment has been designed in accordance with the adaptive management framework promulgated by CALFED ERP as articulated in Figure 2-4 of the 1998 Strategic Plan.

Problem Statement and Goals

This restoration seeks to address the problem of decline in native fishes in the Delta.The reduction in quantity,quality and diversity of habitat for native fishes has likely contributed to the listing of several species that are found in the Delta during parts of their life cycles.The ecosystem approach to species conservation adopted by CALFED calls for sustaining and enhancing the fundamental ecological structures and processes that support the species.**Thus,the goal of this project is to provide dendritic tidal marsh habitat with attributes which will benefit native at-risk species,and discourage attributes (i.e.,non-native SAV)that do not.**

Conceptual Model

The conceptual model underlying the design of this restoration experiment is the link between the decline in natural dendritic intertidal marsh habitat,which historically dominated the Delta (Atwater,1980),and the decline in native at-risk species,including delta smelt,splittail,chinook salmon and steelhead rainbow trout utilizing the Bay-Delta. The presence of extensive dendritic intertidal marsh habitat at a time when native at-risk species maintained healthy populations implies that habitat restoration will likely benefit the native species that coevolved over the development of the historic Delta.However, this is only one part of the conceptual model used here.Indeed,current conditions in the Delta mean we must question the benefits of restoring these habitats may provide for the native species because of the extensive invasions of non-native species and water management activities.Recent studies (Grimaldo et al.,2002)note an association

between subtidal areas,frequently dominated by SAV,and non-native fishes that consume native fishes,or may displace or out-compete them.

The conceptual basis for this project is outlined in Figure 1.The figure shows how the hydrodynamic characters and physiographic setting of various geomorphic features in the Delta provide appropriate conditions,or not,for extensive SAV development.As a consequence,it is also assumed that those features associated with dendritic tidal marsh habitat also provide important functions that benefit native fishes.Essentially,intertidal marshes with extensive dendritic channels drain regularly compared to subtidal areas and thus less likely to be dominated by SAV.However these habitats prove beneficial to native fishes only if it is directly accessible (i.e.,access is direct and not via a dense SAV bed adjacent to the marsh and channel system).Thus an important landscape component of the conceptual model is that active distributary or slough channels also exhibit conditions that are unsuitable (too deep or too turbid)for SAV growth.The final element of the conceptual model to be tested and developed using this experiment is that we have the geomorphic understanding and engineering to establish conditions promoting the development of dendritic tidal marshes with the attributes just described.

Uncertainties

The adaptive management experiment will be designed to address several key uncertainties contained in the conceptual model described above:

Will SAV colonize and persist in and immediately adjacent to a dendritic channel system adjoining an active distributary channel?

What are the important characteristics of dendritic channels and adjacent marsh that benefit native fishes?

What are the process linkages that lead to these benefits?

Can tidal action alone develop and maintain dendritic channels?

Can we cost effectively design and construct tidal marsh plain channel systems that are stable and sustainable in the long term (over decades)?

What are fish responses to dendritic tidal marsh habitat in estuarine vs tidal riverine dominated systems?

What is the relationship between marsh channel pattern,hydrodynamics,and marsh plain vegetation characteristics?

Hypotheses

The above uncertainties will be addressed by testing the following hypotheses:

1.SAV coverage and density are lower or absent in tidal channels with stronger tidal flows and sandier substrate types.

2.Marsh with complex dendritic channel system will provide a greater quantity and diversity of more food for fish,(e.g.,benthic and pelagic,macroalgal and microalgal)compared to open subtidal habitats.This effect may be direct or indirect via the provision of food for prey (e.g.,chironomids or copepods).

3.Fish reproduction,growth and survival depend on geomorphological characteristics of the marsh tidal channel system,specifically:

Channel density (hypothesized positive relationship)

Channel shape in cross-section (hypothesized positive relationship with steep side slopes)

Channel order

o Hypothesized negative relationship for growth;however,this may depend upon the strength of flow out of the dendritic channel system, e.g.,higher order may actually provide better overall habitat because fish are not entirely forced out of the marsh at low tide,but SAV may occupy the higher order channel [s] if flow is not sufficient to suppress SAV growth.

o Hypothesized positive relationship for reproduction where dewatering at low tide may impact fish eggs.

The ratio of marsh edge to marsh area (hypothesized positive relationship)

4.Hydrogeomorphic setting and construction of tidal channel systems can be optimized to minimize the impact of SAV

Grading can be used to design and construct functional tidal channels

Sedimentation from adjacent rivers will hasten the development of a dendritic tidal channel system

Experimental Design

The essential elements of the experimental design used to test these hypotheses will involve using different approaches to the creation of dendritic tidal marsh habitat,and testing these approaches in two areas:

the eastern Delta (close to a riverine source of sediment).Possible location: McCormack-Williamson Tract

the western Delta (remote from direct supply of sediments from riverine sources but close to sediments mobilized and transported by waves and tides).Possible location:Chipps Island

These sites have been selected for the suitability of their current elevations.Within each area land will be selected which is not greatly subsided (<4 ft.below mean sea level -an elevation shallow enough for lateral colonization by tules.)and allocated into 3 parcels of 200 acres or greater in size.This size is considered a minimum to achieve the development of a mature (e.g.,4 th order or greater)tidal channel network.Initial elevations must be sufficiently high that achieving tidal marsh elevations through natural sedimentation processes is likely,and higher elevation areas may be included in one of the treatments that require grading.If necessary,some material may be added to achieve the elevations necessary to complete the treatments.The parcels must exchange directly into a deep distributary channel that is unfavorable for SAV growth (too dynamic or too turbid).

Each of these parcels will receive a different experimental treatment:

Treatment 1 —No Intervention

At this site,tidal action will be introduced to the parcel via a very wide levee ‘breach ’.No further action will occur and the site will be

monitored to assess performance relative to the measures described below.

Treatment 2 —Fill to Appropriate Elevations

At this site,the land will be graded or filled to achieve an elevation in the intertidal range and tidal action will be introduced to the site in a manner similar to Treatment #1.

Treatment 3 —Fill and Excavate Channels

At this site,land will be graded or filled,as in Treatment #2,but in addition a proto-dendritic (i.e.,“starter ”)channel system will be excavated to ‘kick-start ’ the channel development process..

Concept 4. The replication of these treatments in each area will allow the experimental evaluation of the role of riverine vs.tidal sediment sources to bring elevations to appropriate levels (Treatment 1 – hypothesis 5))as well as allowing the testing of hypotheses 1,2 and 3 across a range of delta salinity,turbidity and hydrodynamic conditions.Hypothesis 4 is tested through the comparison of the physical performance of the treatments within an area.

Concept 5. Performance Measurements

The active adaptive management nature of this experiment means that in order to meet the stated goal the project must achieve specific performance measures or changes will be made accordingly.Thus,it is proposed that these treatments should be assessed relative to these measures 5 years after project implementation.This should be enough time for dendritic channel formation to at least begin in treatments 1 and 2,and for some natural adaptation of the channels in treatment 3.In addition,it is likely that within 5 years the area in the eastern Delta will be subjected to at least a moderate flood,supplying riverine sediments to the treatments.

The performance measures are linked to the development and function of the dendritic channel system – the goal is not just to achieve a channel network but one with functions and use patterns that allow our hypotheses to be tested.In some cases these performance measures can only be assessed by comparing the treatment sites with adjacent reference areas (e.g.,sluggish subtidal areas as described in Figure 1).Where this is the case monitoring measures (see below)must encompass not just the restoration sites but also appropriate reference sites.

1.Composition and coverage of SAV
The coverage of SAV within the channel system must be less than coverage in sheltered subtidal areas close to the treatment.The composition of SAV that is present must include native species.

2.Development of channels
Each treatment in each area must develop a dendritic channel network of at least a third order level within five years.

3.Net vertical sedimentation

Treatments which were implemented below mean marsh plain elevation must show vertical accretion (via accumulation of organic matter and/or sediments)towards marsh plain elevation.Treatments which were

implemented at marsh plain elevation must show elevation increase at a rate at least equal to relative sea-level rise.

4.Microalgal composition and production
The benthic,epiphytic,and planktonic microalgal communities include high-quality food organisms for primary consumers (e.g.,cryptophytes, certain diatoms,etc.).Such microalgal production in the restoration sites should be similar to (equal to or greater than)that found in adjacent sheltered subtidal channels and sufficient to support desirable consumer densities.

5.Reproduction,growth and survival of at risk native species
Monitoring must show that reproduction,growth and survival of appropriate at-risk species within the treatment areas is equal to or greater than similar measures in adjacent sheltered subtidal channels.

Adaptive Management Measures

We recommend using the performance measures above to determine whether the project is progressing towards its stated goal within the five-year timeframe.If these measures are not met,contingency actions must be instituted to adjust the design/operation of this project,and to improve the design and operation of future tidal marsh restoration projects.Specifically,the key to this restoration action is the development of dendritic tidal channels without a significant presence of SAV.If Performance Measure #1 is not met five years after project implementation,the initial design specifications will be modified and the site reconfigured,e.g.,marsh surfaces will be graded and sculptured to initiate channel development (similar to the approach proposed for Treatment #3).If channels are developing (e.g.,measure #1 is being met)but Performance Measures #2-#5 are not met then this implies that the dendritic tidal channel habitat is not functioning as anticipated in the conceptual model (Figure 1).The reasons for this will likely be clear from the monitoring data (see below)and the testing of the hypotheses.Information derived from this monitoring maybe used to modify the conceptual model and structurally alter the channel systems to improve function,but unless clearly justified structural improvements can be made,it is recommended that the project be redesigned, rather than adapted from its original concept.

Monitoring to Reduce Uncertainty

The role of the monitoring program is threefold:
1.to provide data on project performance relative to the measures described above;
2.to provide data to test the stated hypotheses and thus reduce uncertainties surrounding the construction and use of dendritic tidal marsh habitat to benefit at-risk species;and,
3.provide direction for adaptive modifications to the experimental treatments that do not meet performance measures.
We recommend that the monitoring design for the project is both ‘process-oriented ’ and examine the evolution of the sites and the resulting structure-process interactions.These

sites must be viewed as “open ” systems,,both influencing and influenced by processes in adjacent and remote environments.Specific measurements should include:

evaluation of physical structure and processes (geomorphic character, hydrodynamics,sedimentation);

emergent plants (composition over time and coverage);

submerged and floating plants (diversity,coverage,and change over time);

organic carbon (OC)fractions (forms of OC produced within and exported from the sites);

invertebrate use and change over time;

benthic algae production

occurrence of juvenile and small pelagic fishes;

turbidity/light attenuation (i.e.,because algal production is light limited);

inorganic nutrients;

spatial habitat complexity;and,

fish response to various habitat components of the marsh.

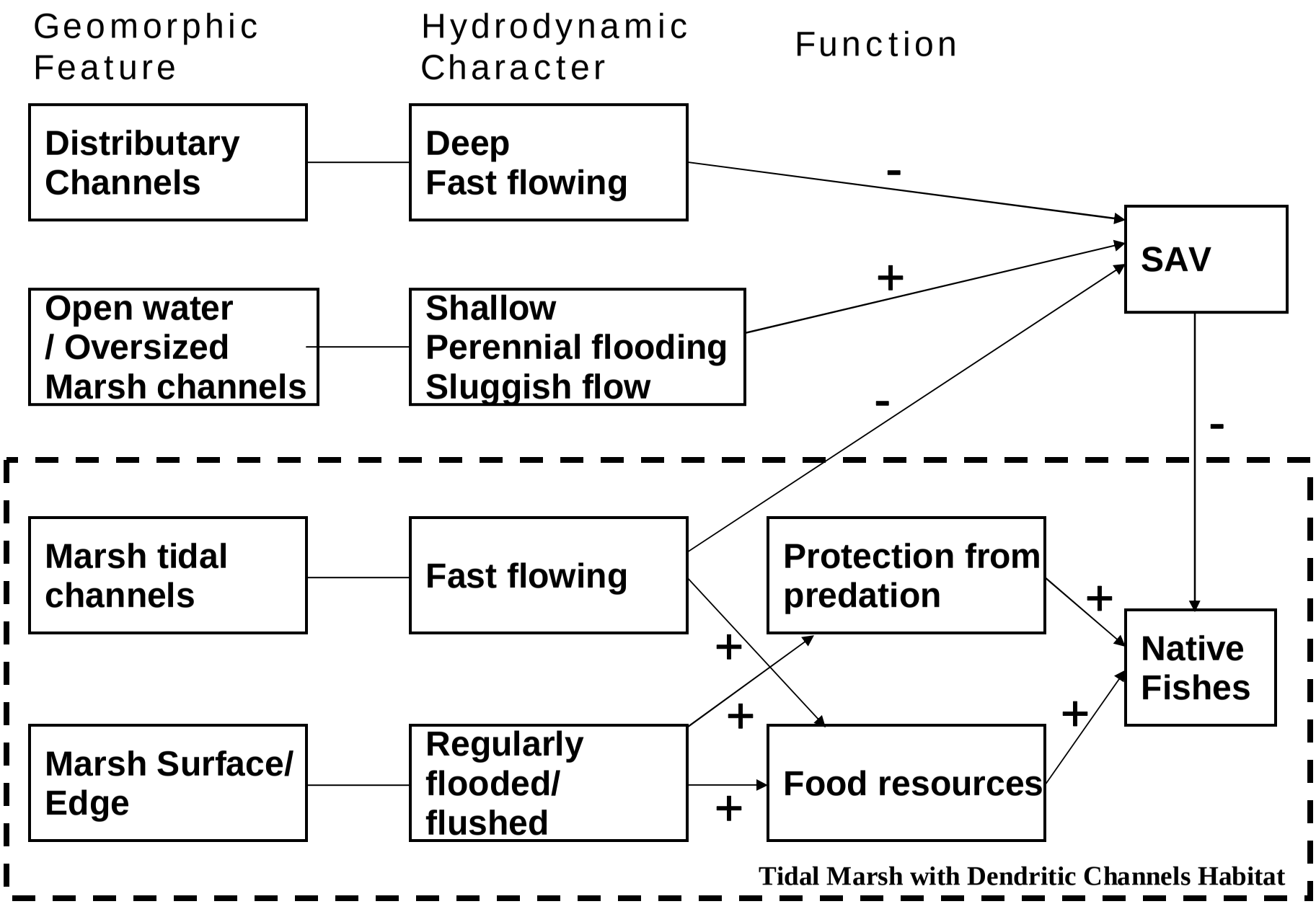
In particular monitoring must evaluate what the fish are eating;where the food came from (local or imported);and,the base of the food source (e.g.,epiphytes vs.benthic microalgae vs.phytoplankton).Such measures will be essential to determine the causal mechanisms behind the functional performance of the habitat for fish and ultimately what attributes of the habitat should be replicated in other habitat designs.

The detailed design of the monitoring plan should be undertaken by a monitoring team, including (at a minimum)an ecologist,engineer,and agency resource manager.The team would provide advice on monitoring and help with “adaptive modifications ” of the monitoring program,as well as the restoration project itself.The team would also ensure monitoring is coordinated with other monitoring programs (in terms of procedures and protocols,timing),would take advantage of existing monitoring programs and data,and would be responsible for integrated reporting,analysis,and interpretation of data, ensuring a long-term commitment to monitoring.The team would also be responsible for communicating the results and interpretations to the CALFED,other scientists,and other interested entities.

Given the limited existing monitoring of tidal marsh habitats in the Delta,it may be necessary for the team to design an extra-intensive (high frequency)preliminary study to determine the appropriate time and space scales for sampling.Similarly,it might plan for periodic revisiting of extra-intensive sampling to evaluate the “evolution ” of the marsh system over time (such as prior to the 5-year post-implementation evaluation).The identification of appropriate reference sites or sampling stations (e.g.,to document non-project related changes in fish and/or SAV)should also be considered by the team in the context of existing monitoring programs.

It is essential that the monitoring program be integrated to link landscape changes and biological response (recognizing that the physical evolution of the landscape and the biology of the marsh go hand in hand)and that data be collected to address Hypotheses 1, 2 and 3 which specifically address these linkages.New technologies should also be considered that allow identification of critical system responses,such as aerial

surveillance with multi-spectral sensing to detect biological responses (e.g.,vegetation composition and landscape structure)to physical changes on a variety of scales,and "biomarkers " for determining carbon sources and pathways..
Results from the monitoring program should be reported annually and biennially a synthesis report should be produced,tracking project performance over time and testing the hypotheses posed here.In addition,presentations to the Bay-Delta restoration community and publication in peer-reviewed journals should be employed to inform restoration practitioners and managers.The ultimate goal should be to systematically reduce the uncertainties associated with the value of dendritic tidal marsh restoration in the Delta for at-risk native fishes.



Conceptual Model for Benefits to Native Fishes (Delta Habitats Group 2002)

APPENDIX F

Geotechnical Assessment

F-1. Geotechnical Assessment of Seepage and Levees

F-2. Peat Settlement Calculations

APPENDIX F-1

Geotechnical Assessment of Seepage and Levees

GEOTECHNICAL CONSULTATION

SEEPAGE AND LEVEES
DUTCH SLOUGH TIDAL MARSH RESTORATION
OAKLEY, CALIFORNIA

Project No. 608.01
August 17, 2005

Prepared by

Hultgren – Tillis Engineers

A California Corporation
Specializing in Geotechnical Engineering

Hultgren-Tillis Engineers

GEOTECHNICAL CONSULTATION

SEEPAGE AND LEVEES
DUTCH SLOUGH TIDAL MARSH RESTORATION
OAKLEY, CALIFORNIA

Project No. 608.01
August 17, 2005

2221 Commerce Avenue, Suite A-1 • Concord, California 94520-4987
Phone (925) 685-6300 • Fax (925) 685-6768

A California Corporation
Specializing in Geotechnical Engineering

Hultgren-Tillis Engineers

August 17, 2005
Project No. 608.01

Philip Williams & Associates
720 California Street, Suite 600
San Francisco, California 94108-2404

Attention: Ms. Michelle Orr

Geotechnical Consultation
Seepage and Levees
Dutch Slough Tidal Marsh Restoration
Oakley, California

Ladies and Gentlemen:

This report presents our geotechnical engineering assessment of seepage potential from the planned Dutch Slough Tidal Marsh Restoration. We also present conceptual criteria for new flood control levees.

If you have any questions, please call.

Sincerely,

Hultgren – Tillis Engineers

Edwin M. Hultgren
Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
EDWIN M. HULTGREN
No. 426
Exp: 12/31/05
GEOTECHNICAL
STATE OF CALIFORNIA

EMH:HDD:RC:la

3 copies submitted

File No. 60801R01-v3

2221 Commerce Avenue, Suite A-1 • Concord, California 94520-4987
Phone (925) 685-6300 • Fax (925) 685-6768

TABLE OF CONTENTS

Page

I. INTRODUCTION 1

II. SITE CONDITIONS 2
- A. Existing Data 2
- B. Subsurface Soil Conditions 2
- C. Groundwater 3

III. SEEPAGE 4
- A. Seepage Impacts 4
- B. Mitigation Measures 4
- C. Typical Conditions 6
- D. Groundwater Monitoring Program 9

IV. NEW LEVEES 10
- A. In-Kind Replacement Section 10
- B. Upgrade from "In-Kind" Levee to FEMA Urban Levee 11
- C. FEMA Urban Levee 12
- D. Seepage Ditches 12
- E. Seismic Considerations 12

REFERENCES

PLATES

Plate 1 Vicinity Map

Plate 2 Site Plan

Plates 3 through 9 Cross-Sections 1 through 7

Plate 10 In-Kind Replacement Levee Section

Plate 11 In-Kind Levee Upgraded to FEMA Urban Criteria

Plate 12 Urban Levee Section

I. INTRODUCTION

This report discusses the future construction of new levee embankments and potential seepage impacts for the planned Dutch Slough project. The Dutch Slough project is located near Oakley, California and is bounded on the north by Dutch Slough and Big Break, on the east by Jersey Island Road, on the south by Contra Costa Canal, and on the west by Marsh Creek. Two existing inlets extend south from Dutch Slough, dividing the property into three segments. The western segment is the former Emerson property, the middle segment is the former Gilbert property, and the eastern segment is the former Burroughs property. The Vicinity Map and Site Plan are presented on Plates 1 and 2, respectively.

