Dutch Slough Tidal Marsh Restoration Project
Preliminary Opportunities and Constraints Report

Prepared for

The California State Coastal Conservancy

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1. INTRODUCTION

1.1 Purpose

This draft report provides an overview of the Dutch Slough restoration project and describes some of the opportunities and constraints that may determine restoration of the site. The purpose of this report is to inform input from scientists on the Adaptive Management Working Group (AMWG) and stakeholders participating on the Restoration Committee. As the project moves forward into the conceptual design and feasibility analysis phase of the restoration project, it is critical to understand the site conditions and the issues that must be resolved to assure a successful project.

1.2 Location

The Dutch Slough restoration site is located in the City of Oakley in northeast Contra Costa County and encompasses 1,166 acres bounded on the north by Dutch Slough, on the south by the Contra Costa Canal, on the east by Jersey Island Road, and on the west by Marsh Creek (Figure 1). The site is located on the historic delta of Marsh Creek, which drains approximately 100 acres on the east side of Mt. Diablo and enters the Sacramento-San Joaquin Delta (Delta) on the northwest corner of the Dutch Slough site.

The project site encompasses three adjacent parcels: the 438-acre Emerson, the 292-acre Gilbert, and the 436-acre Burroughs properties (Figure 2). In addition to Marsh Creek, the property is dissected by two dead end sloughs, Emerson Slough and Little Dutch Slough. Separate levee systems protect each parcel from flooding.

1.3 Site History

Prior to European settlement, the Dutch Slough site was a tidal marsh bordered by seasonal and riparian wetlands and Pleistocene dunes at the historic delta of Marsh Creek. The parcels were diked and drained for agriculture during the nineteenth century, perhaps as early as the 1850's. Emerson, Little Dutch Slough, and the eastern portion of Dutch Slough are all artificial channels that were dredged between 1904 and 1910. These artificial channels displaced a pre-existing channel network that was more sinuous and irregular. The only information on the location and character of the original channels comes from four small-scale maps from 1850 to 1908 that all depict different configurations (Figures 3a-3d).

The 1910 USGS quadrangle depicts Emerson Slough and Little Dutch Slough in their current configuration (Figure 4). The eastern mile-long reach of Dutch Slough had not been created by 1910, but was apparently under construction. The Contra Costa Canal is an artificial tidal channel that was constructed in 1937 to deliver water to large areas of Contra Costa County. Big Break, the 1,600 acres of open water to the west of the Dutch Slough site, was once a reclaimed Delta island that was flooded when a levee broke in 1938.

The Emerson parcel was managed continuously as a dairy from 1913 until 2003. The Gilbert and Burroughs parcels were managed as dairies from the early 1900's until the mid 1970's, when the dairies were closed. For the last 30 years they have been managed as grazing lands. All three parcels were zoned for mixed-use development in the 1990 Contra Costa General Plan. In 1997, the Emerson, Gilbert, and Burroughs families entered into a development agreement with Contra Costa County to develop a master-planned community of 4,500 to 6,100 housing units. The site and the development agreement were subsumed by the City of Oakley when it incorporated in 1999. The California Department of Water Resources (DWR) acquired fee title to the site on October 31, 2003 with funds provided by the State Coastal Conservancy (SCC) and the California Bay-Delta Authority (CBDA).

1.4 City of Oakley Community Park and Residential Development

Under a negotiated agreement with the City of Oakley, the Emerson, Gilbert, and Burroughs families will deed 63 acres and approximately 5 miles of trail easements across the site to the City of Oakley for a community park. 55 acres of upland, at the end of Sellers Road, adjacent to the restoration site and including the former dairy site and the Gilbert house and outbuildings, will be owned by the City for the exclusive purpose of developing a community park. The City will also assume title to an 8-acre waterfront parcel east of Jersey Island Road along Dutch Slough. This parcel is isolated from the restoration site by Jersey Island Road.

The City of Oakley has agreed to work collaboratively with DWR and SCC to develop a master plan for public access to both the restoration site and the community park that balances the objectives of the restoration project with the City's recreational objectives. A conceptual illustration of potential public access on the restoration site is depicted in Figure 5. The City plans to develop the community park site with a combination of active and passive recreation including sports fields, interpretive and educational facilities and a non-motorized boat launch at the head of Emerson Slough. The City has also expressed interest in developing a swimming lagoon on the community park site.

The City will consider approving plans to develop more than 2,000 commercial and residential units on approximately 480 acres immediately south of the Dutch Slough site between the Contra Costa Canal and Cypress Road. This development will probably be constructed in the next five years.

1.5 Restoration Planning and Implementation Process

The Dutch Slough restoration project is a collaborative effort of the SCC, DWR, CBDA, and the City of Oakley. The SCC and the CBDA have granted approximately $30 million for acquisition of the project site and project planning. DWR has assumed title to the property and will oversee land management and project implementation. SCC will lead the planning phase of the restoration project, and has contracted with Phillip Williams and Associates, a private consulting firm, to develop a conceptual design and feasibility analysis. SCC has also granted funding to the Natural Heritage Institute (NHI) to provide technical support to the project management team.

2. OPPORTUNITIES FOR RESTORATION, RESEARCH, AND PUBLIC ACCESS

2.1 Elevation and Tidal Marsh Restoration

The Dutch Slough site was acquired because it is one of the few areas in the Delta with land elevations suitable for tidal marsh restoration. Although the Delta historically encompassed over 350,000 acres of tidal wetlands, most of these historical wetlands have subsided 10-25 feet below sea level, too deep for restoration as tidal marsh, due to oxidation and compaction of the organic peat soils (Figure 6). In contrast, the Dutch Slough site has undergone less subsidence because it is composed mostly of mineral soils deposited by Marsh Creek or by Pleistocene sand dune deposits (Figure 7). Approximately one-half of the site is at or above sea level.

Large areas of tidal marsh can be restored on all three of the Dutch Slough parcels by simply breaching the existing levees. The tidal range in the vicinity of Dutch Slough is approximately 3.3 feet (Figure 8). Due to the large cross sectional area of the existing channels along Emerson and Little Dutch Sloughs (Figure 9), it is probably possible to establish the full tidal range on the Dutch Slough parcels without enlarging the existing sloughs. More specific information about the slough bathymetry is necessary to confirm this assumption. With the existing topography, only about one quarter of the site would revert to inter-tidal[1] marsh if tidal inundation were restored. The remainder of the site is either too high or too low for establishment of inter-tidal marsh and would thus become a combination of open water, sub-tidal emergent marsh, seasonal wetlands and floodplain, and uplands.

The large area of each of the Dutch Slough parcels could allow for the development of a dendritic channel network on each of the three parcels, creating a diversity of different sized tidal sloughs ranging from first order dead-end sloughs that will flood and drain daily to deep, high velocity, fourth order channels.

2.2 Topographic, Edaphic, and Habitat Diversity

2.2.1 Topographic Diversity

The topography and soils of the Dutch Slough site are unusually diverse relative to other lands in the Delta. Site elevations range from 10 feet below sea level to 15 feet above sea level (Table 1 and Figure 10).

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[1] Inter-tidal marsh is referred to here as the zone between mean lower low water and mean higher high water.

2.2.2 Edaphic Diversity

The site encompasses ten different types of organic and mineral soils. The diversity of soils will also result in a greater diversity of vegetation and habitat types including riparian and dune species. Coarser mineral soils will allow for establishment of woody riparian species intermixed with freshwater marsh species. The relatively high elevation aeolian deposits of Delhi sands provide an opportunity for restoring Antioch Dune plant species on the site (Figure 11). This opportunity is discussed further in the dune restoration section below.

2.2.3 Habitat Diversity

The topographic and edaphic diversity of the site creates the opportunity for restoring a diversity of wetland and upland habitats at the site. Many wetland restoration sites are intensively graded to create a mosaic of habitat types. At Dutch Slough, it would be possible to create a mosaic of wetland habitat types along a gradient from open water to dendritic tidal marsh to seasonally inundated floodplain and riparian forest without any site grading (Figure 12 and Table 1). Restoration of the site could create large areas of edge habitat including shaded riverine aquatic and riparian habitat types along the property's extensive shoreline. The site has nearly 6 miles of relatively barren levee shoreline along major tidal sloughs and Marsh Creek that could be revegetated. Tidal inundation to the interior of the site would add nearly 10 miles of edge habitat.

The spatial complexity and the daily wetting and drying of the mash edges should help young salmon and splittail avoid predators and provide an abundant source of chiromindae larvae, one of the main food sources for rearing splittail and salmon (Brown, in press). Furthermore, a range of elevation gradients within a wetland site, as well as disturbance regimes associated with sediment input and other fluvial processes, result in greater biodiversity and utilization by native aquatic species (Bayley 1991).

2.2.4 Channel Density and Complexity

The large area of each of the Dutch Slough parcels could allow for the development of a dendritic channel network (Figure 13) on each of the three parcels, creating a diversity of different sized tidal sloughs ranging from first order dead-end sloughs that will flood and drain daily to deep, high velocity, fourth order channels. It may not be possible or appropriate, however, to attain the high density, multiple order channel network characteristic of salt marshes and depicted in Figure 13. According to Dr. Peter Baye (2004), the high channel densities characteristic of salt and brackish marsh is generally not a feature of tule marshes, including freshwater tidal marshes of the Atlantic coast with very similar species composition to our Delta marshes. In the Delta, tules develop loose, peaty muck soils that don't support stable, vertical banks. As a result, tule marshes tend to develop few, large channels with poorly defined banks. In contrast, salt marsh plant assemblages form fibrous peats conducive to relatively stable vertical channel banks.

2.3 Create Habitat Use by Endangered and Declining Species

The area surrounding Dutch Slough provides habitat for numerous declining and endangered species, and habitat restoration at Dutch Slough could significantly improve conditions for many of these sensitive species. Big Break, the Marsh Creek delta, and lower Marsh Creek already harbor Sacramento splittail, Chinook salmon, Delta smelt, and other aquatic species for which the Dutch Slough site will be restored. Big Break is one of only three locations where adult splittail congregate in large numbers (Meng and Moyle 1995; Baxter 1996). Surveys of Big Break have recorded adult splittail, juvenile salmon, and late juvenile Delta smelt (Hanson 2000; Baxter 2000). Adult salmon exhibiting spawning behavior have been repeatedly observed in the Marsh Creek flood control channel, approximately two miles upstream of Big Break (NHI 2003). Juvenile salmon were also collected in lower Marsh Creek during two consecutive years (Slotton 1998). Over a dozen were netted in less than an hour immediately below the creek's fish passage barrier, indicating that salmon are reproducing in Marsh Creek (Cleugh pers. com. 2002).

2.3.1 Waterfowl

Dutch Slough may be an excellent opportunity to restore waterfowl habitat. The Delta and Central Valley wetlands once supported much larger populations of waterfowl (TBI 1988), and waterfowl habitat restoration at Dutch Slough could compensate for losses in habitat associated with future management changes in the Suisun Marsh and the South Bay salt ponds. Waterfowl would benefit from early successional stages of marsh development characterized by an abundance of open deep water bordered by marsh and tidal channels as well as mature, later successional stages. One distinct sub-habitat that may provide substantial habitat value for waterfowl without undue artificial engineering of the marsh (e.g. water control structures and diked marsh) may be shallow, large ponds along the terrestrial edges of the site, where spring high tides and runoff may form brackish seasonal or perennial ponds. Native submerged aquatic vegetation that thrives in open water and ponds (especially pondweeds, *Potamogeton* spp.) would provide valuable foraging opportunities for waterfowl (Baye 2004).