Most of the site is below normal tide levels in the adjacent Dutch Slough. The land is protected by a series of levees. The Dutch Slough project consists of restoring much of the property to tidal waters and providing enhanced habitat. This will be done by flooding the restoration area. Flood control levees will be required to protect the adjacent areas from tidal action. A new flood control levee will be needed along the eastern property, parallel with Jersey Island Road. This levee would become part of Reclamation District Number 799 (R.D. 799) to the east, commonly referred to as Hotchkiss Tract. A flood control levee or portions of a flood control levee may be needed along the south boundary of the site. Contra Costa Canal abuts the south portion of the site and is of sufficient height to not overtop from tidal action. However, the embankment is not on the Dutch Slough property. A new levee may be needed along the south side of the project. We understand that the project is considering future discussions with the canal owners to incorporate the canal embankment into the perimeter levee system.

Restoring the Dutch Slough project site to tidal waters will alter the groundwater conditions in and around the project. Seepage will likely occur laterally through an underlying continuous aquifer from the project site to adjoining properties. The primary considerations for the levees and seepage are discussed in this report.

II. SITE CONDITIONS

A. Existing Data

The topographic, geotechnical and hydrogeologic data reviewed for this report was supplied from various sources, which are listed in the References section at the end of the report. Each reference was assigned a unique number. The Site Plan (Plate 2) shows the approximate locations of the geotechnical data that were used. Each location is marked with the number of the Reference.

B. Subsurface Soil Conditions

Sand lies beneath essentially the entire Dutch Slough property and extends laterally in all directions onto adjacent properties. The sand is derived from glacier outwash from the Sierra Nevada Range, washed downstream into the western portions of the Delta and then redistributed as windblown dune deposits. The top of the sand varies from about Elevations +2 to -16 feet[1]. Few borings in the area penetrate the full thickness of the sand aquifer. The available data suggests the base of the sand is between Elevation –30 and –50 feet. The sand is underlain by flood plain deposits consisting of silts and clays. Deeper sand units underlie the silts and clays. The lateral continuity of the silt and clay aquitard is not known.

At the south end of the Dutch Slough project area, the sands are overlain by silts and clays, probably derived as flood plain deposits from the Marsh Creek drainage. On the northern portion of the project, the sand is overlain by peat and/or organic silt. These materials were deposited during the last few thousand years as the sea level slowly rose during the Holocene glacier retreat and warming of the earth that has been continuing for the last 11,000 years. Prior to land reclamation that occurred about 100 years ago, the surface of the peat or organic silt was near Elevation +2 feet. As the groundwater was lowered within the project site to allow ranching and farming, the organic materials oxidized and to a lesser degree were eroded by wind. This disappearance (deflation) of the peat is complete in some areas, exposing the underlying sands. In other areas, up to 10 feet of peat remain beneath the interior of the site.

[1] All elevations in this report are based on NGVD 1929 datum.

C. Groundwater

Overall there is a regional landform gradient dipping to the north. Groundwater levels vary somewhat erratically around the site, suggesting local groundwater withdrawal and/or infiltration has a greater impact on groundwater than a possible regional groundwater flow across the Marsh Creek plain.

The existing levees around the Dutch Slough project have allowed the groundwater to be artificially lowered within the project site. Many adjacent levee-protected properties also have lower groundwater levels than existed prior to reclamation. The aquifer beneath the site is being recharged in part from the adjacent Dutch Slough and associated inlets. Contra Costa Canal passes immediately south of the property. The canal is an unlined channel and infiltration from the canal is locally recharging groundwater. Similarly, Marsh Creek may be acting as a recharge source.

III. SEEPAGE

A. Seepage Impacts

The existing groundwater elevation is estimated to be between Elevation +3 to -10 feet between the interior portions of the Dutch Slough properties. When the Dutch Slough project becomes tidal, the groundwater beneath the project site is expected to average near the mean tide elevation, about Elevation +1.5 feet NGVD. The groundwater level in the aquifer below the site will vary with the tides. Without control measures, groundwater will flow laterally through the aquifer from the project area outward to those adjacent properties where the average groundwater levels are lower in elevation. Seepage from beneath the restored Dutch Slough site will raise groundwater elevations beneath those adjacent properties.

In areas where the groundwater may be raised to near the ground surface, the higher groundwater levels can be a detriment to trees and grasses that need to have oxygen in their root zones. Agricultural yields on affected adjacent properties could be reduced. If there are operating septic tanks in the area, their leach fields could be affected by a rise in the groundwater levels.

Residential development is occurring and/or is under consideration for several adjacent properties. In areas where the site grades are raised to allow the homes to be constructed above the flood elevation in the adjacent sloughs, raising the groundwater to near mean tide elevation will generally not affect the individual structures. If the homes are to be at lower elevations, the potential for seepage impacts may become significant, including creating damp areas around the homes. Site specific assessments will be needed for residential projects constructed below the flood level in the adjacent sloughs.

Higher groundwater can adversely affect deeper utility trench excavations, such as for sewers. Higher groundwater can increase infiltration into sewers. More closely spaced sanitary sewer lift stations may be needed in higher groundwater areas.

B. Mitigation Measures

For many areas, seepage impacts may be small and not significant to on-going or planned uses of the adjacent properties. In other areas, it may be desirable to control seepage. There are two common approaches to controlling groundwater seepage. One is to

cut-off or control the groundwater using some form of barrier. The other is to collect the water using some form of a drain or sump.

1. Cut-Off Wall

A cut-off wall that is intended to stop groundwater flow from leaving the Dutch Slough site would need to fully penetrate the aquifer. The limited data suggests that a cut-off system would need to extend to about Elevation –30 feet and possibly as deep as –50 feet. A common approach for constructing deep cut-off walls is to excavate a slurry trench. A slurry trench cut-off wall is typically a three foot wide continuous trench that fully penetrates the aquifer. Most of the excavation would be below the groundwater. Without shoring, a trench would normally collapse below the water level. To prevent this, the trench is kept filled with a bentonite clay slurry. The density of the slurry is selected such that the weight of the fluid in the trench applies greater pressure to the walls of the trench than does the head of the groundwater. To make a permanent, low-permeability barrier, the trench is typically backfilled with the excavated materials that are mixed with added bentonite clay prior to placing in the excavation.

A slurry trench could be a viable method of controlling groundwater around most of the perimeter of the Dutch Slough project where seepage may be a concern. If there are areas where the existing groundwater flow is toward the project site, a cut-off may tend to backup the groundwater flow in these areas. Further site specific assessments of such areas would be needed if a slurry trench is considered in such areas. From the available data, we do not expect that such areas exist around the perimeter of the Dutch Slough project.

2. Collection Systems

The elevation of the groundwater leaving the site and entering a neighbor's property can be controlled by using a groundwater collection system to artificially lower the groundwater at or near the boundary between the two properties. This is commonly done by excavating ditches as is often seen at or near the toes of levees in the area. To be effective, the ditches need to extend through the peat and/or clay overburden and into the sand aquifer. The ditches will require routine maintenance, which would likely consist of annually cleaning growth and sediment from the ditch bottoms. The ditches need to connect to a site's drainage system so the water can be pumped into the adjacent slough.

Another groundwater collection scheme is to install a deep subdrain. Like the ditch, the subdrain would need to penetrate substantially into the aquifer to be effective.

If materials of higher permeability occur in the lower portions of the aquifer, the more simple schemes of partially penetrating ditches or partially penetrating subdrains may not be effective. For such areas, relief wells may be needed. Relief wells are drilled wells that fully penetrate the aquifer. They are typically not pumped but their discharge elevation is set below the top of the groundwater, allowing the water to flow up the relief well and discharge by artesian pressure. In effect, the wells are "relieving" the pressure and lowering the groundwater level. Relief wells would need to discharge into a pipe or ditch below the elevation of the normal groundwater level.

While it is possible to lower the groundwater by a series of individual pumped wells, individual pumped wells are generally not practical for a long term solution for a project which is not an income producing property and which would not generate the cash flow needed to fund the operation and maintenance of a pumping system. The preferred systems for controlling the groundwater around the project site will be systems that are primarily passive.

Among primarily passive systems, those requiring the least maintenance and routine service will be preferable. Some pumping may be unavoidable. Ditches, subdrain systems and relief well discharge pipes would need to discharge into a drainage system that would lift the water back up to its final discharge point. For most areas, this means over the levee and back into the adjacent sloughs. The "lift" may be accomplished by using the pumps for the existing drainage system. The existing drainage systems are usually sized for surface water runoff, flow rates that are much greater than those derived from seepage.

C. Typical Conditions

Seven cross-sections extending from the Dutch Slough project site to the adjoining properties are presented on Plates 3 through 9. The sections were prepared using topographic, soil and groundwater data from various sources listed in the References. The locations at the seven sections are shown on the Site Plan, Plate 2.

1. <u>Cross-Sections 1 through 3</u>

Cross-Sections 1, 2 and 3 extend from the Dutch Slough project site,

across Dutch Slough to Jersey Island. At each location, existing data infers that the sand aquifer may be continuous beneath the slough. Cone penetrometer tests made in the center of Dutch Slough for the PGE/PGT gas transmission line (Harding Lawson Associates, 1990) confirmed the presence of the sand beneath the slough at the pipeline crossing.

Seepage onto Jersey Island is currently dominated by infiltration from Dutch Slough. Infiltration from the Dutch Slough tidal marsh restoration will likely only create a small increase in seepage to Jersey Island. Seepage would be through the shallow aquifer as indicated by the bold arrows on Cross-Sections 1 through 3.

With the seepage impact expected to be small, the project may wish to monitor groundwater elevations to check whether, or to what extent, increased seepage is occurring. The installation of new ditches on Jersey Island, or deepening existing ditches, would likely provide control over increased seepage. Jersey Island is irrigated by Ironhouse Sanitary District effluent. Disposal of the seepage water may create an added load for Ironhouse Sanitary District on Jersey Island. We expect the added load may be very small.

A seepage cut-off could be considered. The more beneficial location for a cut-off wall for Jersey Island would be in the Jersey Island levee. Such a cut-off would control the more prominent seepage from Dutch Slough as well as the much more minor seepage from the restoration project.

2. <u>Cross-Section 4</u>

The existing ground on the Dutch Slough project site at Cross-Section 4 is approximately Elevation +5 feet. This is above the mean high tide level. Existing groundwater elevations beneath the Ironhouse Sanitary District property to the west are generally near the mean tide level. This suggests that restoring the Dutch Slough project site to tidal will have little impact on the Ironhouse property under most conditions. Flooding the Dutch Slough project site will likely increase the amplitude of tidally driven variations in groundwater levels beneath adjacent properties, such as the Ironhouse property to the west. For brief intervals of time, commonly a few days, net seepage increases are expected from higher river stages resulting from flood flows or atmospheric low-pressure-induced tidal surges. The Ironhouse property is being managed to reuse treated effluent for irrigation. As such, the acreage is already fully committed to receive the effluent waters. Adding water load from

groundwater seepage would likely be undesirable for Ironhouse Sanitary District, though the quantities may be small relative to their irrigation capacity. The existing Marsh Creek Channel is likely creating a partial recharge and drainage boundary condition between the Ironhouse property and the Dutch Slough project site.

3. Cross-Sections 5 and 6

Cross-Sections 5 and 6 extend across the Contra Costa Canal to the planned residential properties to the south. Several groundwater monitoring wells are located in this area. For this set of data, groundwater levels range from slightly above mean tide elevation to about 4 feet below. This implies that in some areas the groundwater gradient between the Dutch Slough project site to the adjoining properties will be small and that it will likely be reverse direction over the diurnal tide cycle. In other areas, seepage from the restored Dutch Slough project site will raise groundwater several feet to near mean tide level. Housing developments are underway to the south of the project with additional projects planned to the south and east. Higher groundwater levels could affect dampness around buildings as well as success of various types of landscaping. This will be a particular concern if the houses are constructed below the flood elevation in Dutch Slough.

As discussed for Cross-Section 4 above, daily variations may increase in amplitude and net seepage may increase during floods and tide surges. Increased amplitudes of daily groundwater elevations and increased net seepage could affect the quality of the water in the adjacent Contra Costa Canal. During periods when the canal is drawn down for maintenance, in-flow of groundwater into the canal may result in sloughing of the lower portions of the canal slope and increased maintenance of the canal. We understand that Contra Costa Water District (CCWD) is considering replacing this segment of their canal with an enclosed pipe. The pipe would isolate the CCWD water from adjacent groundwater.

A ditch extending into the aquifer south of a new south boundary levee could be used to control seepage. Cross-Sections 5 and 6 suggest that a ditch would have to be about 20 feet deep to intercept the aquifer below about Elevation -15 feet. Relief wells may be more practical for these conditions. A cut-off wall (slurry trench) may also be considered for Cross-Sections 5 and 6.

4. Cross-Section 7

Cross-Section 7 crosses beneath the planned levee relocation for R.D. 799 and beneath Jersey Island Road. No groundwater data was available in this area. The ground surface is near Elevation –5 feet in a few areas. In these areas, we assume the groundwater may be a few feet below the ground surface. This is the portion of the project perimeter where the future flow gradients are likely the greatest. Seepage will occur from the tidally controlled project site toward the low ground area across Jersey Island Road. A drainage ditch will be installed beyond the toe of the relocated R.D. 799 levee as part of the levee relocation. This ditch can be used to control groundwater levels. A cut-off trench through the aquifer would be the best measure for controlling groundwater seepage from the project site.

The groundwater elevations may vary along the length of Jersey Island Road. There may be areas of peat remaining. The groundwater may need to be controlled to a lower elevation in one segment than currently exists in an adjacent segment overlain with peat. Lowering the groundwater in the peat area below existing conditions may cause consolidation of the peat and may accelerate peat deflation. Both consolidation and deflation can lead to additional or accelerated ground surface subsidence. A more detailed evaluation of this area will be needed for preliminary design.

D. Groundwater Monitoring Program

Groundwater data is limited around the project site. A well planned groundwater level investigation and monitoring program will be needed for project design and implementation. Continuous monitoring of groundwater elevations using automated data loggers will be needed for at least one full year prior to project implementation. The monitoring wells will need to be located such that monitoring can continue after the site becomes tidal. The preferred monitoring locations will be on adjacent properties to verify that seepage is not affecting the property or to indicate that expanded measures are needed to control seepage.

IV. NEW LEVEES

A new levee will be needed along the east boundary of the Dutch Slough project. The proposed east levee will become a realignment of the existing R.D. 799 levee. The existing R.D. 799 levee currently is on the east side of the inlet that separates the former Gilbert parcel and the former Burroughs parcel. We understand the R.D. 799 levee will be relocated along the east side of the Dutch Slough property, immediately west of Jersey Island Road. If the existing canal embankment along the south boundary of the Dutch Slough project cannot be incorporated into the perimter levee system, a new levee may be needed adjacent to the Contra Costa Canal.

Our task was to develop preliminary criteria for a levee that would be an “in-kind” replacement of the existing R.D. 799 levee, one that would provide the same level of protection as the existing levee it is replacing. We have added to that task a scenario in which the levee, once constructed, is upgraded to a FEMA Urban Levee. We also offer a preliminary design concept for constructing the levee as a FEMA Urban Levee from the start.

We reviewed the existing levee configurations for the section of levee that will be replaced. The Reclamation District Engineer for R.D. 799, Burns Engineering, provided us with cross-section surveys (Kjeldsen-Sinnock & Associates 1992) and a more recent crest elevation survey (Kjeldsen Sinnock Neudeck, Inc., 2000). In their 1992 survey report, Kjeldsen-Sinnock & Associates compared the as-built cross-section surveys to “the minimum standards for local districts for short term levee rehabilitation under the FEMA Hazard Mitigation Plan”. On the 1992 cross-section surveys, we observed that the design template for the FEMA Hazard Mitigation Plan fit within the surveyed cross-sections. The template included a minimum crown elevation of 8 feet, a minimum crown width of 16 feet, a waterside slope of 1.5:1 (horizontal:vertical) or flatter and a landside slope of 2:1 or flatter. The more recent levee crest elevation data from 2000 indicates that, in general, the levee crest is at Elevation +9 or higher.

A. In-Kind Replacement Section

For purposes of developing a replacement flood control levee that generally matches the configuration of the existing levee, we assumed a crest elevation of +9 feet, a minimum crest width of 16 feet, a waterside slope of 2:1, and a landside slope of 3:1. A typical In-Kind Replacement Section is shown on Plate 10.

The 2:1 waterside slope assumes that the ground will be raised on the waterside of the levee for habitat. If the levee slope is in contact with water during flood events, it should be covered by riprap.

The new levee would be constructed of lean clay. Considerable clay deposits are indicated in the borings on the southern portion of the Dutch Slough site. Borrow areas in these clay zones can be used to create deeper water areas within the final restoration master plan. Portions of the planned eastern levee alignment may be underlain by peat, most notably the northern extremity of this alignment, near Dutch Slough. The alignment to the south is not expected to encounter weak marsh deposits. Peat will need to be excavated from beneath the planned levee alignment exposing the underlying sand or stiff clay soils. The site preparation will extend beyond the toe of the levee to accommodate future buttressing and raising the levee to create a FEMA Urban Levee.

At the far north end of the eastern levee, the new levee will abut into the existing flood control levee along Dutch Slough. This levee is underlain by peat in many areas. It would be most desirable to select a connection location where the peat thickness is minimal. Regardless, we anticipate that some peat will likely exist under the existing flood control levee along Dutch Slough and that the new connection will need to be designed to account for the peat in the new levee's design cross-section. A transition section of the new levee near its connection with the existing Dutch Slough levee will likely have wide berms to maintain stability of the new section and to aid in controlling levee settlement induced by lateral creep. Where the new levee abuts into Dutch Slough differential settlement will result from the weight of the new embankment being placed adjacent to the existing levee. A core will need to be installed into this segment of the existing levee to minimize the risk of piping due to cracking that may be caused by differential settlement.

B. Upgrade from "In-Kind" Levee to FEMA Urban Levee

The levee described in the preceding paragraphs may need to be upgraded in the future to a FEMA Urban Levee, which includes a minimum crest elevation at least 3 feet above the base flood elevation. For the purpose of this report, we have assumed that the reclamation district would want to include an internal drain in the levee and increase the crest width to about 22 feet. We have further assumed that the final landside slope would be inclined

at 4:1 to provide coverage for the internal drain that would be added to the initially constructed "In-Kind" levee. This configuration is shown on Plate 11.

C. FEMA Urban Levee

If the initial levee reconstruction is to be a FEMA Urban Levee, we suggest that the typical levee cross-section may be similar to that shown on Plate 12. Internal drains shown on Plates 11 and 12 are not requirements for FEMA flood protection. However, most flood protection levees are uplands levees that are designed to retain intermittent floods. Upland levees typically can be maintained during the non-flood seasons. In the Delta, the waterside of the levee is constantly retaining water and maintenance of the levees is more difficult than in upland levee situations. We have included an internal drain as a seepage control measure to reduce the risk of internal erosion (piping) through the embankment for a new urban levee for R.D. 799.