2.3.2 Antioch Dune Restoration

Restoration of endangered dune species such as Contra Costa wallflower and evening primrose may not be feasible without intensive management, but restoration of a broader community Antioch dune species may be possible (Baye 2004). During the Pleistocene, the Antioch dunes were active, mobile sand deposits formed under different climactic and geomorphic conditions. During the Holocene and prior to sand quarrying (early 20th c), the Antioch dunes were characterized by more mature soil profiles vegetated by grassland, scrub, and oak woodland. These ancient, relict dune sand deposits differ from the unstable recent (Holocene) coastal dunes, though they share a few species.

The familiar diverse habitats and rare species associated with the 20th century Antioch dunes were due mostly to quarrying that exposed raw mineral sandy subsoil and artificially reactivated dune instability (Baye 2004). This caused a significant (historic) expansion of species adapted to open sand habitats such as the Contra Costa wallflower and evening primrose. Naturally disturbed exposures of open sand occur along the north-facing shoreline scarp of the Sacramento River and associated bluff-top dune blowouts of limited extent were probably the principal refuge for relict species dependent on bare dune gaps, now endangered plants. Replicating these conditions in the small dune soil remnants at Dutch Slough would be very difficult without intensive management. Altered dune substrate is present, but not the topography and processes that would maintain habitat dynamics.

The dune deposits on the Dutch Slough site are small, very low in elevation and slope, and are highly enriched by soil organic matter (loamy sand), as indicated by soil colors and lush growth of non-native weeds. Native dune plants would not compete successfully under these conditions. Baye did observe, however, that exposure of subsoil strata (unweathered paleodune sand, no appreciable organic content) along the graded road was associated with local abundance of dune lupine (*Lupinus chamissonis*), a few specimens of evening primrose[2], and a marked decline in agricultural weeds.

If restoration of early-succession Antioch dune vegetation is pursued as part of the Dutch Slough project, Dr. Baye suggests inverting the soil profile – excavating deeper mineral sands and depositing them on the surface to create a barren sandy substrate. This would most likely provide a competitively advantageous condition for native dune species relative to dominant local weeds. The small patch of bush lupine and evening primrose along the sandy graded roadside indicates the feasibility of using inverted dune soil profiles (exposing mineral sand) as a restoration method. Nevertheless, evening primrose and wallflower are unlikely to persist in competition with larger shrubs like lupines in the absence of periodic disturbances. Perhaps a mixture of dune scrub (dominant lupine), and some rotational artificial disturbances (allowing alternation of disturbance/gap-formation phases, and recolonization by adjacent seed-sources of forbs in temporary stable periods) would be feasible. The US Fish and Wildlife Service (USFWS) has recommended using "managed rotational trampling" for some urban dune areas of the Golden Gate National Recreation Area to sustain populations of reintroduced gap-dependent dune annuals (Recovery Plan Coastal Plants of the Northern San Francisco Peninsula).

2.3.3 Restoration of Rare, Riparian Plant Communities

The Dutch Slough project may provide an opportunity to restore rare, riparian plant communities that were once more common in the Delta but are now extinct or nearly extinct in the Delta. One example is the willow-ladyfern riparian community described by Herbert Mason. Dr. Baye suggested that the existing levees would provide a suitable opportunity for creating stands of the willow-ladyfern community. The sand mound riparian woodland is another rare plant community that could be restored on the site, perhaps on the sand deposits in the middle of the Burroughs parcel. Baye recommends

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[2] Peter Baye observed a vegetative perennial rosette, which would be consistent with the perennial Antioch dunes evening-primrose (*Oenothera deltoides* ssp. *howellii*), but he was unable to definitively identify it without a flower. He recommends that *Oenothera* rosettes present along the road be flagged and identified diagnostically next spring.

further study of the historic plant communities of the Delta and evaluation of opportunities to recreate some in specialized sub-habitats at Dutch Slough.

2.3.4 Other Resident Species

The diversity of birds and other animals along the Big Break shoreline, in Marsh Creek, and upstream suggest that many other CALFED priority species will use the restored Dutch Slough site. Over 150 native species (Figure 14 and Table 2) have been observed (Glover, pers com; Orlof 2000), of which 18 are CALFED priority species (r - Bank Swallow, Black Rail, Sandhill Crane, Swainson's Hawk, Yellow Warbler; m - Black Tern, Black-Crowned Night-Heron, California Gull, Common Yellowthroat, Cooper's Hawk, Great Blue Heron, Great Egret, Northern Harrier, Snowy Egret, White-Faced Ibis, White-Tailed Kite, Yellow-Breasted Chat, Western Pond Turtle). A recent survey of lower Marsh Creek by a DWR biologist confirmed a western pond turtle population of approximately 15-20 individuals (Hamilton, pers com, 2001). East Bay Regional Park District scientists and USFWS experts believe the area supports giant garter snakes (Bobzien pers. com. 2001).

2.3.5 Rare Plant Species

Dr. Peter Baye tentatively identified two species of rare plants during a brief field visit in December of 2003 (Baye 2003). He observed extensive stands of what appears to be Suisun Marsh Aster (*Aster lentus)* in the ditches south of the old vineyard and along the edges of Marsh Creek bordering the Emerson Parcel. The time of observation was not optimal for diagnostic identification, and there is a possibility that the population is an intergrade with *A. chilensis*. The population should be sampled next fall during flowering and early fruit maturation. This population should be considered for propagation and transplanting during marsh restoration.

On the graded sandy roadside at the south end of the Dutch Slough vineyard site, Dr. Baye also observed an evening-primrose (*Oenothera* sp.) It had a vegetative perennial rosette, which would be consistent with the perennial Antioch dunes evening primrose (*Oenothera deltoides* ssp. *howellii*). It would be remarkable, but not unprecedented, to find a disjunct population of this species outside Antioch dunes. It has also spontaneously appeared (late 1990's) at another Contra Costa County quarry site where development had been planned (Summit development), along with *Oe. deltoides* ssp. *cognata*. (B. Pavlick reviewed this disjunct site.) Baye recommends that any *Oenothera* rosettes along the road should be flagged and identified diagnostically next spring.

2.3.6 Native Fish

There are opportunities on the site to recreate disturbance events that may benefit native fish, including daily and seasonal tidal fluctuation, annual flood inundation, pulses of water and sediment from Marsh Creek, seasonal changes in salinity, and wind and wave action. Evidence from the Yolo Bypass and Cosumnes River suggests that seasonally inundated floodplains and riparian forests may act as spawning habitat for splittail and rearing habitat for juvenile salmon and splittail (Sommer pers. com. 2001; Sommer et al. 1997; Sommer 2001; Crain et al. 2000). Seasonally inundated floodplains and inter-tidal marshes provide important habitat for the rearing and spawning life stages of native

aquatic species including Sacramento splittail, juvenile salmon, Delta smelt, and the giant garter snake (Chotkowski 1999; Junk et al. 1989; Sommer et al. 2000).
Winter and spring flooding of the marsh plain may similarly benefit native fish by creating areas for them to disperse and feed on the marsh plain relatively free of predators. Restoration of Dutch Slough may create prolonged tidal flooding in some dry years, preventing catastrophic declines in splittail by creating critical splittail spawning habitat in dry years when the Yolo Bypass does not flood (Sommer 2000).

Periodic disturbance events associated with fluctuating Delta salinities and flood flows in Marsh Creek could also create conditions favorable to native fish. During dry years, salinity levels of 2 parts per thousand (ppt) salt at Dutch Slough (DWR 1995) may impede non-native species such as *Egeria densa*.[3] Increased local turbidity from flood flows on Marsh Creek will reduce predation on juvenile salmon and splittail, and flood flows will deposit sediment and reshape habitat at the delta of Marsh Creek, triggering early successional processes and increasing habitat complexity. The lack of these types of habitats and processes for early life stages of endangered fish may be a major reason for the decline of these populations (Bennett and Moyle 1996).

Daily fluctuations of the tides, winter flooding, and seasonal variations in salinity will favor native fish and the macroinvertebrates they feed upon by creating habitat niches that are not subject to colonization by exotic predators or invasive aquatic vegetation. The daily and seasonal cycles of wetting and drying combined with the spatial complexity of dendritic tidal marsh and riparian habitats provide essential refuge and feeding opportunities during critical early life stages of endangered transient and anadromous fish when they are both growing and vulnerable to predation. The site's location at the mouth of Marsh Creek and in the western portion of the Delta where the tidal range and salinity fluctuation is greater will accentuate this spatial and temporal diversity. The site's proximity to the confluence of the Sacramento and San Joaquin Rivers and its relatively good connectivity to Suisun Marsh along a corridor of wetland sites[4] increases the probability that native fish will utilize the site.

2.3.7 Delta Smelt

The importance of freshwater tidal wetlands to Delta smelt is more speculative (Lindberg and Marzuola 1993). Although they are primarily an offshore species, tidal wetland vegetation or shallow-water sandy substrate seem like an obvious substrate for Delta smelt spawning, but this has neither been observed in the field nor in the laboratory (Brown, in press). In fact, no one has yet observed Delta smelt spawning in the wild. With sufficient monitoring, the Dutch Slough project could yield important information about where Delta Smelt spawn.

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[3] Research from the Maldivia River Basin in Chile indicates that *Egeria* declines at 2 ppt in the field (Havenstein et al. 1986).

[4] These include Big Break, Little Break, Sherman Island, and Browns Island.

2.4 Marsh Creek Delta

Restoring the Marsh Creek flood control channel and integrating it into the restoration of the Emerson parcel provides a rare and learning rich opportunity to restore tidal marsh and floodplain habitat on the delta of a creek. Deltas are geomorphically and hydrologically dynamic environments. The resulting habitat complexity and the annual cycles of intermediate disturbance events that characterize delta environments serve biological functions that native species have evolved to utilize. Today, Marsh Creek is confined to a narrow trapezoidal channel through its historic delta (Figures 15 and 16). It would be relatively easy to restore a more natural delta with 2-3 anastomosing distributary channels that would convey water and sediment onto the Emerson parcel. Marsh Creek sediments would help build subsided marsh elevations on the Emerson parcel, reducing the area of shallow sub-tidal habitat. Seasonal pulses of sediment and water on to the delta surface would most likely trigger successional processes, resulting in a dynamic and spatially complex system. Restoration at the delta of Marsh Creek will provide an excellent opportunity to study the role of sediment in marsh plain evolution as well as to increase our understanding of splittail and juvenile salmon utilization of tidally inundated marsh and floodplains.