D. Seepage Ditches

Seepage ditches would be located beyond the outside toes of the new and existing levees around the Dutch Slough restoration area. The purpose of the seepage ditch is to pull the water level down beneath the levee toe to reduce the risk of seepage exiting the face of the levee. The seepage ditch can also aid in controlling the groundwater level beyond the project.

E. Seismic Considerations

Portions of the sand subgrade may be at risk of liquefying during a large earthquake. Exposed subgrade may need to be densified prior to constructing the embankment. Site densification treatment will need to extend beyond the levee footprint to allow for a potentially widened levee for a FEMA Urban Levee design. Deep dynamic compaction will likely be a viable method of providing subgrade densification.

REFERENCES

References

1. Balance Hydrologics, Inc. 2003. Hydrologic and Hydraulic Analyses, Cypress Grove Project, City of Oakley, California. February 2003.

2. GeoSyntc Consultants, Inc. 2000. "Final Geotechnical Engineering Report, Intake Channel Levees, Contra Costa Canal, Oakley, California". June 15, 2000.

3. G.S. Dodson & Associates. 2000. "Ironhouse Sanitary district, Monitoring Well Installation Report. October 2000.

4. Green Mountain Engineering. 2004. "Reclamation District 2137 Levee Survey 2004. October 21, 2004.

5. Harding Lawson Associates. 1990. "Soil Investigation and Testing, River Crossings, PGT-PG&E Pipeline Expansion Project, Sacramento River Delta, Subcontract No. 20822-SC-06". October 1990.

6. Hultgren – Tillis Engineers. 2003. "Geotechnical Investigation, Landslide Repairs, Marsh Creek Levees, Contra Costa County, California". March 31, 2003.

7. Hultgren – Tillis Engineers. 2003. "Geotechnical Investigation, Triple Decker Project, Jersey Island, Contra Costa County, California". July 30, 2003.

8. Hydrofocus, Inc. 2003. "Beneficial Use Impact Study, Well Construction Report, Ironhouse Sanitary District, Wastewater Treatment Facility, Contra Costa County". June 26, 2003.

9. Kaldveer Associates. 1991. "PGT - PG&E Pipeline Expansion Project, Subcontract No. 20822-SC-06A, Sacramento/San Joaquin River, Delta, California". September 1991.

10. Kjeldsen-Sinnock & Associates, Inc. 1992. "Reclamation District No. 799, Hotchkiss Tract, Levee Cross Section, Profile and Sounding Survey". April 1992.

11. Kjeldsen Sinnock Neudeck, Inc. 2000. "Reclamation District No. 799, Hotchkiss Tract Profile As-Built Survey, Contra Costa County, California". November 2000.

12. Kleinfelder, Inc. 2000. "Preliminary Geotechnical Investigation Report, Proposed 60-Acre Subdivision, East Cypress Road, Oakley, California". April 7, 2000.

13. Kleinfelder, Inc. 2003. "Responses to Select Draft, Environmental Impact Report Comments, Cypress Grove Project, Oakley, California. August 28, 2003.

14. Luhdorff & Scalmanini Consulting Engineers. 2004. Dutch Slough Restoration Site, Shallow Ground-Water Monitoring Network". June 2004.

15. Milani & Associates. 2005. "Jersey Island Cross Sections". March 2005.

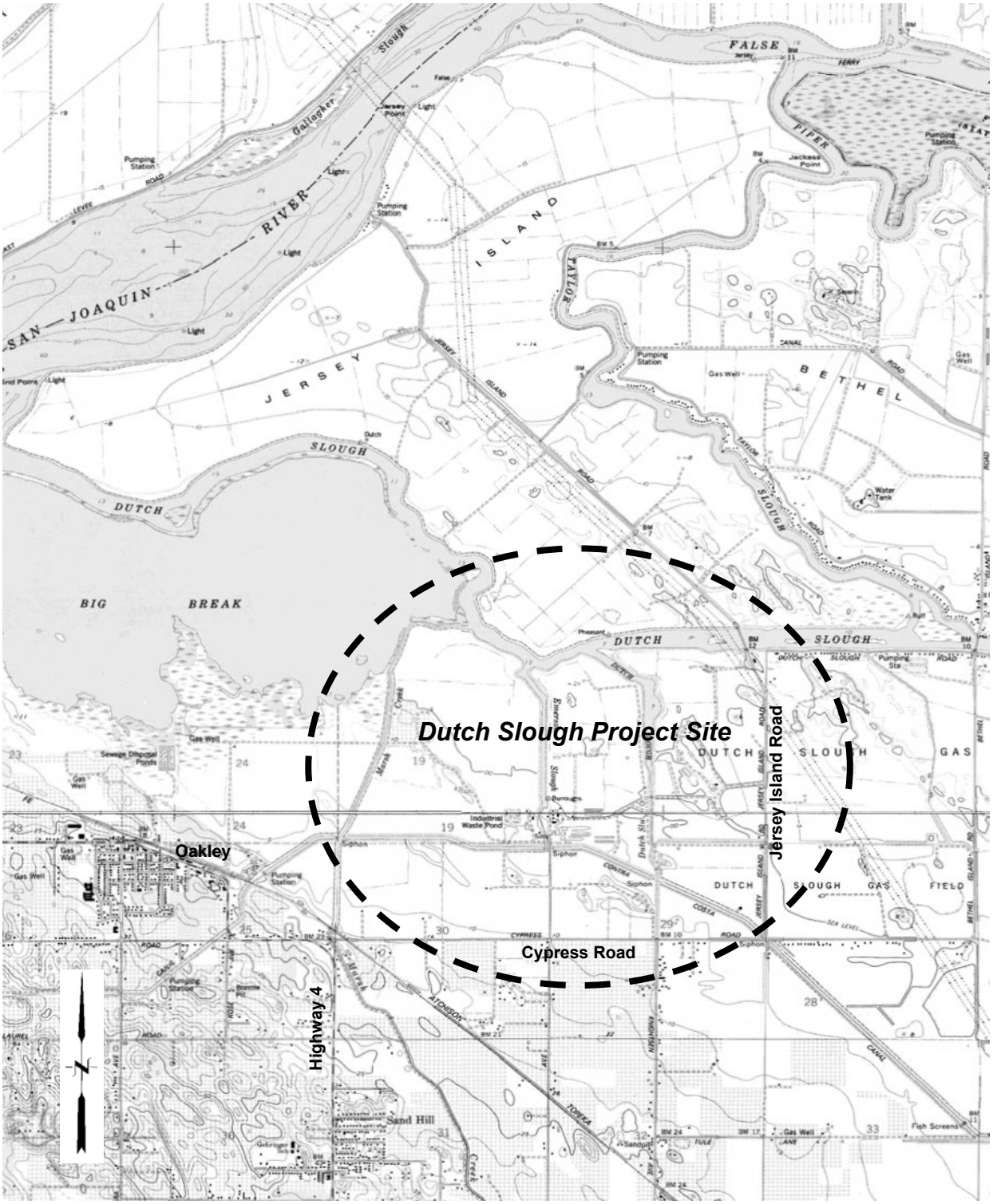
16. Neil O. Anderson and Associates. 1996. "Contra Costa Intake Canal Levee Failure, Pumping Plant #1, Oakley, California". December 24, 1996.

17. Raney Geotechnical. 1996. “Geotechnical Consulting, Ironhouse Sanitary District, Effluent Discharge Pipe Alignment, Sta 0+00 through 47+00, Contra Costa, California”. December 17, 1996.

18. Roger Foott Associates, Inc. 1994. “Geotechnical Evaluation, Hotchkiss Tract Levees”. September 1994.

19. Ronald Greenwell and Associates, Inc. 2000. “Topographic Survey Map of Ironhouse/ Marsh Creek, Contra Costa County for Natural Heritage Institute”. September 2000.

PLATES

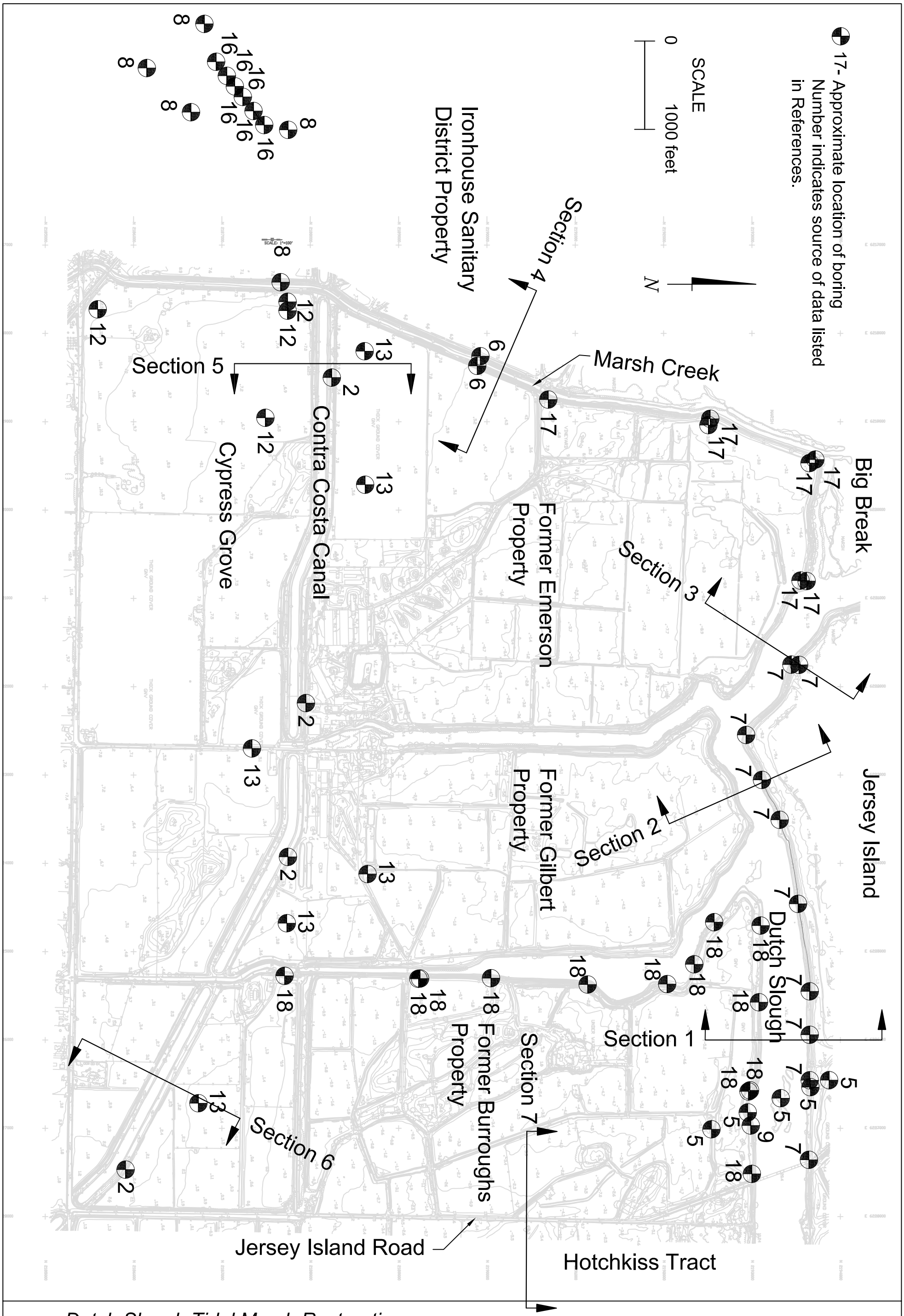


Not to Scale

Dutch Slough Tidal Marsh Restoration
Oakley, California

Vicinity Map

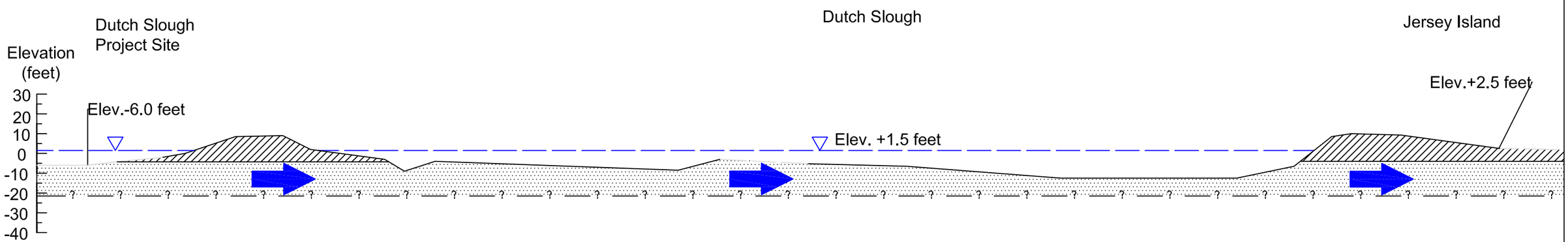
Hultgren - Tillis Engineers	Project No. 608.01	Plate No. 1



Dutch Slough Tidal Marsh Restoration
Oakley, California

Site Plan

Hultgren - Tillis Engineers	Project No. 608.01	Plate No. 2



Groundwater flow from Dutch Slough project to adjacent property

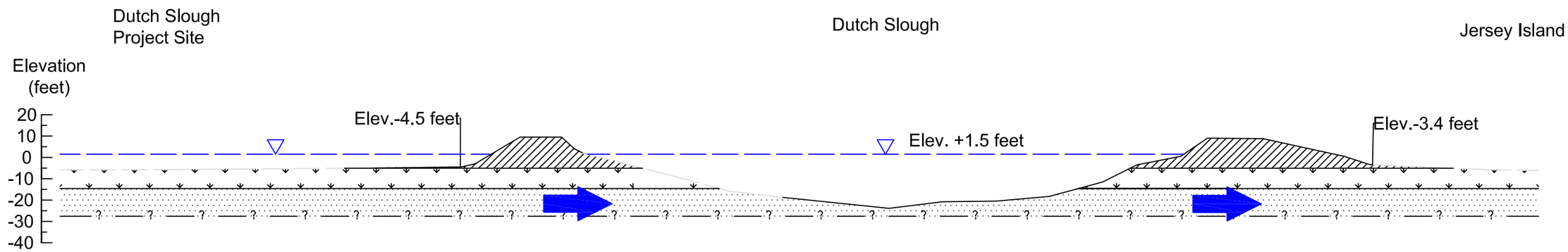
Clay / Silt

Sand

Note:
Ground surface shown as dark line where existing cross-section information is available.
Light line is used for inferred ground surface.

Scale: 1" = 50 '

Dutch Slough Tidal Marsh Restoration *Oakley, California*	**Cross-Section 1**	
Hultgren-Tillis Engineers	Project No. 608.01	Plate No. 3



Groundwater flow from Dutch Slough project to adjacent property

Clay / Silt

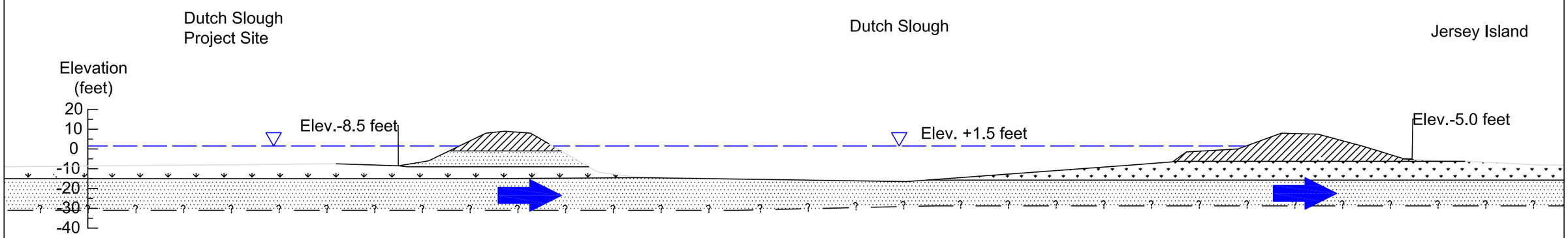
Peat / Organic silt

Sand

Note:
Ground surface shown as dark line where existing cross-section information is available.
Light line is used for inferred ground surface.

Scale: 1" = 50 '

Dutch Slough Tidal Marsh Restoration *Oakley, California*	**Cross-Section** 2	
Hultgren-Tillis Engineers	Project No. 608.01	Plate No. 4



Groundwater flow from Dutch Slough project to adjacent property

Clay / Silt

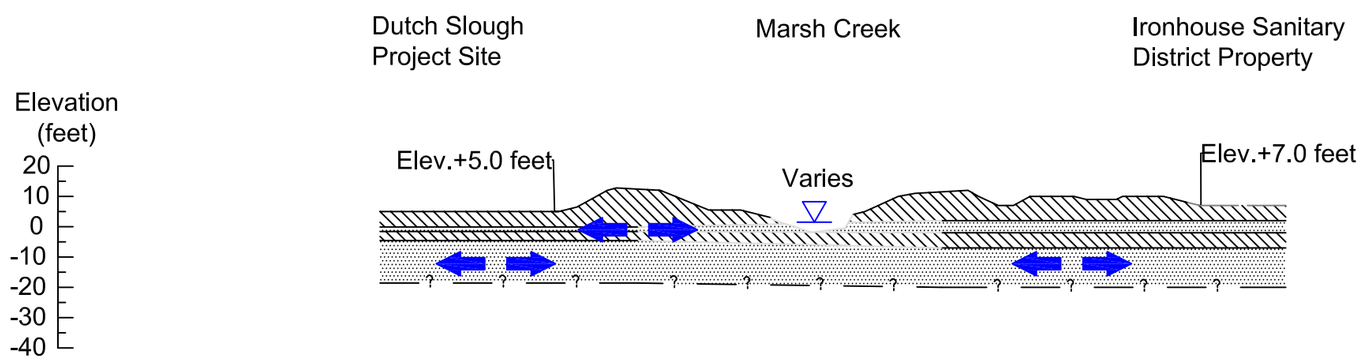
Peat / Organic silt

Sand

Note:
Ground surface shown as dark line where existing cross-section information is available.
Light line is used for inferred ground surface.

Scale: 1" = 50 '

Dutch Slough Tidal Marsh Restoration *Oakley, California*	**Cross-Section** 3	
Hultgren-Tillis Engineers	Project No. 608.01	Plate No. 5



Seepage gradient toward creek and Ironhouse Property may be intermittent and may reverse

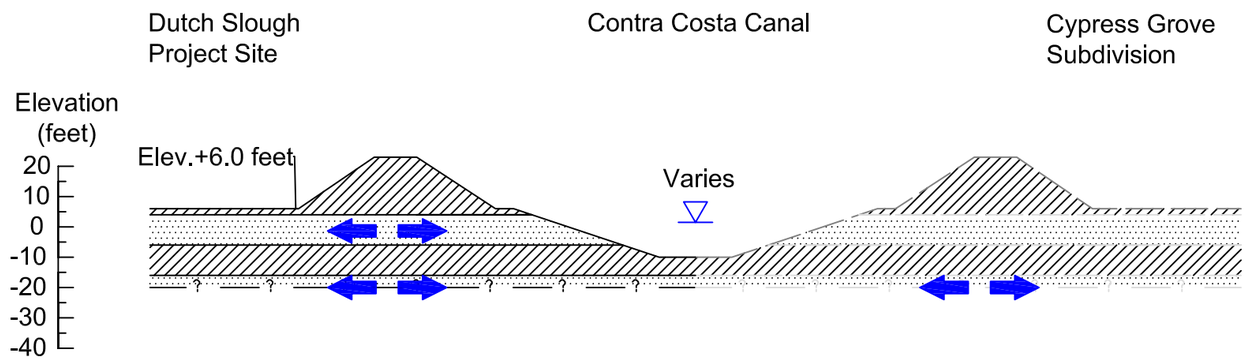
Clay / Silt

Sand

Note:
Ground surface shown as dark line where existing cross-section information is available.
Light line is used for inferred ground surface.