Although Marsh Creek drains 100 square miles, it is unclear whether it conveys a significant amount of water and sediment to its mouth at Big Break. The only long-term stream gauge record for Marsh Creek is the discontinued gauge site above Marsh Creek reservoir, which only measures run-off from 42.6 square miles. Annual run-off at the gauge averaged 8,000 acre feet between 1964 and 1983, but varied widely between zero during extreme droughts and 40,000 acre feet in 1984 (Figure 17). Instantaneous peak discharge from the reservoir has similarly varied from zero in dry years to nearly 6,000 cfs in 1982 (Figure 18). These peaks do not reflect run-off from tributaries and urbanizing areas downstream of the gauge, but a USGS gauge recently installed on the creek near Brentwood may provide an estimate of these inputs.

Quantifying the amount of coarse and suspended sediment in Marsh Creek is more problematic. No records of sediment input are available, but an analysis of the watershed, stream cross sections, and aerial photographs of Big Break provide some quantitative information. Streams draining the coastal range generally have large sediment yields, but 100% of coarse sediment and some fraction of suspended sediment from much of the upper watershed are blocked by Marsh Creek Reservoir, a small flood detention reservoir. Large amounts of sediment may still be delivered by Sand and Deer Creek tributaries, which drain about 20 square miles, as well as from erosion and incision of the Marsh Creek flood control channel. The Natural Heritage Institute compared historic cross section data from the Marsh Creek flood control channel along the boundary of the Dutch Slough parcel and found that the 7,800 linear feet of channel have generally degraded except in the lowest 1,800-foot segment, which no longer conveys the flows of Marsh Creek (Table 3). Figure 16 illustrates some of the surveyed cross sections for aggrading, equilibrium, and incising reaches of lower Marsh Creek. Although this channel degradation trend implies a lack of upstream sediment supply, it could also be a result of incision resulting from flow training in the confined flood control channel.

Although sedimentation surveys have not been conducted for Big Break, data from aerial photographs suggest that the area is gradually accumulating sediment. Figure 19 compares aerial photographs of Big Break from 1939 and 1996. Although we cannot pinpoint the exact dates of these photographs to quantify water surface elevations at the time of the photos, these images support the notion that the tidal wetlands are expanding and that the island maybe rebuilding itself both from sediment and biomass accretion. The mouth of Marsh Creek is currently located on the western edge of Big Break, but historically it emptied into the Delta approximately 1,500 feet to the east at Dutch Slough. As a result, most of Marsh Creek's sediment was historically delivered into the deeper, high velocity environment of Dutch Slough and may never have settled in Big Break. The mouth of Marsh Creek apparently shifted to its current site some time between 1978 and 1986, and some recent aerial photographs clearly show new sediment deposits at the present mouth in Big Break (Figure 20). Core samples and an analysis of the stratigraphy of the recent sediment deposits in the abandoned reach of the Marsh Creek flood control channel could provide use information about the grain size distribution and bedload of Marsh Creek, the magnitude of storm deposition of coarse sediment load, interannual variation in deposition rates, and the amounts of organic accumulation between depositional events.

Diverting some or all the flows of Marsh Creek into the Emerson parcel could expose wetlands on the site to polluted urban run-off from upstream areas. This could be detrimental to the wetlands on the Emerson parcel, but it could provide the benefit of reducing the flow of pollutants from Marsh Creek directly into the Bay-Delta waters.

2.5 Western Delta Location and Salinity Gradients

Seasonal fluctuations in salinity levels at the Dutch Slough site provides an opportunity for controlling salinity-intolerant invasive species and studying the effects of salinity variations on community ecology and marsh evolution. The CALFED Strategic Plan for the Ecosystem Restoration Program (CALFED 2000) recommended the development of a large-scale pilot project that examines the relationship between variable salinity and the maintenance of native species in the Delta, especially in shallow-water habitats:

> "Historically, the Delta and other parts of the estuary had salinity regimes that fluctuated from year to year as well as from month to month and, often, daily with tides. The native organisms presumably evolved in such variable conditions and should be favored by them. Many of the non-native species (e.g., freshwater aquatic plants, freshwater and marine clams), in contrast, may be favored by the more stable conditions now present as the result of regulation of freshwater inflows into the Delta. Opportunities exist to restore large tracts of former tidal shallow-water habitat in the north Delta, lower Yolo Basin, and along river channels and sloughs in the vicinity of Sherman Island. Once these shallow-water habitats are in place, it may be possible to vary the position of the salinity gradient in these areas, thereby testing the

> effects of variable salinity on native and introduced organisms in the shallow-water habitats." (CALFED 2000)

Before the regulation of upstream rivers by dams, salinity levels varied more widely in the Delta (Figures 21a and 21b). During high spring outflow, waters with 2 ppt were pushed out to San Francisco Bay, and during the low-flow fall period, 2 ppt extended deep into the eastern Delta. Under current regulated flow conditions, salinity levels of 2 ppt only extend east to the vicinity of Dutch Slough about one in every four years (DWR Atlas). It is unlikely that these salinity levels and their frequency of recurrence are sufficient to erode the dominance of invasive exotics.

It may be possible to artificially increase salinity levels in the vicinity of Dutch Slough through tide gate structures at Dutch Slough or manipulation of Delta flows elsewhere in the Delta. Constructing some type of tide gate at one of the Dutch Slough parcels may be worth further consideration during the Dutch Slough planning phase. It will probably not be practical, however, to base the Dutch Slough restoration plans on the assumption that the state or federal government will attempt to manipulate salinities with structures elsewhere in the Delta.

It may also be possible to locally increase salinity levels through design strategies that trap and evaporate marginally brackish high tide events. The AMWG discussed the potential for creating shallow ponds on high surfaces and along the perimeter of the marsh that would flood on high tide events. Overtime, evaporation would concentrate salinity levels in the ponds creating a competitive advantage for native species. Orienting tidal sloughs parallel with the prevailing winds would also help flood these high pond features and accentuate evaporation.