Scale: 1" = 50 '

Dutch Slough Tidal Marsh Restoration *Oakley, California*	**Cross-Section** 4	
Hultgren-Tillis Engineers	Project No. 608.01	Plate No. 6



Seepage gradient toward canal and adjacent property may be intermittent and may reverse

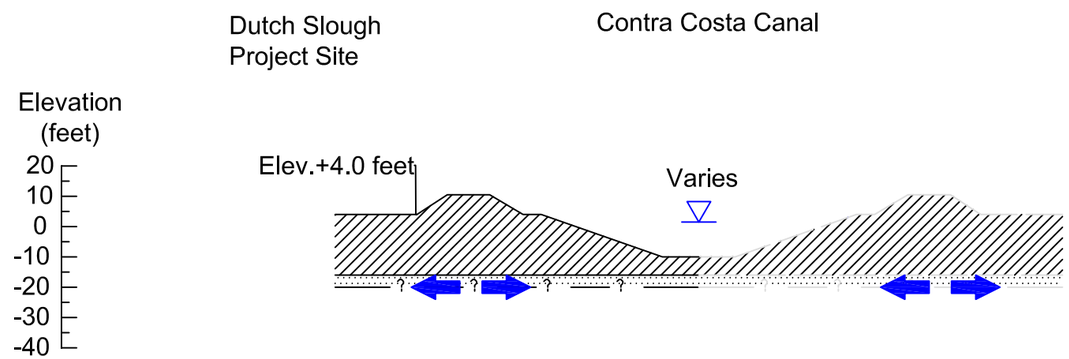
Clay / Silt

Sand

Note:
Ground surface shown as dark line where existing cross-section information is available.
Light line is used for inferred ground surface.

Scale: 1" = 50 '

Dutch Slough Tidal Marsh Restoration *Oakley, California*	**Cross-Section** 5	
Hultgren-Tillis Engineers	Project No. 608.01	Plate No. 7



Seepage gradient toward canal and adjacent property may be intermittent and may reverse

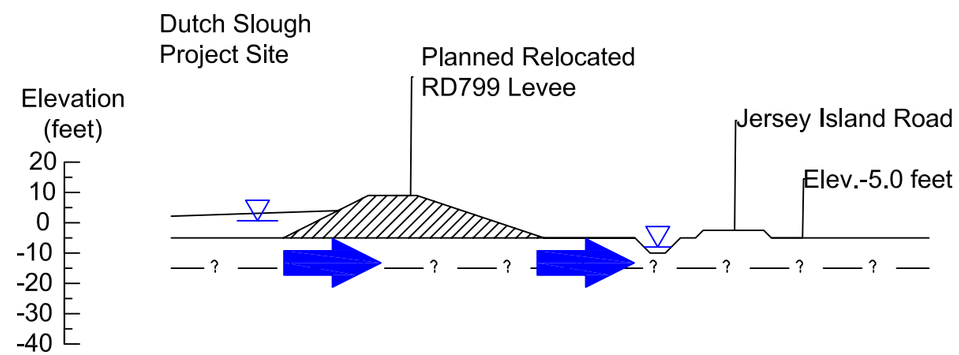
Clay / Silt

Sand

Note:
Ground surface shown as dark line where existing cross-section information is available.
Light line is used for inferred ground surface.

Scale: 1" = 50 '

Dutch Slough Tidal Marsh Restoration *Oakley, California*	**Cross-Section** 6	
Hultgren-Tillis Engineers	Project No. 608.01	Plate No. 8



Groundwater flow from Dutch Slough project to planned ditch

Clay / Silt

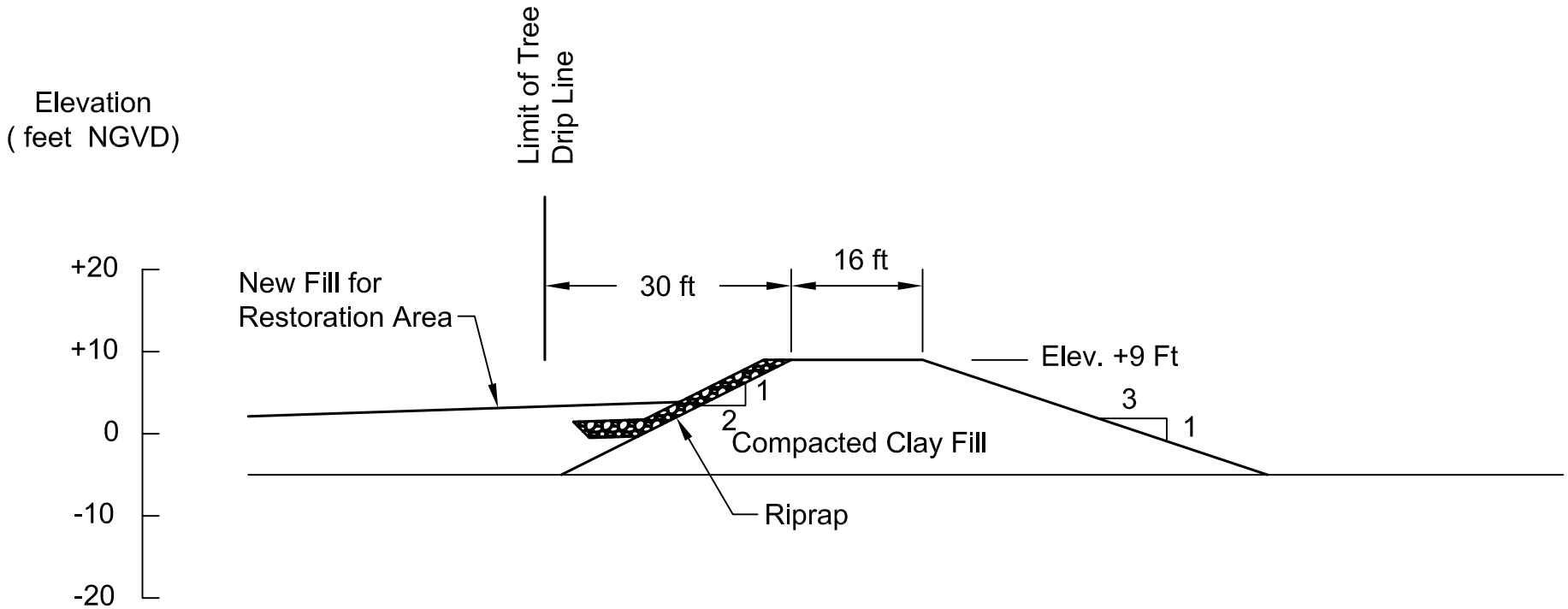
Sand

Note:
Ground surface shown as dark line where existing cross-section information is available.
Light line is used for inferred ground surface.

Scale: 1" = 50 '

Dutch Slough Tidal Marsh Restoration *Oakley, California*	**Cross-Section 7**	
Hultgren-Tillis Engineers	Project No. 608.01	Plate No. 9

In-Kind Replacement Levee Section



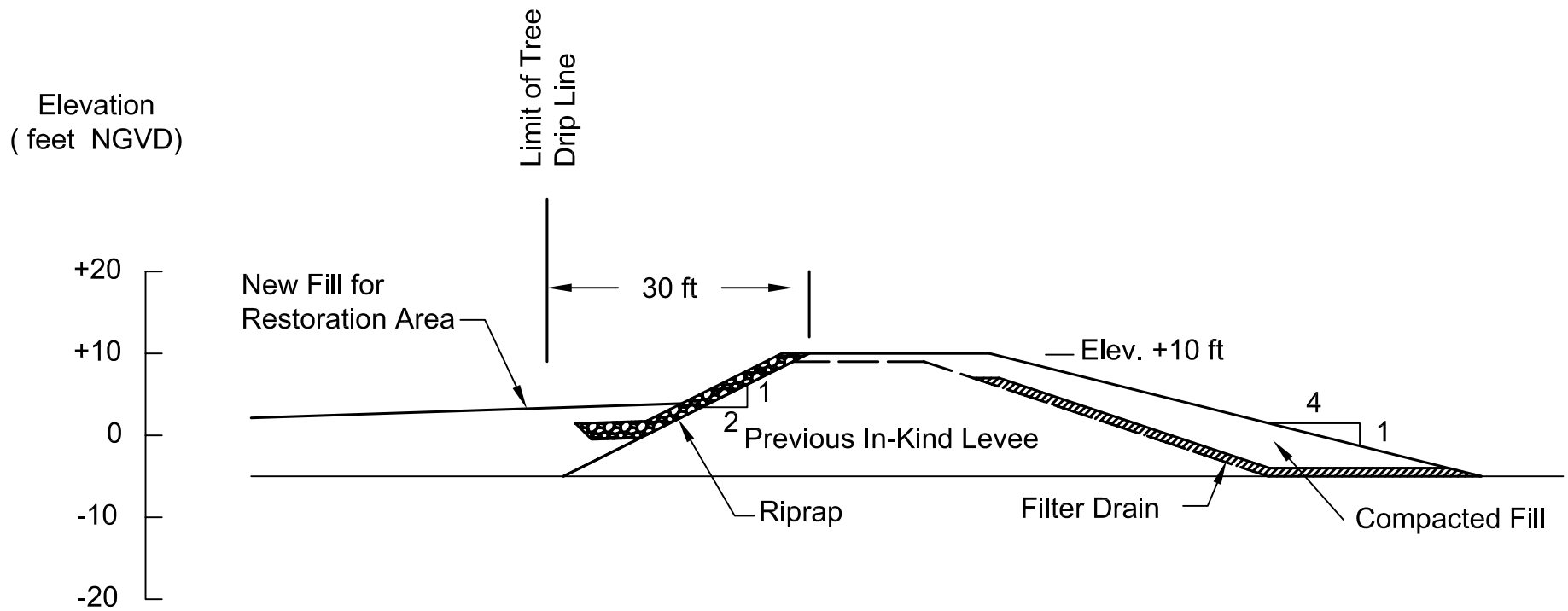
SCALE

0 20 feet

1 inch = 20 feet

Dutch Slough Tidal Marsh Restoration Oakley, California	In-Kind Replacement Levee Section	
Hultgren - Tillis Engineers	Project 608.01	Plate 10

In-Kind Levee Section Upgraded to FEMA Urban Criteria



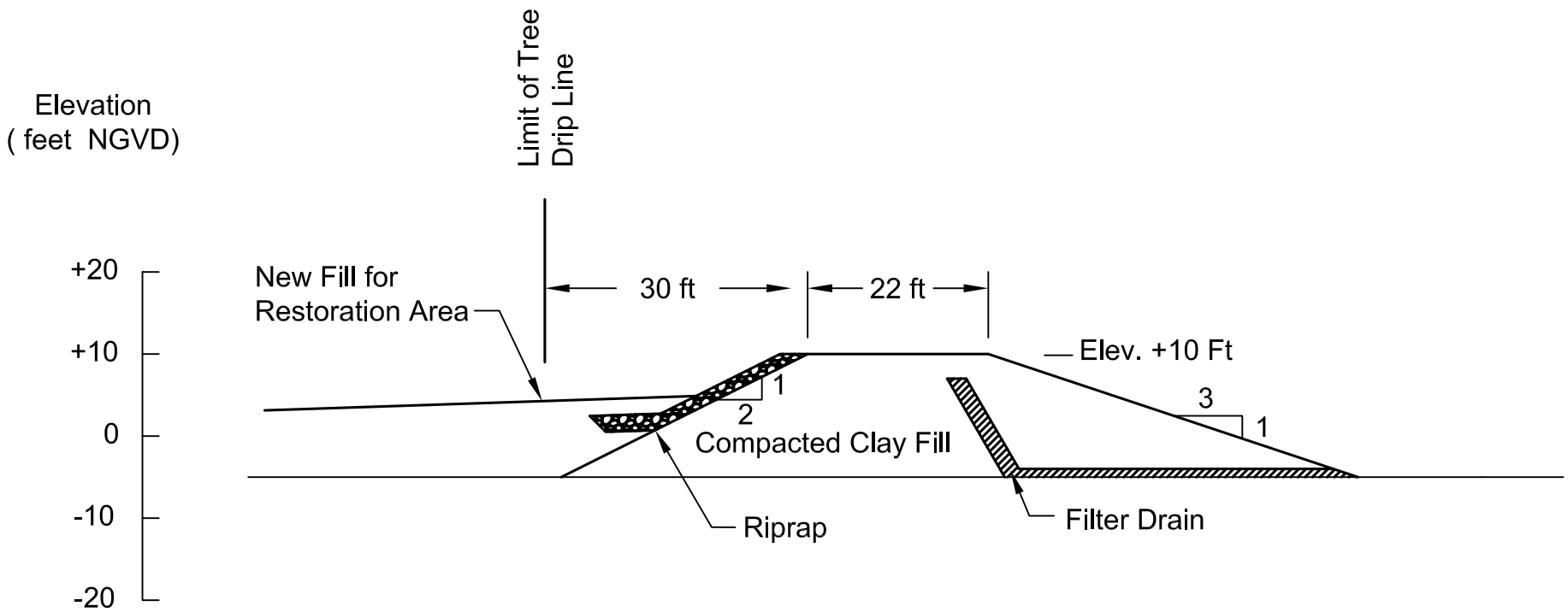
SCALE

0 20 feet

1 inch = 20 feet

Dutch Slough Tidal Marsh Restoration Oakley, California	In- Kind Levee Upgraded to FEMA Urban Criteria	
Hultgren - Tillis Engineers	Project 608.01	Plate 11

Urban Levee Section



SCALE

0 20 feet

1 inch = 20 feet

Dutch Slough Tidal Marsh Restoration Oakley, California	Urban Levee Section	
Hultgren - Tillis Engineers	Project 608.01	Plate 12

APPENDIX F-2

Peat Settlement Calculations

FORMULA FOR COMPUTING SETTLEMENT

1. Compute compression in each layer as follows:

$$\left(\text{Layer Compression}\right) = \left(\text{Layer Thickness}\right) * \left\{ \left(\text{Rebound Compression Ratio}\right) * \text{Log 10} \left(\frac{\left(\text{Preconsolidation Pressure}\right)}{\left(\text{Effective Overburden Pressure}\right)} \right) + \left(\text{Virgin Compression Ratio}\right) * \text{Log 10} \left(\frac{\left(\text{Final Pressure}\right)}{\left(\text{Preconsolidation Pressure}\right)} \right) \right\}$$

2. Sum compression for all layers to get estimate of consolidation settlement.

Top of Layer ft	Bottom of Layer ft	Middle of Layer ft	Thickness ft	Effective Overburden Pressure psf	Preconsolidation Pressure psf	New Pressure Load psf	Final Pressure psf	Rebound Compression Ratio -	Virgin Compression Ratio -	Vertical Strain -	Change in Thickness ft
-5	-6	-5.5	1	8	100	500	508	0.06	0.42	0.362	0.362
-6	-7	-6.5	1	24	118	500	524	0.06	0.42	0.313	0.313
-7	-8	-7.5	1	40	196	500	540	0.06	0.42	0.226	0.226
-8	-9	-8.5	1	56	274	500	556	0.06	0.42	0.170	0.170
-9	-10	-9.5	1	72	322	500	572	0.06	0.42	0.144	0.144
-10	-11	-10.5	1	88	338	500	588	0.06	0.42	0.136	0.136
-11	-12	-11.5	1	104	354	500	604	0.06	0.42	0.129	0.129
										Consolidation Settlement =	1.4 feet
Notes: (1)				(2)	(3) (4)	(5)	(6)				

Note 1 - Peat 7 feet thick
Note 2 - Existing effective overburden pressure assumes that when fill is placed, ground water level will quickly raise to original gound surface as water starts to squeeze out of the peat.
Note 3 - Preconsolidation pressure assumes that the groundwater has been drawn down 4 feet at some time in the past
Note 4 - A minimum preconsolidation pressure of 100 psf was assumed
Note 5 - New load is four feet of fill at 125 pcf (Elev -5 to -1 feet)
Note 6 - Final load assume that the fill load is above the water table and that the peat is below the water table.

Reference: Table 8 of "An Engineering Manual for Settlement Studies" by Duncan and Buchignani

Top of Layer	Bottom of Layer	Middle of Layer	Thickness	Effective Overburden Pressure	Preconsolidation Pressure	New Pressure Load	Final Pressure	Rebound Compression Ratio	Virgin Compression Ratio	Vertical Strain	Change in Thickness
ft	ft	ft	ft	psf	psf	psf	psf	-	-	-	ft
-5	-6	-5.5	1	8	100	500	508	0.06	0.42	0.362	0.362
-6	-7	-6.5	1	24	118	500	524	0.06	0.42	0.313	0.313
-7	-8	-7.5	1	40	196	500	540	0.06	0.42	0.226	0.226
-8	-9	-8.5	1	56	274	500	556	0.06	0.42	0.170	0.170
-9	-10	-9.5	1	72	322	500	572	0.06	0.42	0.144	0.144
-10	-11	-10.5	1	88	338	500	588	0.06	0.42	0.136	0.136
-11	-12	-11.5	1	104	354	500	604	0.06	0.42	0.129	0.129
-12	-13	-12.5	1	120	370	500	620	0.06	0.42	0.124	0.124
-13	-14	-13.5	1	136	386	500	636	0.06	0.42	0.118	0.118

Consolidation Settlement = 1.7 feet

Notes:

(1) (2) (3) (4) (5) (6)

Note 1 - Peat 9 feet thick
Note 2 - Existing effective overburden pressure assumes that when fill is placed, ground water level will quickly raise to original gound surface as water starts to squeeze out of the peat.
Note 3 - Preconsolidation pressure assumes that the groundwater has been drawn down 4 feet at some time in the past
Note 4 - A minimum preconsolidation pressure of 100 psf was assumed
Note 5 - New load is four feet of fill at 125 pcf (Elev -5 to -1 feet)
Note 6 - Final load assume that the fill load is above the water table and that the peat is below the water table.

Reference: Table 8 of "An Engineering Manual for Settlement Studies" by Duncan and Buchignani

Top of Layer	Bottom of Layer	Middle of Layer	Thickness	Effective Overburden Pressure	Preconsolidation Pressure	New Pressure Load	Final Pressure	Rebound Compression Ratio	Virgin Compression Ratio	Vertical Strain	Change in Thickness
ft	ft	ft	ft	psf	psf	psf	psf	-	-	-	ft
-7	-8	-7.5	1	8	100	750	758	0.06	0.42	0.435	0.435
-8	-9	-8.5	1	24	118	750	774	0.06	0.42	0.385	0.385
-9	-10	-9.5	1	40	196	750	790	0.06	0.42	0.296	0.296
-10	-11	-10.5	1	56	274	750	806	0.06	0.42	0.238	0.238
-11	-12	-11.5	1	72	290	750	822	0.06	0.42	0.226	0.226
-12	-13	-12.5	1	88	306	750	838	0.06	0.42	0.216	0.216
-13	-14	-13.5	1	104	322	750	854	0.06	0.42	0.207	0.207

Consolidation Settlement = 2 feet

Notes:

(1) (2) (3) (4) (5) (6)

Note 1 - Peat 7 feet thick
Note 2 - Existing effective overburden pressure assumes that when fill is placed, ground water level will quickly raise to original gound surface as water starts to squeeze out of the peat.
Note 3 - Preconsolidation pressure assumes that the groundwater has been drawn down 3.5 feet at some time in the past
Note 4 - A minimum preconsolidation pressure of 100 psf was assumed
Note 5 - New load is six feet of fill at 125 pcf (El;ev -7 to -1 feet)
Note 6 - Final load assume that the fill load is above the water table and that the peat is below the water table.

Reference: Table 8 of "An Engineering Manual for Settlement Studies" by Duncan and Buchignani

Top of Layer	Bottom of Layer	Middle of Layer	Thickness	Effective Overburden Pressure	Preconsolidation Pressure	New Pressure Load	Final Pressure	Rebound Compression Ratio	Virgin Compression Ratio	Vertical Strain	Change in Thickness
ft	ft	ft	ft	psf	psf	psf	psf	-	-	-	ft
-9	-10	-9.5	1	8	100	1000	1008	0.06	0.42	0.487	0.487
-10	-11	-10.5	1	24	118	1000	1024	0.06	0.42	0.436	0.436
-11	-12	-11.5	1	40	196	1000	1040	0.06	0.42	0.346	0.346
-12	-13	-12.5	1	56	243	1000	1056	0.06	0.42	0.306	0.306
-13	-14	-13.5	1	72	259	1000	1072	0.06	0.42	0.292	0.292

Consolidation Settlement = 1.8 feet

Notes:

(1) (2) (3) (4) (5) (6)

Note 1 - Peat 5 feet thick
Note 2 - Existing effective overburden pressure assumes that when fill is placed, ground water level will quickly raise to original gound surface as water starts to squeeze out of the peat.
Note 3 - Preconsolidation pressure assumes that the groundwater has been drawn down 3 feet at some time in the past
Note 4 - A minimum preconsolidation pressure of 100 psf was assumed
Note 5 - New load is eight feet of fill at 125 pcf (Elev -9 to -1 ft)
Note 6 - Final load assume that the fill load is above the water table and that the peat is below the water table.

Reference: Table 8 of "An Engineering Manual for Settlement Studies" by Duncan and Buchignani

APPENDIX G

Planting Methods and Costs

Appendix G. Planting Methods and Costs

The following planning-level cost estimates are for restoration planting site preparation (initial weed control, debris removal, and demolition), seed collection, contract nursery container plant costs, seeding and mulching, installation of container plantings, and installation of irrigation. The bioengineering cost estimates include materials and labor for installation and planting of structural treatments. These estimates do not include restoration planning, preparation of construction bid packages, CEQA/NEPA or permit acquisition, earthmoving, maintenance, monitoring, performance reporting, or remediation, if needed. Ranges for costs are given because restoration costs can vary greatly based on variable factors such as weather, inflation and labor costs (volunteer, non-union or union scale), access challenges, proximity of materials, availability of propagules, planting density and complexity, soil amendment needs, irrigation costs, transportation methods and costs, and installation or maintenance methodology.

Lower Tidal Marsh Vegetation

Methods

It is assumed that it will be unnecessary to plant any tules or bulrushes in the intertidal zones, that they could become established through natural recruitment using water management prior to introducing tidal flows. The fields would be flooded then drawn down (thus eliminating the potential for egeria invasion) periodically in cycles at a schedule that would favor tules and not favor cattails, phragmites, egeria or other undesirable invasive species. A limited amount of tule rhizomes will be planted on a large scale, possibly using farm equipment or volunteer labor, and will supplement natural recruitment. It is also assumed that bioengineering or shoreline stabilization measures will not be necessary because riprap will be maintained on the outboard side of levees facing Dutch Slough (with riparian plantings in between rocks) and that the inboard side of levees will be gradual slopes that would stabilized using volunteer recruitment of tules prior to introducing tidal flows as discussed above.

Costs

The costs associated with these measures include the installation of water control structures and the labor costs for operating those structures on a cyclical basis of flooding and draw down.

Upper Tidal Marsh Vegetation

Methods

It is assumed that it will be unnecessary to plant any tules or bulrushes in the intertidal zones, that they could become established through natural recruitment using water management prior to introducing tidal flows. The fields would be flooded then drawn down periodically in cycles at a schedule that would favor tules and not favor cattails, phragmites, egeria or other undesirable invasive species. A limited amount of tule rhizomes will be planted on a large scale, possibly using farm equipment or volunteer

labor, and will supplement natural recruitment. It is also assumed that bioengineering or shoreline stabilization measures will not be necessary because riprap will be maintained on the outboard side of levees facing Dutch Slough (with riparian plantings in between rocks) and that the inboard side of levees will be gradual slopes that would stabilized using volunteer recruitment of tules prior to introducing tidal flows as discussed above.

Costs
The costs associated with these measures include the installation of water control structures and the labor costs for operating those structures on a cyclical basis of flooding and draw down.

Riparian Vegetation

Methods
Following initial control of weeds, a seed mix of native riparian grasses, sedges, and wildflowers would be drilled on areas within appropriate elevations. Cuttings from native riparian trees and shrubs would be collected from the project vicinity and installed in the riparian zones. Long "pole" cuttings would be planted in deeply augured holes so as not to rely on irrigation. Riparian trees and shrubs could also be field grown and transplanted in the winter as bare root stock as appropriate. Low elevation moist areas would be planted with water tolerant species such as alders and sandbar willow, while intermediate and higher riparian zone areas would be planted with deep-rooted riparian species such as cottonwoods, valley oaks, and Oregon ash. Areas above the zone of inundation or natural sub-irrigation (i.e., tops of habitat levees) and other clearings would be seeded with a mix of moist grassland species such as meadow barley and planted with plugs of creeping wildrye. These openings or clearings would be included in the design for added diversity by supporting riparian herbaceous vegetation (grasses and forbs), including possibly several special-status plant species.

Costs
Riparian community restoration costs using these low intensity techniques with no irrigation could be done for about $12,000 per acre.

Native Grasslands (Including Seasonal Floodplain Vegetation) and Broadleaf Herbaceous Communities

Methods
Seeds from a number of native grasses would be obtained from the project region and stored for direct seeding. The seed mix would include early successional species such as meadow barley and California brome for quick cover and late successional species such as purple needlegrass and California melic for long-term sustainability. Following initial control of weeds, these native grasses would be drill seeded and mulched on clay soils in upland areas of the site beginning at elevations approximately 5' above mean higher high water (+8.2' NGVD). The seed mix would also include native wildflowers such as California poppies and lupines. Native grasses would also be a component of seasonal floodplains at elevations (from MHHW to 5' above MHHW) that would be transitional

between high marsh, riparian communities and native grasslands. The floodplains would support native graminoids such as creeping wildrye, meadow barley, and Baltic rush adapted to seasonally inundated environments. Sandy soils in the higher elevations would be seeded with a mix of grasses such as one-sided bluegrass and forbs such as lupines and asters adapted to dry coarse soils.

Costs

Depending on methods, native grassland and other herbaceous community restoration costs could average about $1,200 per acre.

Antioch Dune Scrub Vegetation

Methods

Seeds from a number of native dune shrubs and forbs would be collected from the project vicinity and either stored for direct seeding or contract grown in a qualified native plant nursery to plug size. Prior to planting, the site could be prepared by importing sand from sources such as Decker Island or Montezuma Slough to recreate dunes. Another method that may be more cost effective is to invert the existing Delhi sands to expose subsoil with less organic matter and non-native seed sources. Native plants would then be seeded, plugs planted, or Deepot shrubs planted on 6 to 8 foot centers in sands above +8.2' NGVD. Because of site-specific uncertainties, these methods should be tested using an adaptive management approach. Smaller-scale pilot projects may be initiated early in the project, prior to full-scale project implementation. The test plots may compare various sources of sand, amendment levels and planting approaches, including selective fertilization and/or mulching of specific plantings, mycorrhyzal treatments, seed inoculation, and other methods.

Costs

Depending on installation methods, planting density and other variables discussed above, native dune restoration costs could range from $12,000 per acre.

APPENDIX H

Hydrodynamic Modeling of Tidal Drainage

Appendix H. Hydrodynamic Modeling of Tidal Drainage

INTRODUCTION

This analysis used MIKE11 hydrodynamic modeling to assess tidal drainage for the Dutch Slough Tidal Marsh Restoration Project. The purpose of this assessment was to evaluate the potential for tidal damping in Alternative 2 (Preferred Alternative). The domain of the MIKE11 model included Little Dutch Slough and the restored marsh and open water areas on the Gilbert and Burroughs parcels that drain to Little Dutch Slough in Alternative 2. The downstream boundary of the model was Dutch Slough at the mouth of Little Dutch Slough. The upstream boundary of the model was the upstream end of the Little Dutch Slough channel at Cypress Rd.

METHODS

Model Setup

The Little Dutch Slough cross-sections used in the model are based on four cross-sections surveyed by PWA on May 12, 2005 (Figure 1 - Appendix B). The locations of these cross-sections are shown in Figure 2. Upstream of the existing culvert and road crossing, PWA measured channel widths from an aerial photograph and assumed channel depth and cross-section shape to schematize this portion of the Little Dutch Slough channel. The restored marsh and open water areas on the Gilbert and Burroughs parcels are represented as very wide channels connected to Dutch Slough by a breach (Figure 3). The lengths, widths, and bottom elevations of the channels representing the restored marsh and open water areas were based on the planned acreages and elevations of these areas (Table 1).

The breaches connecting the restored marsh and open water areas to Little Dutch Slough were sized using empirical hydraulic geometry equations that relate the restored tidal prism (i.e., volume between MLLW and MHHW) to equilibrium channel dimensions (Williams and others, 2002). Breaches sized in this manner are not expected to limit tidal drainage for restored marsh and open water areas. Thus, any tidal damping observed in the modeling is likely to be due to the constriction of flow through the existing Little Dutch Slough channel.

PWA used a Manning's n value of 0.033 for both the Little Dutch Slough channel and restored marsh areas. This is a typical n value for tidal channels. In restored marsh areas, the Manning's n value for the vegetated marshplain is expected to be higher than the typical value used to model both tidal channels and the vegetated marshplain in the restored marsh areas. It is assumed that the restored tidal channel systems will be designed to provide adequate tidal circulation and reduce tidal damping in restored marsh areas. Using the typical n value for tidal channels for restored marsh areas is consistent with this assumption and the modeling approach for assessing the potential for tidal damping due to flow constriction in Little Dutch Slough.

PWA performed one-month long model simulations to capture spring and neap tide cycles. Tides measured by USGS in Dutch Slough for January 2001 (www.iep.ca.gov; Station DUT007) were used as the downstream water level boundary condition. A closed boundary condition was used for the upstream end of Little Dutch Slough.

PWA used the model as a tool to evaluate the potential for tidal damping in restored marsh areas relative to existing tide levels in Dutch Slough and Little Dutch Slough. Measured tides were not available for the upstream end of Little Dutch Slough to calibrate the model. Modeled water levels may not accurately represent absolute water levels expected for restored conditions, but are useful for evaluating the relative potential for tidal damping.

The model setup for Alternative 2 is based on a previous version of the preferred alternative that is slightly different than the preferred Alternative 2 analyzed in the final Dutch Slough Tidal Marsh Restoration Plan and Feasibility Report. The main difference is that the average elevation of the very large low marsh area on the Burroughs parcel in Alternative 2 is -0.3 ft NGVD, whereas it was 0.6 ft NGVD in the previous version of the preferred alternative. These differences are not expected to significantly change the findings or conclusions of this modeling effort.

Table 1. Restored Marsh and Open Water Area Dimensions used for Model Setup

	Area (ac)	Elevation (ft, NGVD)	Branch Width (ft)	Branch Length (ft)
Gilbert open water	93	-6.0	1310	3100
Gilbert large low marsh	91	-0.3	1310	3020
Gilbert small mid marsh	14	1.5	1310	480
Gilbert medium mid marsh	37	1.5	1310	1220
Burroughs open water	66	-6.0	1310	2190
Burroughs very large low marsh	139	0.6	1310	4610
Burroughs small low marsh	12	-0.3	1310	400
Burroughs medium low marsh	34	-0.3	1310	1130
Burroughs large mid marsh	82	1.5	1310	2730

Model Scenarios

PWA performed five hydrodynamic model scenarios to assess: (1) potential tidal damping in Little Dutch Slough and restored marsh and open water area, (2) the effect of enlarging Little Dutch Slough on potential tidal damping, (3) and the effect of managing open water areas as non-tidal on potential tidal damping. PWA modeled the open water areas as tidal in four of the simulations and as managed in one simulation. The tidal open water management options represent the greatest potential for tidal damping. The five scenarios are:

- **Existing Conditions**. This model scenario includes the existing Little Dutch Slough channel as shown in Figures 1 and 2. This scenario represents a baseline for assessing potential tidal damping in

Little Dutch Slough. The existing conditions model scenario does not include the existing culvert and road crossing, which will be removed in Alternative 2, for the purpose of comparing results to Alternative 2 scenarios.

- **Alternative 2 with Existing Little Dutch Slough**. The nine restored marsh and open water areas planned for Alternative 2 were added as channel segments in the configuration shown in Figure 3. The existing configuration and dimensions of Little Dutch Slough were used to represent conditions after breaching the restored areas, without any channel enlargement due to scour or dredging. This scenario likely represents the greatest potential for tidal damping.
- **Alternative 2 with Downstream Scour in Little Dutch Slough.** The restored marsh and open water areas were added as in the previous scenario and as shown in Figure 3. Scour was estimated in the 3780 ft wider northern (furthest downstream) reach of Little Dutch Slough. The estimated dimensions of the scoured channel are smaller than the equilibrium dimensions predicted from tidal prism hydraulic geometry relationships (Figure 4). The estimate of channel scour is therefore conservative and represents an interim condition some time after breaching, before the channel has scoured to the expected equilibrium dimensions.
- **Alternative 2 with Downstream Scour & Upstream Dredging in Little Dutch Slough.** The restored marsh and open water areas were added as in the previous scenarios and as shown in Figure 3. Dredging was included for the 2220 ft narrow southern (upstream) reach of Little Dutch Slough. It was assumed that 2 – 3 ft of material would be dredged from the channel bottom (Figure 5). The hydraulic geometry relationships predict larger equilibrium dimensions than the dimensions assumed for the dredged channel.
- **Alternative 2 with Existing Little Dutch Slough and Managed Open Water.** The restored marsh areas were modeled as in the Existing Little Dutch Slough scenario, but the open water areas were not included in the model. This scenario represents the restoration option to manage open water areas as non-tidal.

RESULTS

Figure 6 shows the modeled water surface elevation profiles in Little Dutch Slough for the maximum and minimum water levels (i.e., highest high tide and lowest low tide), and also the channel thalweg profile, for each model scenario. Figures 7a to 7c show modeled time series of water levels in the most upstream reach of Little Dutch Slough near the large restored mid marsh area on the Burroughs parcel for the entire length of the model simulation.

Existing Conditions: The existing conditions model run shows that the tide range throughout Little Dutch Slough corresponds with the tide range in Dutch Slough (Figure 6). These results indicate full tidal drainage. Any tidal damping observed in the results for the following scenarios relative to the existing conditions results are expected to be due the effects of restoring tidal action in Alternative 2.

Alternative 2 with Existing Little Dutch Slough: Model results indicate that the existing Little Dutch Slough channel is undersized compared to the restored tidal prism from the restored marsh and open

water areas and has the potential to cause tidal damping. The results show that tidal damping raises the low tide level in the majority of Little Dutch Slough by approximately 0.5 ft or more (i.e., near the open water breaches and upstream; Figure 6). Tidal damping also lowers the high tide level, most noticeably in the narrow upstream portion of Little Dutch Slough (Figure 6). In Little Dutch Slough near the large mid marsh on the Burroughs parcel, model results show that tidal damping raises the lower low tides and lowers the higher high tides by approximately 0.7 ft on average, with damping on the low tides ranging from approximately 0.3 – 1.3 ft (Figures 7a to 7c).

At other restored tidal marshes where initial tidal damping occurred due to the constriction of tidal flows through an undersized channel, monitoring results showed that restored tidal flows scoured and enlarged the undersized channel over time (Williams and others, 2002). At these sites, channel scour increased conveyance of tidal flows and improved tidal drainage, offsetting the temporary initial tidal damping. Based on these results, Little Dutch Slough is expected to scour and enlarge over time, eventually allowing for adequate tidal drainage.

The expectation that Little Dutch Slough has the potential to scour is supported by predictions of equilibrium channel dimensions from hydraulic geometry relationships and modeled flow velocities. PWA has developed hydraulic geometry relationships that are regressions between marsh area or tidal prism and channel dimensions for mature marshes (Williams and others, 2002; Simenstad and others 2000). These relationships provide a geomorphic design tool to assess the potential for tidal channel scour. For Little Dutch Slough, channel dimensions predicted to be in equilibrium with the potential restored tidal prism are larger than existing channel dimensions (Figure 4). This indicates the potential for Little Dutch Slough to scour.

Hydraulic modeling results show that restored tidal flow velocities in Little Dutch Slough are higher than velocities for the existing conditions scenario and are within the range of scouring velocities. The peak velocities modeled for initial damped conditions in the wider downstream reach of Little Dutch Slough are approximately 2 ft/s on a typical tide cycle, which is within the range of threshold velocities for erosion available in the literature (approximately 1 - 4 ft/s, Delft 1989). Actual channel scour will depend on the critical shear stress for erosion of the substrate in Little Dutch Slough, which is not known. Peak modeled velocities for damped conditions in the narrower upstream reach of Little Dutch Slough are approximately 1 ft/s on a typical tide cycle. These results indicate that channel scour in the narrow upstream reach may be delayed. Flow constriction in this undersized reach of the channel and the resulting tidal damping in restored marsh areas may limit velocities and the rate of channel scour for an extended period of time, as observed at Sonoma Baylands (Williams and others, 2002).

Alternative 2 with Downstream Scour in Little Dutch Slough: Model results indicate that enlarging the wider downstream reach of Little Dutch Slough results in less tidal damping. The results show that the low tide and high tide levels are not significantly damped in the wider, enlarged downstream reach of Little Dutch Slough (Figure 6). Enlarging the downstream reach reduces tidal damping in the narrow upstream reach (without any enlargement of the upstream reach; Figure 6); however, tidal damping in the

upstream reach is still significant for both low and high tides, most noticeably at the upstream end near the large mid marsh area on the Burroughs parcel (Figures 7a to 7c).

Alternative 2 with Downstream Scour & Upstream Dredging in Little Dutch Slough: Model results indicate that enlarging the narrow upstream reach of Little Dutch Slough (in addition to the wider downstream reach) further reduces tidal damping of high tide levels and results in little to no tidal damping of low tide levels. Damping of the high tide level in the most upstream reach is reduced (Figure 6) and ranges from approximately 0 to 0.5 ft for a single diurnal tide cycle (Figures 7a to 7c). During neap tide cycles, low tide levels are not damped (Figures 6 and 7a to 7c). During spring tide cycles, damping of low tide levels near the upstream end of Little Dutch Slough and the large mid marsh area on the Burroughs parcel ranges from approximately 0 to 0.3 ft.

Alternative 2 with Existing Little Dutch Slough and Managed Open Water: Model results indicate that with Existing Little Dutch Slough channel geometry, managing the open water areas as non-tidal may result in initial tidal damping, but to a lesser degree than if the open water areas are tidal (Figure 8).

CONCLUSIONS

Limited conveyance in Little Dutch Slough is expected to result in initial short-term tidal damping, unless Little Dutch Slough is dredged or until tidal scouring enlarges the slough. With the existing channel dimensions, initial tidal damping may stress low marsh vegetation and impede drainage into Little Dutch Slough. If the open water areas on the Gilbert and Burroughs parcels are managed (*i.e.*, non-tidal), model results indicate that initial tidal damping may still occur, but to a lesser degree than if the open water areas are tidal.