2.6 Develop Techniques for Restoration of Subsided Lands

Although the Dutch Slough restoration site is not as subsided as most Delta lands, it encompasses 370 acres that are between 3 and 10 feet below sea level. Approximately 50 acres are 7 to 10 feet below sea level. These subsided lands provide an opportunity for field-testing various techniques to restore subsided lands to elevations suitable for tidal marsh. Several techniques could be tested as part of the overall Dutch Slough project. Dredged spoils from other portions of the Delta could be imported to the site for placement on subsided peat soils, and compaction of the underlying soils could be measured over time. Sediments from Marsh Creek could be diverted onto the Emerson parcel to build up the most subsided areas. Tules could be cultivated to encourage bio-accretion, particularly on less subsided areas. Finally, excess rice straw bale could be imported from the Sacramento Valley to build up subsided areas.

DWR has contracted 36,000 tons of rice straw bale that is available for a subsidence reversal pilot project at Dutch Slough. Ideally, wetland vegetation could be planted on top of the rice straw, but rice straw is not a suitable substrate for supporting vegetation unless it is first capped with approximately 2 feet of soil. Straw (or rice wastes), like sawdust, woodchips, or any material with very high C:N ratios, is unsuitable as a growing medium (root zone substrate) for wetland vegetation, except in the most extreme eutrophic conditions. High C:N ratios induce strong microbial competition for soil N, and strongly immobilizes available nitrogen, inducing acute nutrient deficiency. Thus, if straw material is considered as a substrate to elevate subsided diked and drained delta marshlands, it should be restricted to foundation or sub-layers well below the rooting zone (about 30 cm) of marsh vegetation.

2.7 Cultivate Managed Nontidal Marsh as Tool for Site Preparation

The existing network of irrigation ditches and drains creates an opportunity to easily cultivate marsh vegetation (tules) before the site is flooded. Establishing tules on the site before reintroducing tidal action could serve several useful functions that would reduce competition from exotic species, cost effectively facilitate vegetation establishment, accelerate marsh plain accretion, and manage water quality. Marsh establishment in non-tidal conditions can be achieved by simple flooding and drawdown schedules used by waterfowl managers. It can be enhanced efficiently by distributing widely spaced plugs of rooted tules, or even disking in dormant rootstocks of tule-cattail sods from dredged marsh areas. Managed marsh could be developed quickly (probably 3 years for about 70% cover) as an interim management measure to stabilize flooded tules in the intertidal zone. A survey of tule establishment suggests that tules can colonize and persist in water of more than 1 foot below mean lower low water (Simenstad et al, 2000). It is possible that tules established prior to flooding can persist at even greater depths. It may still be advantageous to cultivate tulles on elevations where they cannot persist over the long run. The most basic functions of developing a dense emergent marsh at elevations at and below those at which they would survive in tidal conditions include:

- Stabilizing the underlying substrate, and preventing erosion, resuspension, and export of sediment from the site during storm wind-wave conditions;
- Providing highly significant bed roughness to accelerate sediment accretion and damp and dissipate wind-wave energy, relative to bare, planar bed conditions;
- Providing a persistent (2-3 year for sacrificial stands) canopy above the substrate in subtidal areas, reducing light availability and recruitment of *Egeria* clones while the canopy persists, and accelerating accretion of subtidal substrate (potential subtidal *Egeria* habitat) to intertidal elevations unsuitable for *Egeria* (tule-dominant);
- Providing complex submersed stem architecture for fish habitat;
- Pre-establishing persistent mature clonal populations of tules and cattails across the entire intertidal zone, most of which would be unavailable to direct seedling establishment in tidal conditions;
- Accelerating peat accretion and marsh restoration; and
- Assimilating excess nitrates and phosphorous thus reducing water quality degradations associated with previous dairy operations on Emerson Slough.

2.8 Public Access

The Dutch Slough site will provide an opportunity for people to access the Delta shoreline and learn about the process of wetland restoration. The popular Marsh Creek Regional Trail, which extends from Antioch Pier to the City of Brentwood already traverses the southwestern boundary of the site. The project team will develop a public access master plan to define the exact location and configuration of the trail network. The conceptual trail plan (Figure 5) negotiated with the City of Oakley assumes that the trails will be largely confined to the top of the levees and the southern edge of the site near the base of the Contra Costa Canal, but this conceptual plan may be revised during development of the public access master plan. As currently planned, the trail system will circumnavigate the Emerson parcel along the existing levee road. The road will eventually be paved to accommodate emergency vehicles and policing. Wildlife viewing platforms and small-scale fishing piers may be developed along the trail to sufficiently provide for and direct public access. The interior of the Emerson parcels will be open to canoe and kayak access along a prescribed water trail. No trails will be constructed on the levees surrounding the Gilbert parcel or on the west levee of the Burroughs parcel.

2.9 Contra Costa Canal Buffer

The Contra Costa Canal creates a buffer between the Dutch Slough restoration site and neighboring lands to the south that will be developed as residential communities. As a result of the Canal, the only places people can enter the site from land are from Jersey Island Road on the east, Sellers Road to the south, and from the Marsh Creek Trail on the west.

2.10 Adaptive Management

As one of the first large-scale tidal marsh restoration projects in the Delta, the Dutch Slough project provides a significant opportunity to improve understanding of restoration science in this ecosystem. The site is easily subdivided into three similar parcels that will allow the project managers to treat each parcel differently to test restoration techniques and hypotheses in the spirit of adaptive management. Adaptive management employs the scientific method to maximize the information value of restoration and management actions. With the assistance of a panel of scientists, the project team will design restoration actions to test hypotheses about how ecosystems function and how best to restore them. In this respect, adaptive management interventions are conducted as experiments. This does not suggest that management interventions are conducted on a trial-and-error basis, because management actions are guided by the best ecological engineering information available.