To achieve full tidal drainage, Little Dutch Slough will need to be enlarged, either by dredging or allowing the channel to scour in response to the restored tidal flows. PWA modeled scenarios to assess the effect of enlarging Little Dutch Slough. Based on model results, enlarging the wider downstream (northern) reach of Little Dutch Slough is expected to allow full tidal drainage in marshes draining to this reach and improve tidal drainage in marshes draining to the narrow upstream (southern) portion of Little Dutch Slough. Additional enlargement of the narrow upstream (southern) portion of Little Dutch Slough is expected to be necessary to achieve full tidal drainage in marshes draining to this reach.

Dredging the narrow upstream reach of Little Dutch Slough is recommended due to the limited potential for this reach to scour. It may be possible to avoid dredging the wider downstream reach of Little Dutch Slough by allowing this reach to scour. Monitoring experience from similar restoration projects in San Francisco Bay suggests that channel scour may occur within several years after breaching. Further assessment of the rate of channel scour and the resilience of low marsh vegetation to partial drainage is recommended in future design phases to assess whether or not it is necessary to dredge the entire length of Little Dutch Slough.

REFERENCES

Delft Hydraulics. 1989. Handbook: Sediment Transport by Currents and Waves. Report H 461. June. By Leo C. van Rijn.

Simenstad, C., J. Toft, H. Higgins, J. Cordell, M. Orr, P. Williams, L. Grimaldo, Z. Hymanson, and D. Reed and others (BREACH Interdisciplinary Research Team). 2000. Sacramento/San Joaquin Delta Breached Levee Wetland Study (BREACH), Preliminary Report to CALFED.

Williams, P.B., M.K. Orr, and N.J. Garrity, 2002. Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects. Restoration Ecology Vol. 10 No. 3, pp. 577-590.

FIGURES

Figure 1. Schematic Channel Network: Existing Conditions
Figure 2. Little Dutch Slough Cross-Sections
Figure 3. Schematic Channel Network: Alternative 2
Figure 4. Downstream Scour Cross-Section (XS4)
Figure 5. Upstream Dredging Cross-Sections
Figure 6. Profiles of Tidal Drainage in Little Dutch Slough
Figure 7a – 7c. Little Dutch Slough at Burroughs Large Mid Marsh

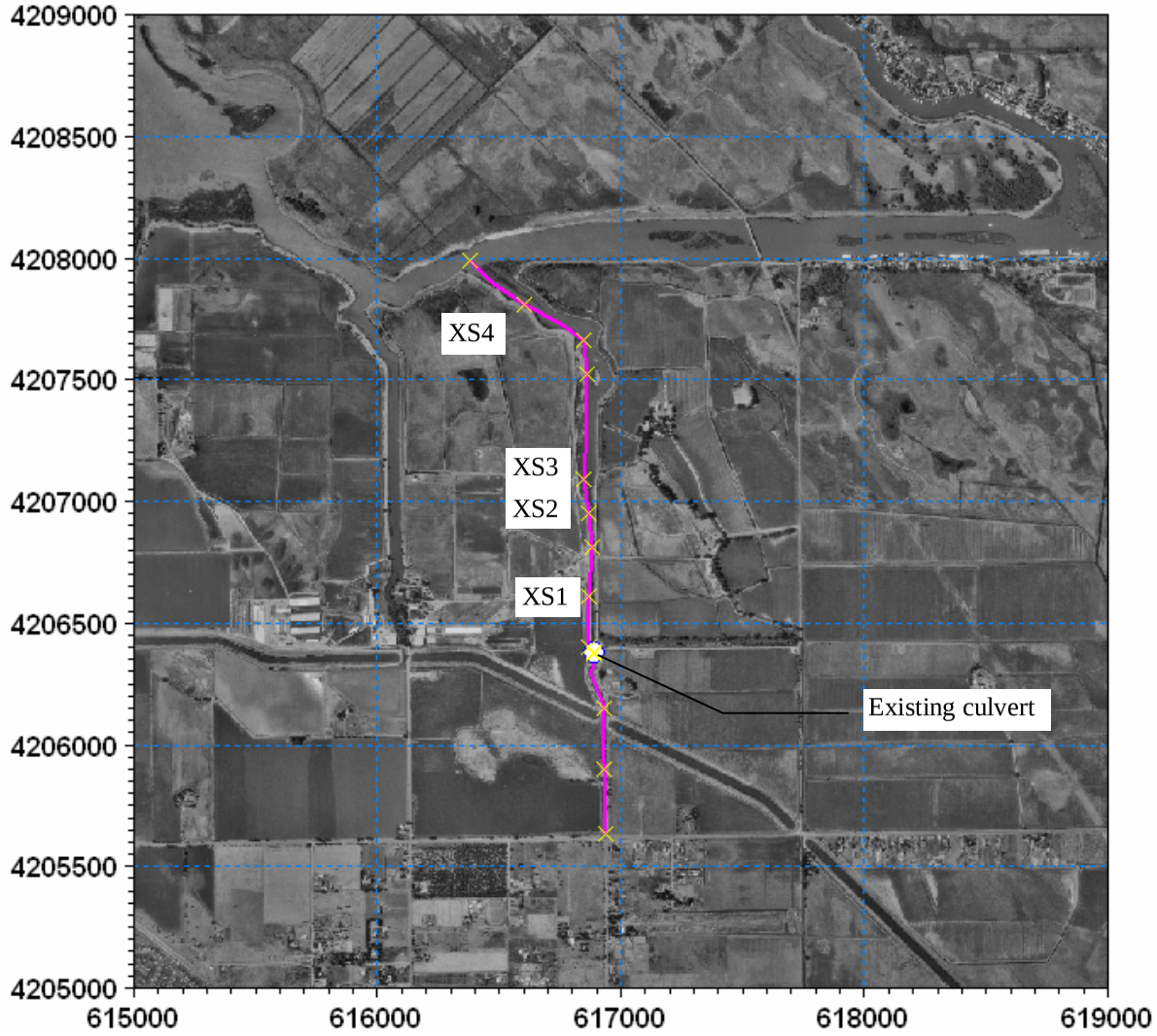
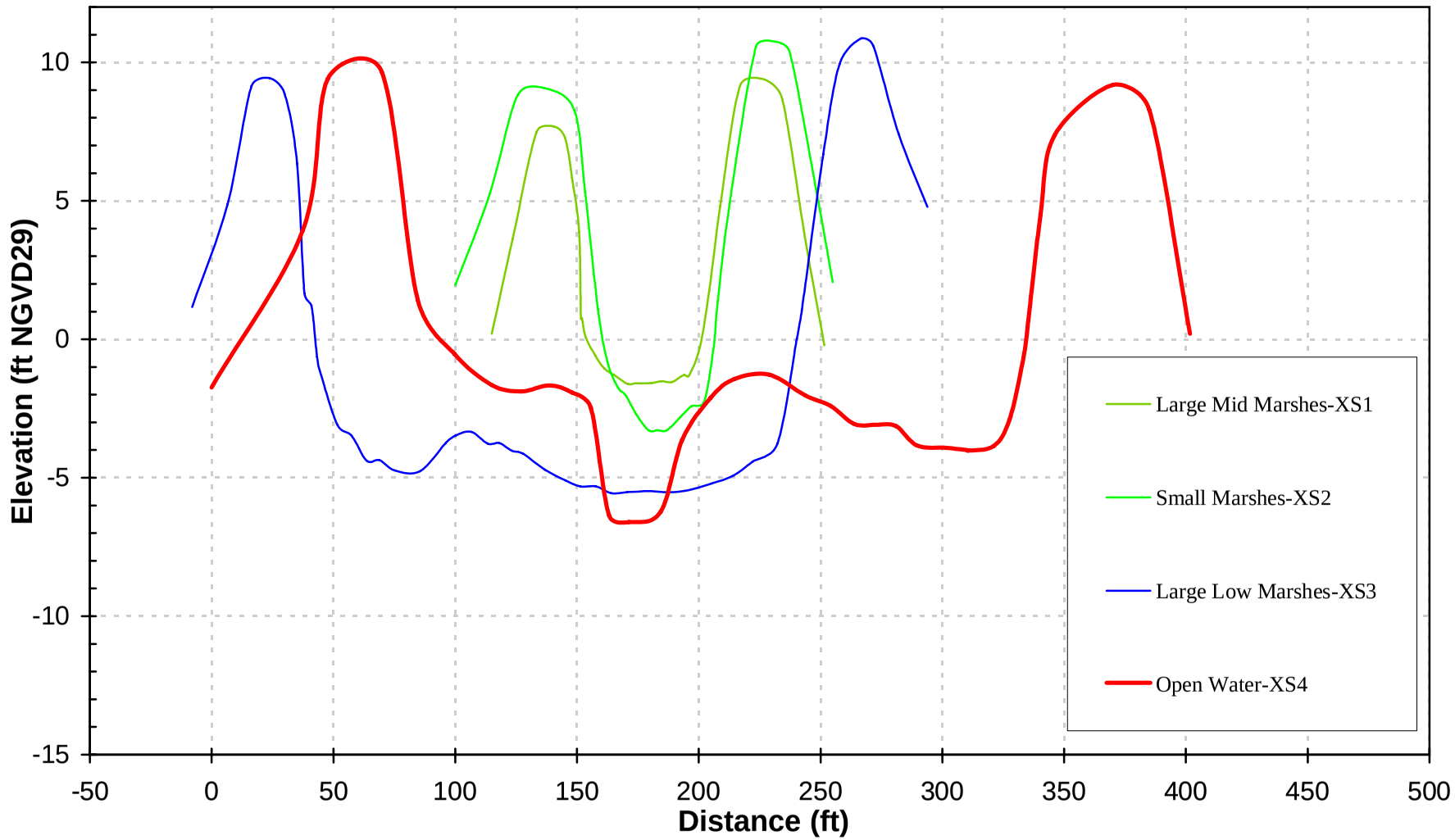


figure 1

Dutch Slough Tidal Marsh Restoration

Schematic Channel Network: Existing Conditions

PWA Ref 1714.00 **Appendix H** PWA



Notes:
Survey was done by PWA on May 12, 2005.
Location of cross-sections are identified on Figure 1.

figure 2

Dutch Slough Tidal Marsh Restoration
Little Dutch Slough Cross-Sections

PWA Ref 1714.00 **Appendix H** PWA

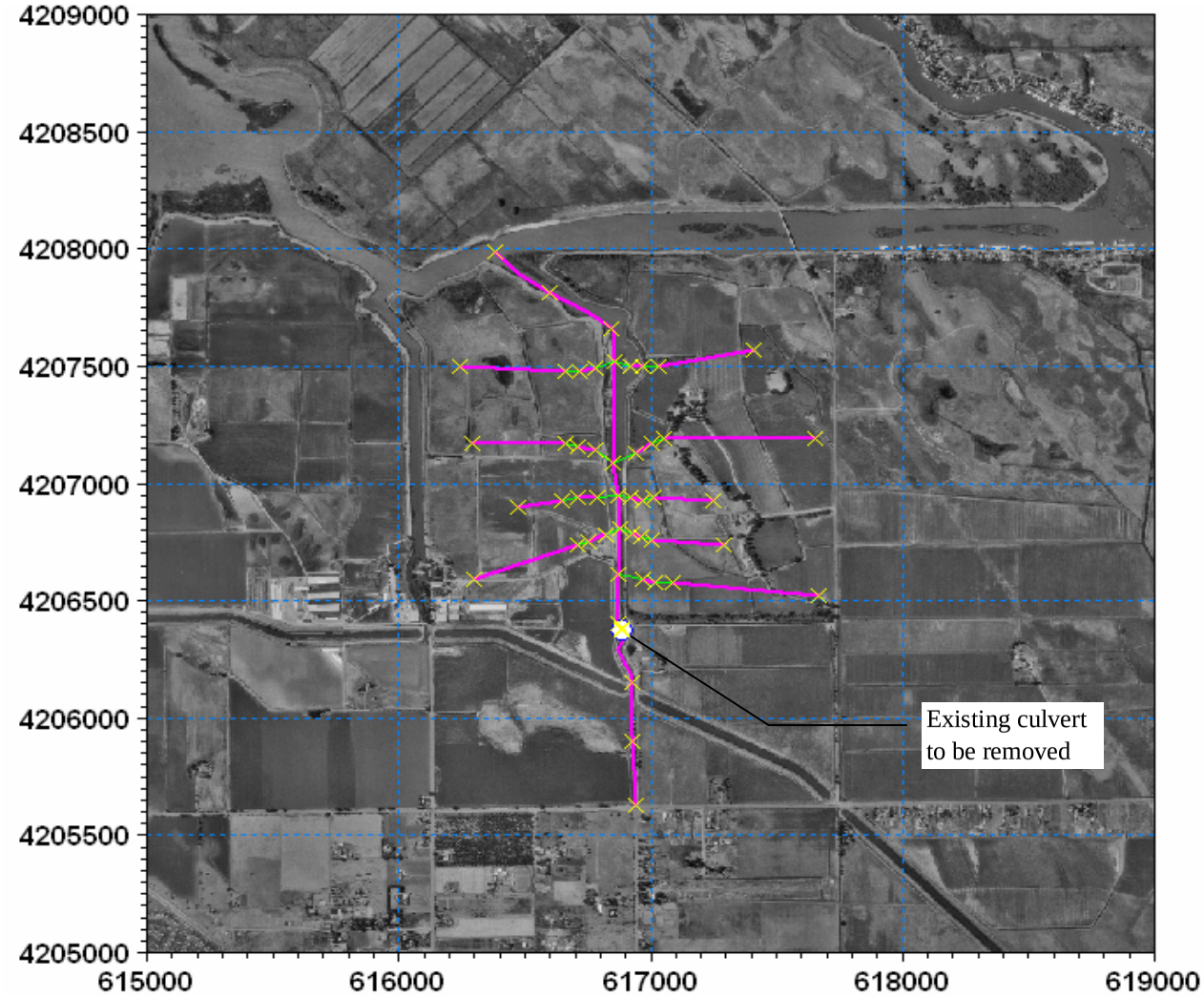
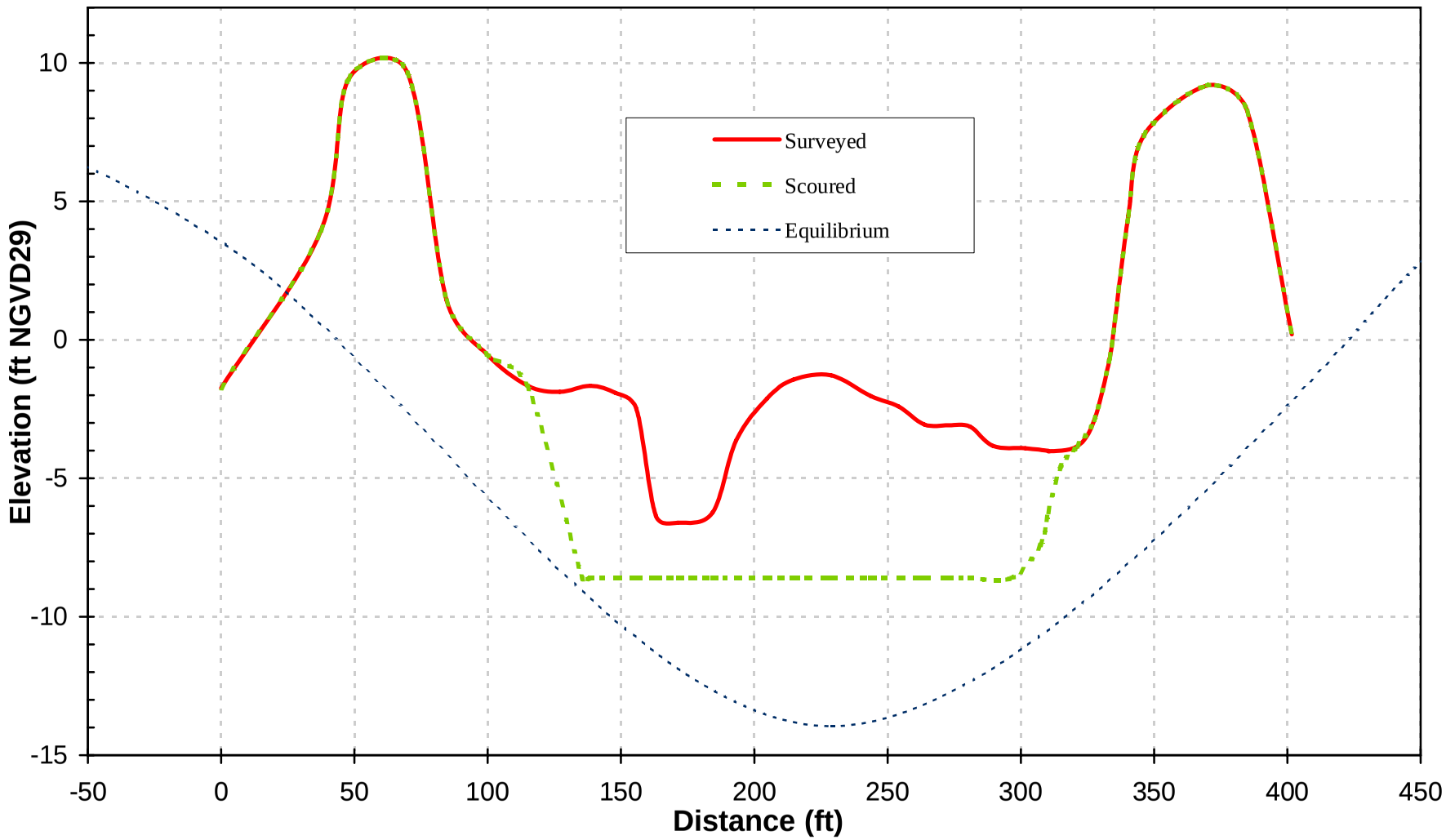


figure 3

Dutch Slough Tidal Marsh Restoration
Schematic Channel Network: Alternative 2

PWA Ref 1714.00 **Appendix H** PWA

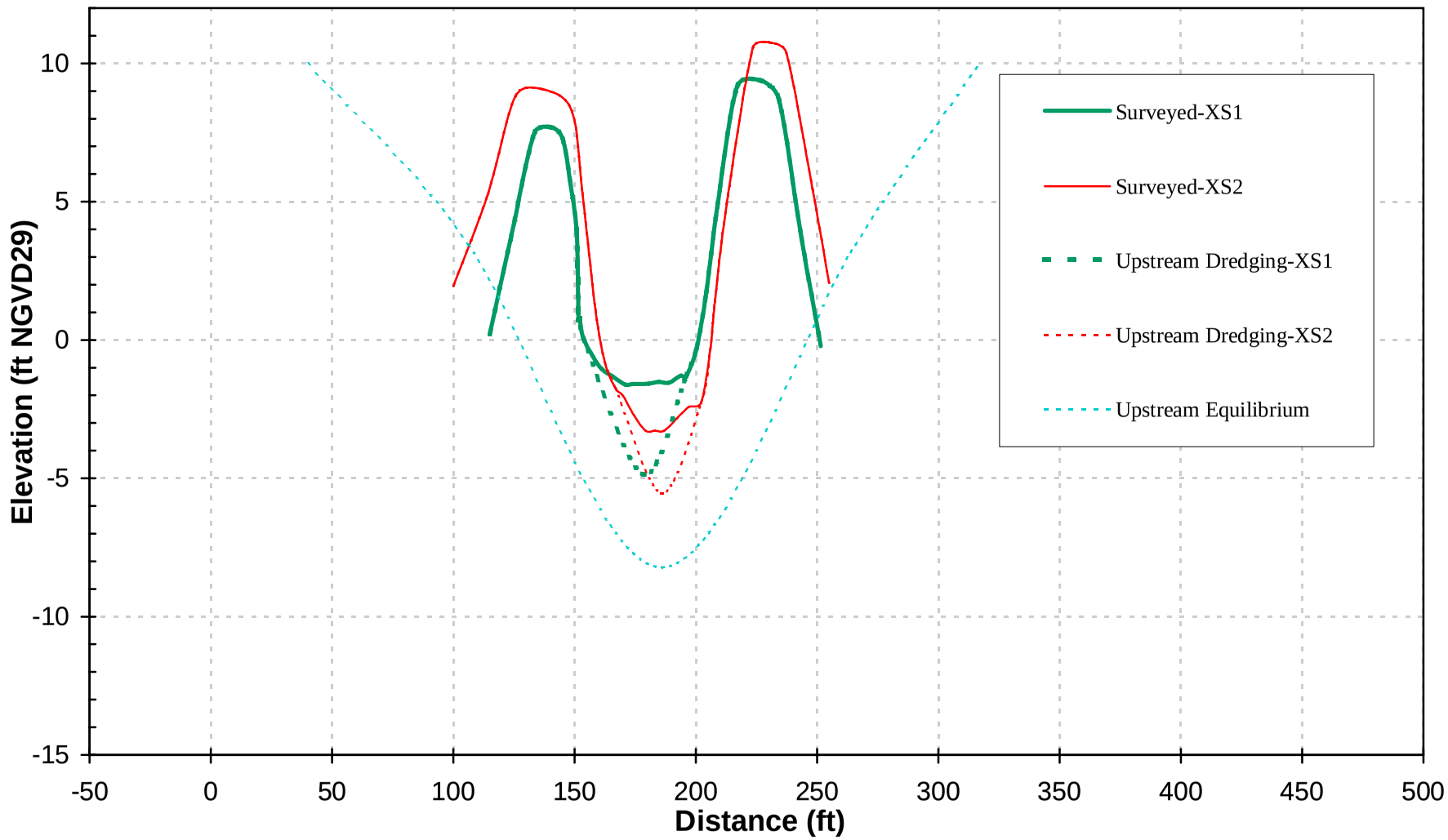


Notes:

figure 4

Dutch Slough Tidal Marsh Restoration
Downstream Scour Cross-Section (XS4)

PWA Ref 1714.00 **Appendix H** PWA

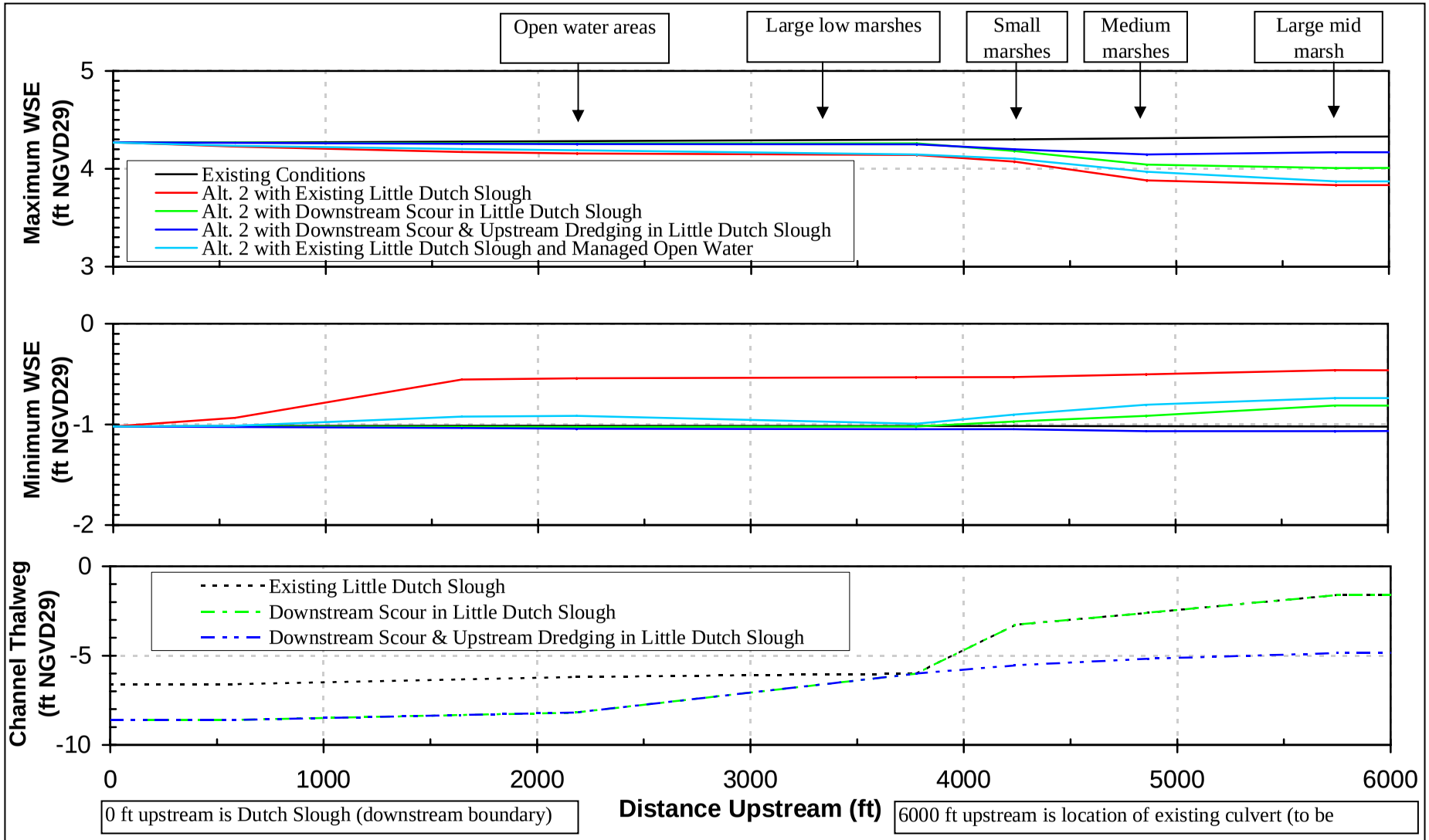


Notes:
Upstream Equilibrium cross-sections were calculated by using hydraulic geometry equations.

figure 5

Dutch Slough Tidal Marsh Restoration
Upstream Dredging Cross-Sections

PWA Ref 1714.00 **Appendix H** PWA

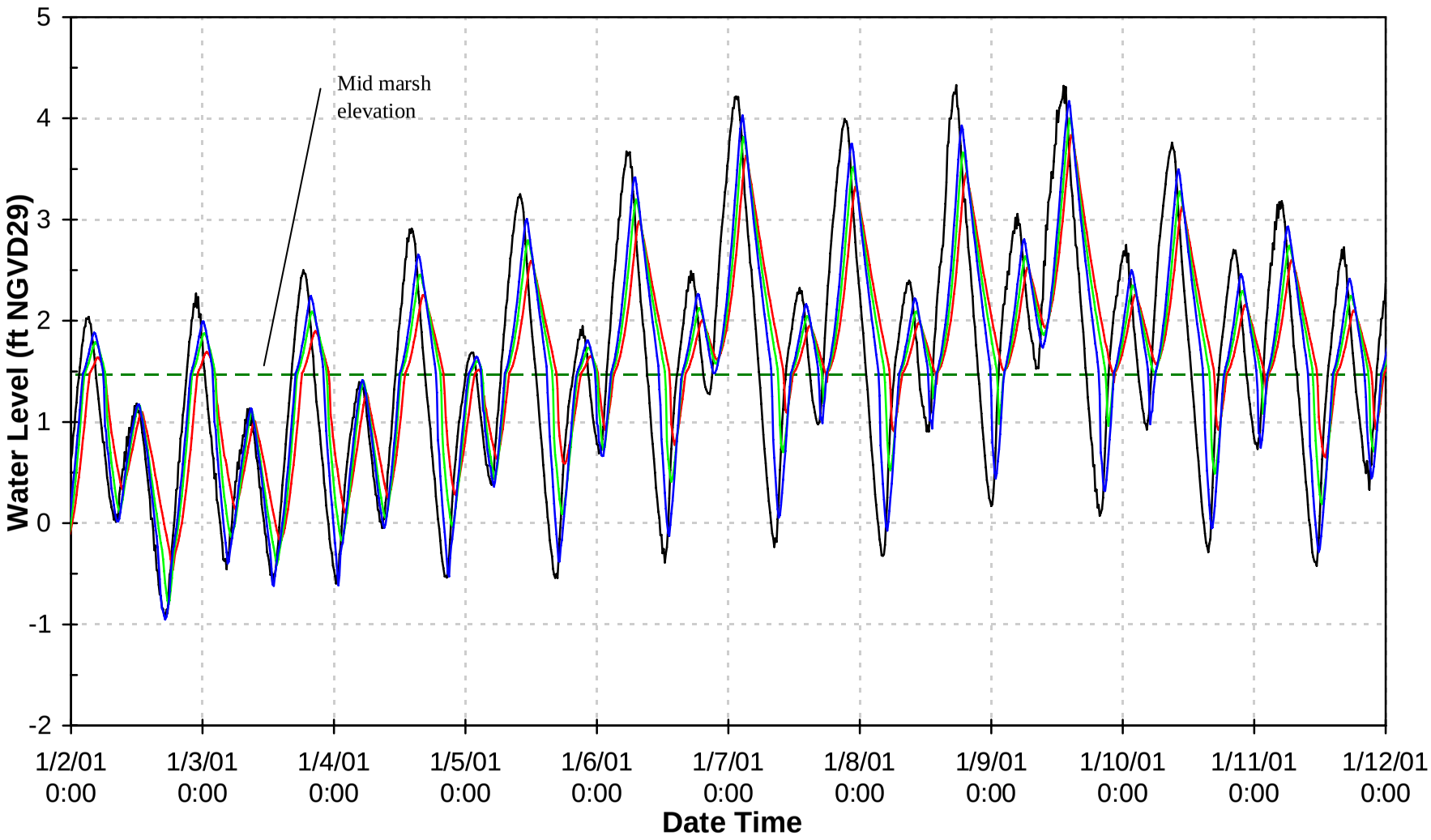


Notes:
WSE Results from MIKE 11 Simulation Scenarios for January 1-30, 2001.
Downstream scour scenario assumes Little Dutch Slough is enlarged downstream of large low marsh areas (0-3780 ft) .
Upstream dredging scenario assumes Little Dutch Slough is enlarged upstream of small marshes (3780-6000 ft).

figure 6

Dutch Slough Tidal Marsh Restoration
Profiles of Tidal Drainage in Little Dutch Slough

PWA Ref 1714.00 **Appendix H** PWA

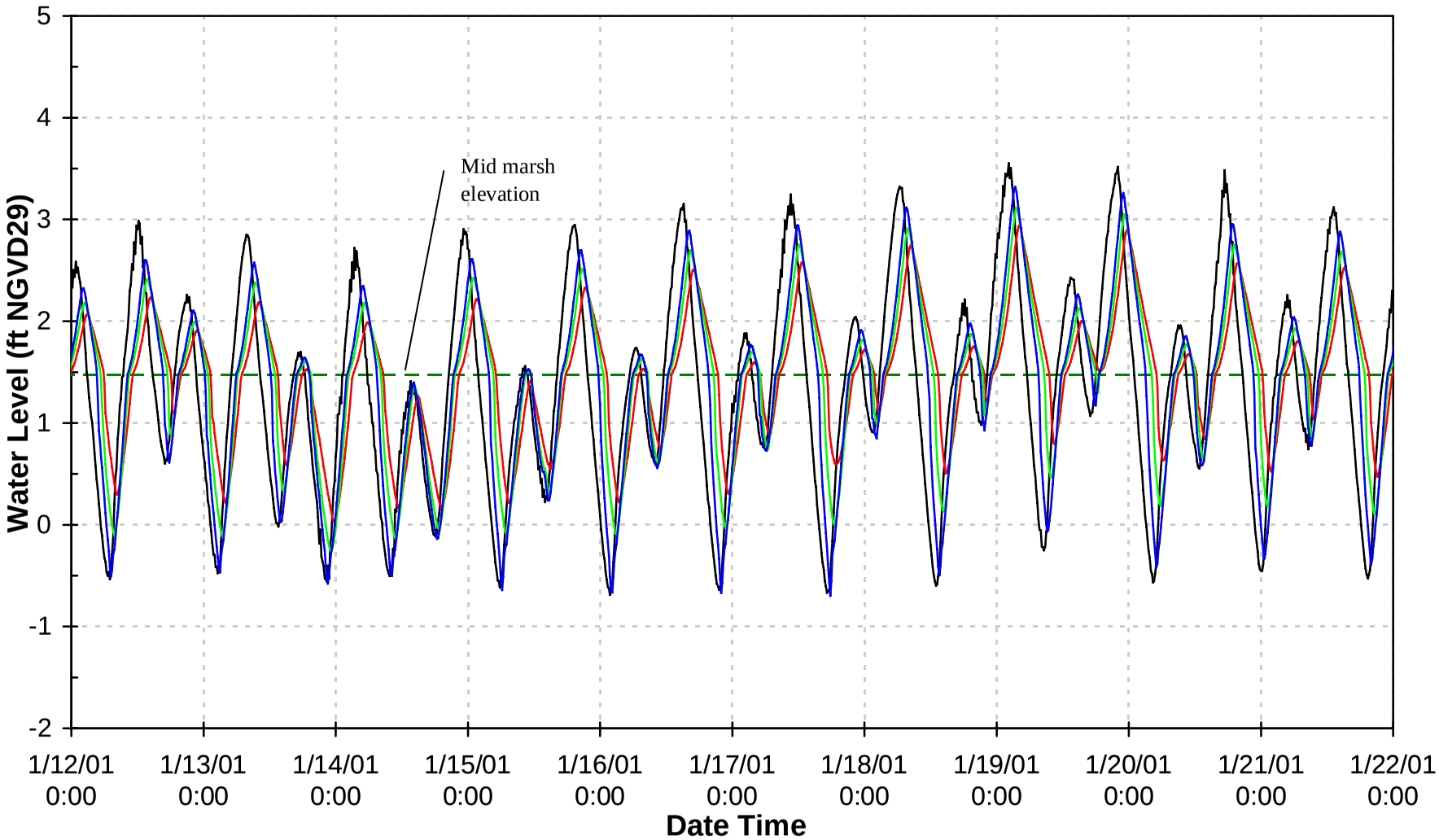


Existing Conditions
Alt. 2 with Existing Little Dutch Slough
Alt. 2 with Downstream Scour in Little Dutch Slough
Alt. 2 with Downstream Scour & Upstream Dredging in Little Dutch Slough

figure 7a

Dutch Slough Tidal Marsh Restoration
Little Dutch Slough at Burroughs Large Mid Marsh

PWA Ref 1714.00 Appendix H PWA

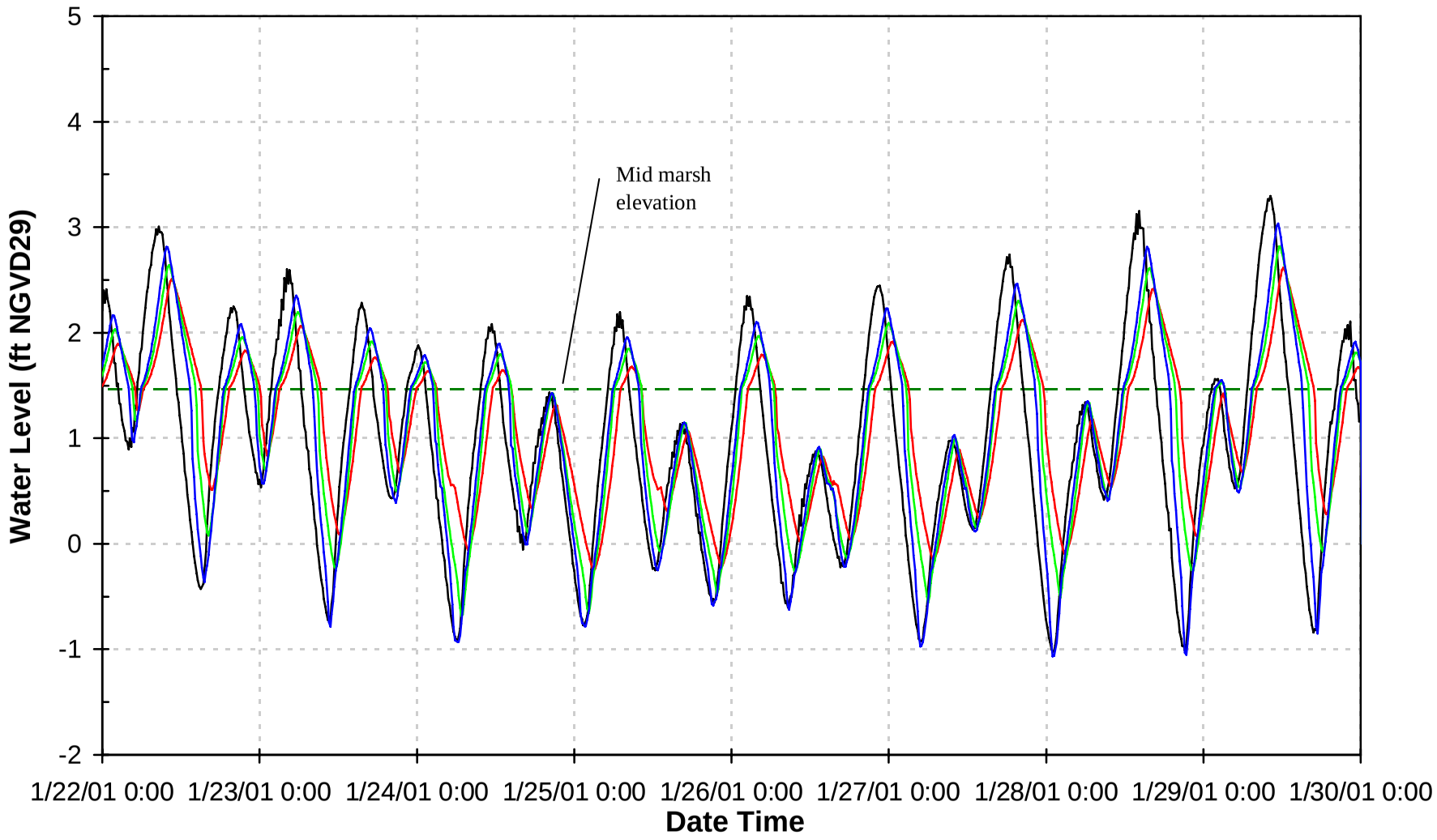


Existing Conditions
Alt. 2 with Existing Little Dutch Slough
Alt. 2 with Downstream Scour in Little Dutch Slough
Alt. 2 with Downstream Scour & Upstream Dredging in Little Dutch Slough

figure 7b

Dutch Slough Tidal Marsh Restoration
Little Dutch Slough at Burroughs Large Mid Marsh

PWA Ref 1714.00 Appendix H PWA



Existing Conditions
Alt. 2 with Existing Little Dutch Slough
Alt. 2 with Downstream Scour in Little Dutch Slough
Alt. 2 with Downstream Scour & Upstream Dredging in Little Dutch Slough

figure 7c

Dutch Slough Tidal Marsh Restoration
Little Dutch Slough at Burroughs Large Mid Marsh