The California Bay-Delta Authority's Strategic Plan for Ecosystem Restoration (CALFED 2000) proposes employing adaptive management to resolve the critical uncertainties that currently hamper efforts to improve resource management and design restoration actions. The Strategic Plan identified 12 critical uncertainties that should be evaluated in the course of restoration activities and 8 opportunities for pilot projects in the Delta to reduce these uncertainties. The Dutch Slough site is well suited for addressing the following uncertainties:

- Strategic Plan Uncertainty #1, Introduced Species: Initiate a program that, among other things, establishes habitat conditions that favor native fishes.
- Strategic Plan Uncertainty #6, Importance of Fresh Water Marsh Habitat: Develop large-scale pilot projects accompanied by long-term monitoring to resolve key uncertainties regarding the role of fresh water marsh for sustaining native fish and ecosystem productivity.
- Strategic Plan Uncertainty #7, Contaminants in the Central Valley:
- Strategic Plan Uncertainty #12, Importance of the Delta for Salmon: Pilot projects to enhance and measure fry rearing in the Delta.

The following opportunities could be pursued at the Dutch Slough site:

- Strategic Plan Opportunity #2: Expand or enhance seasonal near-Delta floodplains
- Strategic Plan Opportunity #3: Initiate several large-scale pilot projects using different approaches to restoring tidal marshes in the Delta.
- Strategic Plan Opportunity #4: Develop means to control invasive aquatic plants in the Delta.
- Strategic Plan Opportunity #7: Establish large-scale pilot projects on leveed Delta islands to test and monitor techniques for returning subsided Delta islands to shallow-water and marsh habitats.
- Strategic Plan Opportunity #8: Develop large-scale pilot projects that examine the relationship between variable salinity and the maintenance of native species in the Delta, especially in shallow-water habitats.

3. PROJECT IMPLEMENTATION ISSUES AND CONSTRAINTS

3.1 Levee Management

In order to avoid negative impacts to neighboring islands and Delta water quality, the project must be designed to largely maintain the current configuration of levees around the Dutch Slough parcels. To allow for tidal restoration, the levees must necessarily be breached, but these breaches should be relatively small and engineered so that they do not expand over time. Partial or complete removal of the levees would increase wave fetch and potentially increase wave erosion on neighboring Delta islands. Increased erosion of levees on neighboring islands would increase levee maintenance costs for neighboring landowners and could result in levee failure on neighboring islands. Partial or complete removal of the levees could alter Delta hydrodynamics and potentially increase salinity levels in drinking water exported from the Delta. This water quality consideration is addressed below.

The interior levee slopes, including the Contra Costa Canal, should be bio-engineered to prevent erosion of the inside of the levees once tidal inundation is restored to the parcels. The eroded remnant levees around Big Break and Franks Tract illustrate how the levees that once surrounded these flooded Delta islands eroded over time due to erosion of the interior levee bank by wave action. Figure 22 depicts a conceptual bio-engineering design that would minimize erosion of the interior levee bank and thereby maintain the existing levee configuration indefinitely. The bio-engineered levee would be graded at a gentle slope and planted with marsh and riparian vegetation to dissipate wave energy. The top elevation of the levee could be lowered below its current height, because the levee would no longer need to prevent inundation of the interior. Rather, the new purpose of the levee would be to interrupt wave fetch and minimize hydrodynamic changes in the Delta.

3.2 Water Quality

Tidal marsh restoration could alter local and regional water quality by altering salinity patterns, the formation of dissolved organic carbons, and the bio-availability of mercury contamination in the Delta. Maintaining and improving water quality for the ecosystem and for human consumption is a high priority goal of CBDA and DWR. Consequently, it is essential to design the Dutch Slough project to minimize or avoid adverse water quality impacts. The following section provides a summary of the main water quality issues and constraints.

3.2.1 Altering Salinity Gradients Through Changes in Channel Geometry and the Tidal Prism

Recent modeling showed a strong link between changes to the geometry of the Delta/Suisun Marsh and hydrodynamic changes, which affect salinity mixing. Consequently, DWR conducted preliminary hydraulic modeling to evaluate potential changes to the salinity regime throughout the Suisun Marsh and Delta (Figure 23). DWR conducted its own one-dimensional analysis and contracted with RMA to run a two-dimensional analysis with their model. Modeling of the preliminary breach scenarios for the full 1,200-acre Dutch Slough project indicated only a slight and very local increase in salinity during critically dry hydrology. These small changes are within the tolerance of the model. Urban water supply diversions were not affected.

Additional modeling analysis will be necessary during project planning to evaluate the potential hydrodynamic and water quality effects of various restoration alternatives. With careful design of the levee breaches and tidal channels, the proponents are hopeful that negative water quality impacts can be avoided. Furthermore, when the project is analyzed as part of preliminary regional plans for Big Break, Franks Tract, and Lower Sherman Lake, salinity changes are very positive. Monitoring of baseline and post-implementation phases will be necessary to detect any changes in salinity patterns and modify the project accordingly.

3.2.2 Dissolved Organic Carbons

Restoring tidal wetlands could potentially increase the level of dissolved organic carbons (DOCs) in Delta waters. Dissolved organic carbons provide nutrients that can benefit the ecosystem by enhancing productivity (Jassby et al. 1993), but when disinfected with chlorine, chloramine, or ozone as part of the drinking water treatment process, they can be harmful to human health (DWR 1994). Current land uses in the Delta and its watershed currently provide significant inputs of dissolved organic carbons to Delta waters (Amy et al. 1990*)*. Some forms of DOC play an important role in the formation of a variety of chemicals referred to as disinfection byproducts (DBPs), which are suspected carcinogens. These compounds are formed when water is disinfected in drinking water treatment plants. There are various forms of DOC, and some of them are more prone to forming DBPs than others (Fram 1999).