PWA Ref 1714.00 Appendix H PWA

APPENDIX I

Preliminary Volume and Cost Estimates by Parcel

Table I-1. Alternative 2 - Summary of Assumptions for Preliminary Volumes

General Project

Item	Design Elevation (ft NGVD)	Design Area (acres)	Design Width (ft)	Design Length (ft)	Side Slope (Horiz:Vert) (ft/ft)
Earthwork Activities					
New East Levee - Fill Placement	9	NA	+16 crest	7,700	3:1 (outboard), 2:1 (inboard)
Miscellaneous Activities					
Outboard Levee Armorin(	9 to (-)1	NA	2.5	7,700	2:1
Cut Off Wall	(-)40	NA	3	7,700	vertical

Emerson Parcel

	Design Elevation (ft NGVD)	Design Area (acres)	Design Width (ft)	Design Length (ft)	Side Slope (Horiz:Vert) (ft/ft)
Foot Bridge on Emerson Parcel	NA	NA	8	200	NA
Main Channel Excavation	(-)5.6 (max invert)	NA	80 (max top)	1,000	2:1
Tributary Channel Excavation	Varies	NA	Varies	18,900	2:1
Marshplain Grading	Varies +1.5 to (-)0.8	240	NA	NA	NA
Low Elevation Fill Placement	(-)0.8	49	NA	NA	NA
Marsh Drainage Divide	+3.15 crest	NA	10 top	5,800	5:1 to (-)2 NGVD, then 2:1
Habitat Levee Slope Fill	NA	NA	NA	1,500	5:1 from +5 to (-)2 NGVD, then 3:1

Gilbert Parcel

Item	Design Elevation (ft NGVD)	Design Area (acres)	Design Width (ft)	Design Length (ft)	Side Slope (Horiz:Vert) (ft/ft)
Main Channel Excavation	(-)5.7 (max invert)	NA	80 top	750	2:1
Tributary Channel Excavation	Varies	NA	Varies	14,100	2:1
Marshplain Grading	Varies +1.5 to (-)0.3	140	NA	NA	NA
Marsh Drainage Divide	+6 crest	NA	10 top	5,700	5:1 to (-)2 NGVD, then 2:1
Habitat Levee Slope Fill	NA	NA	NA	6,400	5:1 from +5 to (-)2 NGVD, then 3:1

Burroughs Parcel

Item	Design Elevation (ft NGVD)	Design Area (acres)	Design Width (ft)	Design Length (ft)	Side Slope (Horiz:Vert) (ft/ft)
Main Channel Excavation	(-)6.8 (max invert)	NA	108 top	3,000	2:1
Tributary Channel Excavation	Varies	NA	Varies	28,000	2:1
Marshplain Grading	Varies +1.5 to (-)0.3	280	NA	NA	NA
Marsh Drainage Divide	+3.15 crest	NA	10 top	4,200	5:1 to (-)2 NGVD, then 2:1
Habitat Levee Slope Fill	NA	NA	NA	4,500	5:1 from +5 to (-)2 NGVD, then 3:1

Table I-2. Alternative 2 - Preliminary Cost Estimate by Parcel

	Description	Units	Unit Cost	Emerson Parcel	Gilbert Parcel	Burroughs Parcel	Total
1.	**Site Preparation**						**$2,326,000**
A.	Mobilization (5%)	lump sum	$858,000	$286,000	$286,000	$286,000	$858,000
B.	Vegetation Clearing	acres	$800	$248,000	$240,000	$120,000	$608,000
C.	Demolition	each	$20,000	$40,000	$140,000	$380,000	$560,000
D.	Construction Survey	lump sum	$300,000	$100,000	$100,000	$100,000	$300,000
2.	**Utilities Relocation**						**$312,000**
A.	Ironhouse Pipeline Relocation	linear feet	$50	$240,000	-	-	$240,000
B.	Marsh Creek Levee Road Resurfacing	tons	$24	$72,000	-	-	$72,000
3.	**New East Levee**						**$4,905,500**
A.	Foundation Excavation	cubic yards	$3.00	-	-	$144,000	$144,000
B.	Credit for Reduced Import (Burroughs Parcel)	cubic yards	-$2.00	-	-	-$96,000	-$96,000
C.	Levee Fill Placement (Imported)	cubic yards	$10.00	-	-	$1,860,000	$1,860,000
D.	Outboard Levee Armoring	linear feet	$165	-	-	$1,270,500	$1,270,500
E.	Groundwater Cut-Off Wall	lump sum	$1,727,000	-	-	$1,727,000	$1,727,000
4.	**Foot Bridge on Emerson Parcel**	square feet	$100	$160,000	-	-	**$160,000**
5.	**Breaches**	each	$50,000	$100,000	$200,000	$250,000	**$550,000**
6.	**Little Dutch Slough Dredging**	cubic yards	$37	-	-	$118,000	**$118,000**
7.	**Marshplain Grading**			**$3,008,000**	**$1,603,000**	**$2,200,000**	**$6,811,000**
A.	Fill Placement (Onsite Borrow)	cubic yards	$3.00	$2,190,000	$747,000	$1,026,000	$3,963,000
B.	Fill Placement (Imported)	cubic yards	$2.00	-$116,000	$464,000	$370,000	$718,000
C.	Low Elevation Fill Placement (premium)	cubic yards	$3.00	$762,000	$285,000	$468,000	$1,515,000
D.	Main Channel Excavation (premium)	cubic yards	$4.00	$52,000	$32,000	$96,000	$180,000
E.	Tributary Channel Excavation (premium)	cubic yards	$5.00	$120,000	$75,000	$240,000	$435,000
8.	**Habitat Levee**			**$301,500**	**$293,000**	**$329,000**	**$923,500**
A.	Levee Slope Fill (premium)	cubic yards	$1.50	$1,500	$3,000	$3,000	$7,500
B.	Riparian Planting	acres	$25,000	$300,000	$200,000	$275,000	$775,000
C.	Levee Lowering (premium)	cubic yards	$3.00	$0	$90,000	$51,000	$141,000
9.	**Revegetation**			**$616,000**	**$554,000**	**$450,000**	**$1,920,000**
A.	Marsh Revegetation (Tule Pre-establishment)	acres	$1,000	$240,000	$282,000	$140,000	$662,000
B.	Riparian Planting (including Dunes)	acres	$12,000	$228,000	$72,000	$60,000	$360,000
C.	Native Grassland Planting	acres	$1,200	$48,000	-	-	$48,000
D.	Water Control Structures	each	$50,000	$100,000	$200,000	$250,000	$550,000
E.	Water Level Management (for Marsh Revegetation)	years	$100,000	$100,000	$100,000	$100,000	$300,000
	Sub-total - IMPORT FILL AT NO COST			**$5,473,000**	**$3,619,000**	**$9,298,500**	**$18,026,000**
	Construction Contingencies (30%)			$1,642,000	$1,086,000	$2,790,000	$5,408,000
	Planning and Design (10%)			$547,000	$362,000	$930,000	$1,803,000
	TOTAL - IMPORT FILL AT NO COST			**$7,662,000**	**$5,067,000**	**$13,018,500**	**$25,237,000**
Additional Costs for On-Site Borrow from Subtidal Areas							
10.	**Additional Vegetation Clearing**	acres	$800	-	$96,000	$48,000	$144,000
11.	**Additional On-Site Excavation for Marshplain Fill**	cubic yards	$6.50	-	$1,359,000	$1,443,000	$2,802,000
	Sub-total - ADDITIONAL COSTS FOR ON-SITE BORROW FROM SUBTIDAL AREAS			**-**	**$1,455,000**	**$1,491,000**	**$2,946,000**
	Construction Contingencies (30%)			-	$437,000	$447,000	$884,000
	Planning and Design (10%)			-	$146,000	$150,000	$295,000
	TOTAL - ON-SITE BORROW FROM SUBTIDAL AREAS			**$7,662,000**	**$7,105,000**	**$15,106,500**	**$29,362,000**
Annual Maintenance and Monitoring Costs							
12.	Maintenance of Adaptive Management Design Features	lump sum	$3,000	$1,000	$1,000	$1,000	$3,000
13.	New East Levee Maintenance	miles	$15,000	-	$0	$22,500	$22,500
14.	Project Performance Monitoring	lump sum	$60,000	$20,000	$20,000	$20,000	$60,000

Table I-3. Alternative 2 - Preliminary Volume Estimate by Parcel

	Description	Units	Emerson Parcel	Gilbert Parcel	Burroughs Parcel	Total
1.	**Site Preparation**					
A.	Mobilization (5%)	lump sum	-	-	-	1
B.	Vegetation Clearing	acres	310	300	150	760
C.	Demolition	each	2	7	19	28
D.	Construction Survey	lump sum	-	-	-	1
2.	**Utilities Relocatior**					
A.	Ironhouse Pipeline Relocation	linear feet	4,800	-	-	4,800
B.	Marsh Creek Levee Road Resurfacing	tons	3,000	-	-	3,000
3.	**New East Levee**	**linear feet**				**7,700**
A.	Foundation Excavation	cubic yards	-	-	48,000	48,000
B.	Credit for Reduced Import (Burroughs Parcel)	cubic yards	-	-	48,000	48,000
C.	Levee Fill Placement (Imported)	cubic yards	-	-	186,000	186,000
D.	Outboard Levee Armoring	linear feet	-	-	7,700	7,700
E.	Groundwater Cut-Off Wall	lump sum	-	-	-	1
4.	**Foot Bridge on Emerson Parce**	square feet	1,600	-	-	1,600
5.	**Breaches**	each	2	4	5	11
6.	**Little Dutch Slough Dredging**		-	-	3,200	3,200
7.	**Marshplain Grading**	**cubic yards**	**672,000**	**481,000**	**527,000**	**1,680,000**
A.	Fill Placement (Onsite Borrow)	cubic yards	730,000	249,000	342,000	1,321,000
B.	Fill Placement (Imported)	cubic yards	-58,000	232,000	185,000	359,000
C.	Low Elevation Fill Placement (premium)	cubic yards	254,000	95,000	156,000	505,000
D.	Main Channel Excavation (premium)	cubic yards	13,000	8,000	24,000	45,000
E.	Tributary Channel Excavation (premium)	cubic yards	24,000	15,000	48,000	87,000
8.	**Habitat Levee**		**12,900**	**11,900**	**8,500**	**33,300**
A.	Levee Slope Fill (premium)	cubic yards	1,000	2,000	2,000	5,000
B.	Riparian Planting	acres	12	8	11	31
C.	Levee Lowering (premium)	cubic yards	0	30,000	17,000	47,000
9.	**Revegetation**	**acres**	**299**	**288**	**145**	**732**
A.	Marsh Revegetation (Tule Pre-establishment)	acres	240	282	140	662
B.	Riparian Planting (including Dunes)	acres	19	6	5	30
C.	Native Grassland Planting	acres	40	-	-	40
D.	Water Control Structures	each	2	4	5	11
E.	Water Level Management (for Marsh Revegetation)	years	-	-	-	3
10.	**Additional Vegetation Clearing**	acres	-	120	60	180
11.	**Additional On-Site Excavation for Marshplain Fill**	cubic yards	-	209,000	222,000	431,000

Annual Maintenance and Monitoring Costs						
12.	Maintenance of Adaptive Management Design Features	lump sum	-	-	-	1
13.	New East Levee Maintenance	miles	-	-	1.5	1.5
14.	Project Performance Monitoring	lump sum	-	-	-	3

APPENDIX J

Marsh Creek Delta Restoration Project

Prepared by:

Natural Heritage Institute

Appendix J. Marsh Creek Delta Restoration Project
Prepared by the Natural Heritage Institute

The Marsh Creek Delta Restoration Project is located on 100 acres of land owned by the Ironhouse Sanitary District and approximately 10 acres of flood control channel owned by the Contra Costa Flood Control District. The project is an important potential component of the adjacent Dutch Slough Tidal Marsh Restoration project along the east side of Marsh Creek.

The project objectives are to:

- Restore riparian vegetation and natural fluvial processes and forms along the Marsh Creek flood control channel (10 acres along 0.9 miles of channel).
- Restore a large area of higher elevation tidal marsh (MTL) west of marsh creek that is comparable to tidal marsh treatments on the Dutch Slough property.
- Provide 500 to 600 thousand cubic yards of borrow material for creation of tidal marsh on subsided portions of the Dutch Slough property.
- Maintain the potential to restore a complex delta system at the mouth of Marsh Creek.

Existing Conditions

The site currently consists of 100 acres of irrigated pasture owned by the Ironhouse Sanitary District and approximately 10 acres of flood control channel owned by the Contra Costa Flood Control District. The flood control channel is bordered on either side by levees that confine the entire flow of Marsh Creek preventing the creek from flooding its historic Delta. The flood control district employs a chemical mowing program along the channel and levee banks to prevent colonization of riparian vegetation and maintain flood conveyance capacity. The sanitary district irrigates the pasture with treated wastewater. The elevation of the levees ranges from twelve to fourteen feet NGVD and the average elevation of the pasture is six feet NGVD.

The restoration site is currently dissected by the Contra Costa Canal, which constrains the course of marsh creek where the two cross. The Contra Costa Water District now plans to encase the canal and bury below the thalweg elevation of Marsh Creek. The canal encasement project will effectively eliminate any surface expression of the canal and thus create the opportunity to restore a broad flood/marsh plain and sinuous channel at the mouth of Marsh Creek.

Project Description

The project will be implemented in phases to maximize adaptive management research opportunities and to minimize unintended consequences. The first phase of the project entails excavating 500 to 600 thousand yards of soil on the Ironhouse pasture to create a

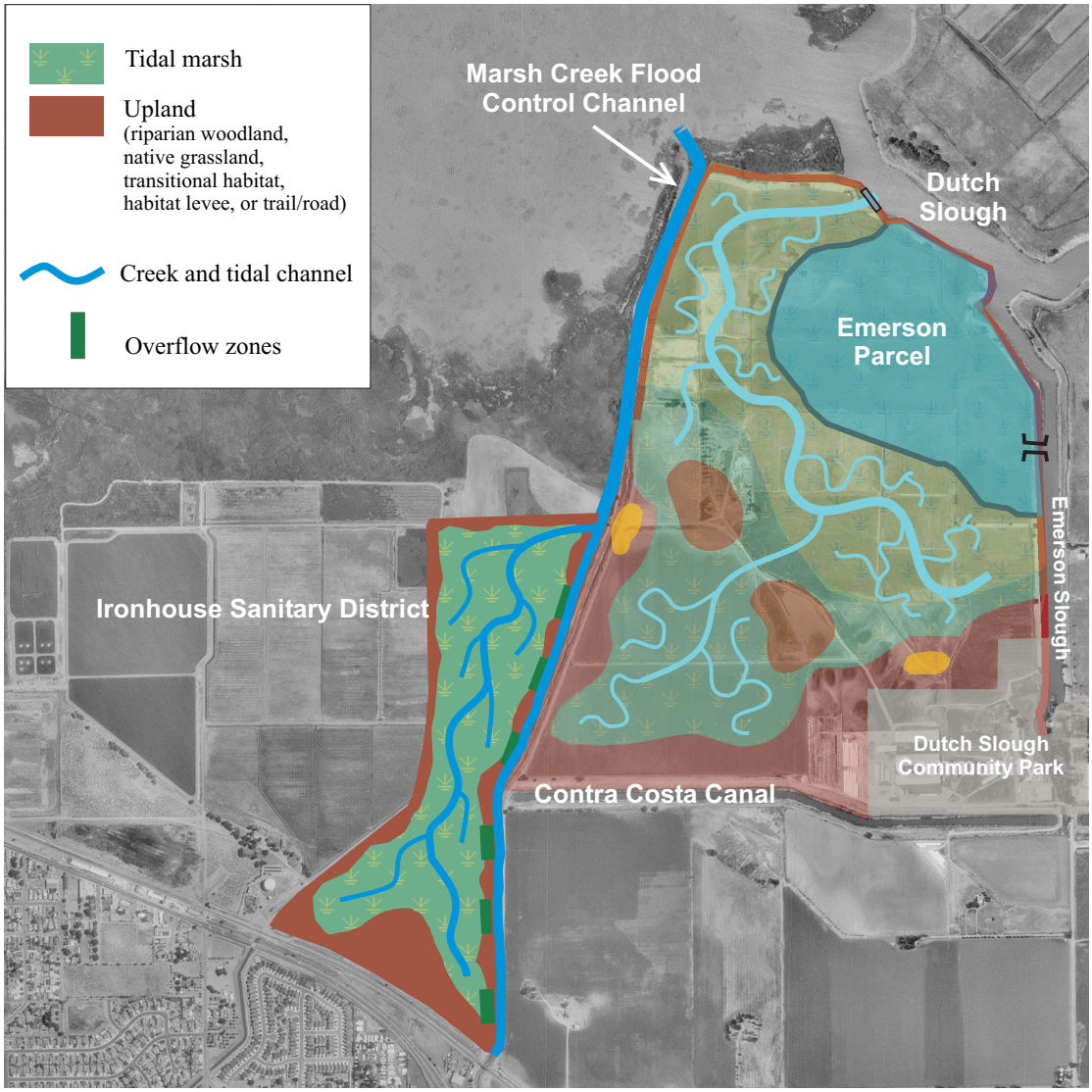
tidal marsh immediately west of Marsh Creek (Figure J-1). The excavated material will be placed on the adjacent Dutch Slough property to provide the fill material necessary to create large tidal marsh areas on subsided portions of the property. The excavation would grade the Ironhouse pastures to an elevation of approximately 1.5 feet, but would leave an upland edge around the perimeter of the restoration site. The site would be revegetated using the same method employed in the larger Dutch Slough restoration project.

During the first phase, Marsh Creek will not be routed through the restored marsh, but will be hydrologically connected to the restored marsh via a tidal channel that opens into Marsh Creek immediately upstream of the pedestrian bridge. Water would not be routed through the restored marsh until the results of a monitoring program determine that the water quality in marsh creek would not degrade the restored marsh or that routing the creek through a marsh would not exacerbate water quality problems or create sediment routing problems.

During phase one, the conveyance capacity of marsh creek will be expanded to allow for riparian vegetation to be planted along the existing flood control alignment without reducing the existing conveyance and sediment routing. Conveyance capacity will be expanded by creating several notches in the left bank levee to allow floodwater to spread-out into the restored marsh zone during high flow events. The purpose of the overflow zones or notches is to expand channel capacity without routing bedload into the restored marsh or otherwise disrupting the sediment routing functions of the existing channel. The overflow notches should be graded to an elevation approximating the water surface elevation associated with 2-5 year storm events. After initial riparian vegetation plantings, the marsh creek flood control channel would be allowed to meander and evolve.

Monitoring during the first phase of the Marsh Creek Delta restoration project, in combination with monitoring of the larger Dutch Slough Project, will enable managers to measure the ecological benefits of high marsh relative to low marsh and riparian zones. Water quality and sediment monitoring during the first phase will determine whether it is prudent to breach the flood control levees to reroute marsh creek into new channel(s) across the restored Ironhouse or Dutch Slough marshes.

Phase two of the project would entail breaching the Marsh Creek flood control levees in one or more places and routing Marsh Creek onto the Ironhouse and/or Dutch Slough marshes. The first phase of the project will be designed to allow for future breaches at a variety of locations including 1) the upper end of the restored ironhouse marsh, 2) the southwest corner of the Emerson parcel, and 3) immediately upstream of the pedestrian bridge.



SCALE

10 ac

0 0.2 0.4 0.6 0.8 1 Mile

1000 0 1000 2000 3000 4000 5000 Feet

PWA#: 1714 WstMrshCkDelta_portrait_1_06v2.cdr

figure **J-1**

Dutch Slough Tidal Marsh Restoration

Marsh Creek Delta Restoration

PWA