Tidal marsh restoration in the Delta will create DOC, but it is unclear whether they will create more or less harmful DOC than already exists (Brown, draft). The net impact of restoring farmlands to wetlands is unclear. Depending on the type of restored wetland and a variety of factors including soil, location, and hydrodynamics, the restored wetland may create more or less reactive DOC than the agricultural land it replaced. A review of Jassby et al. (1993) indicates that restored tidal wetlands will export organic carbon to adjacent deep-water habitats, but it is unclear how much will be exported or whether it will significantly increase formation of DBPs. Some fraction of the DOC exported from tidal wetlands will likely be very reactive in formation of DBPs, but it is uncertain how large this source amount and reactivity would be compared to other sources of DOC. The amount and types of DOC created by a particular wetland restoration project may vary depending on construction methods used to restore the wetland. Agricultural land opened to tidal action for wetland restoration might export more organic carbon than agricultural land that is covered with clean dredge spoils as part of project construction. Agricultural lands and restored wetlands in the western Delta, downstream of pumps that divert water from the Delta, may be a smaller source of DOC in drinking water than lands near the pumps. The Dutch Slough Project should be designed to address these issues and quantify the production of DOC.

The effect of DOC on drinking water quality depends on the drinking water treatment method. Drinking water treatment methods that depend solely on chlorine are more likely to result in production of trihalomethanes, forms of disinfectant byproducts that are regulated by the U.S. Environmental Protection Agency. The Contra Costa Water District relies largely on ozone disinfection, a process that significantly reduces the production of trihalomethanes, but can cause the formation of bromate, a different regulated DBP. The District does, however, utilize chloromine to treat residual carbon resulting in some potential trihalomethane formation (Gartrell, pers com, 2002). Since the Dutch Slough project is in close proximity to Rock Slough, one of the main drinking water intakes for the Contra Costa Water District, any additional DOC created as a result of the Dutch Slough project is a concern for the District (Gartrell, pers com, 2002).

As with other tidal marsh restoration projects, it is unclear whether the Dutch Slough project will result in increased DOC from existing conditions. Historically the land has been managed for a dairy operation and irrigated pasture. Irrigation drainage water from these operations may presently be contributing large quantities of DOC and other potentially harmful constituents, such as nitrates, to Delta waters. Baseline monitoring and coordination with regulatory agencies, CALFED, and research scientists will be necessary to measure existing levels of DOC discharge from the site and to identify restoration design strategies to reduce DOC export from the site.

The project team will monitor levels of DOC and other nutrients during project implementation and after the site has been restored to tidal marsh. If the site does increase levels of DOCs that adversely affect drinking water quality, the project sponsors will work with the CALFED program to appropriately identify mitigation measures. The CALFED BDPAC drinking water subcommittee is currently working on a mitigation framework that could facilitate mitigation of all CALFED-sponsored projects that might impact drinking water quality, including water supply enhancement and ecosystem restoration projects (Gartrell, pers com, 2002). Under such a framework, the CALFED program would fund water quality improvement projects to more than offset the potentially adverse effects of other projects to ensure that the CALFED Bay-Delta Program can meet its goal of continuous improvements in drinking water quality. The Contra Costa Water District has suggested that funding to implement the CALFED Rock Slough and Old River Water Quality Improvement Projects or to line the Contra Costa Canal might be appropriate mitigation measures for projects that harm Contra Costa drinking water quality (Gartrell, pers com, 2002). The project partners anticipate that this sort of global mitigation program would be the most appropriate vehicle for resolving conflicts that are likely to arise from implementation of the CALFED program.

3.2.3 Methylmercury

Mercury methylation resulting from tidal marsh restoration is a serious issue for all tidal marsh restoration projects in the Bay-Delta ecosystem (Davis et al. 2002). Mercury enters the Bay-Delta environment from urban run-off and several upstream sources in the Sierra and Coast Ranges (Davis et al. 2002). Mercury can present a health problem if it is converted to methylmercury. Methylation of mercury is controlled by environmental conditions such as pH, dissolved organic carbon, oxidizing environment, and the presence of ions such as chloride and sulfate.

During the last decade several studies have evaluated the sources, concentrations, and fate of mercury in the Marsh Creek watershed, Big Break, and Delta waters near the Dutch Slough site. There is an abandoned mercury mine on Marsh Creek 30 miles upstream from the Dutch Slough site (Figures 24a and 24b). A three-year study of mercury concentrations in fish and macroinvertebrates in the Marsh Creek watershed found that levels of methylmercury in lower Marsh Creek were significantly lower than levels in upper Marsh Creek and hypothesized that the transport of mercury downstream from the mine was significantly impeded by the Marsh Creek reservoir (Slotton et al. 1998). The authors caution, however, that the number of samples from lower Marsh Creek was not sufficient to characterize a long-term trend and that future pulses of mercury from upstream could be triggered by large storm events.

Historical geomorphic analysis suggests that Marsh Creek may not have historically deposited mercury at Big Break (NHI 2002). Soil and geologic maps indicate that the dominant course of Marsh Creek during the Holocene has been toward Discovery Bay to the east (SCS 1977; USGS 1994). By the late nineteenth century, the Marsh Creek channel had assumed its current alignment but maps from that era show the channel as discontinuous, interrupted by the sandy dune soils two miles upstream of its current mouth (State Geologic and US Surveys 1871; McMahon 1908). Early USGS maps and flooding records indicate that Marsh Creek, due to its complex and avulsing pattern near Brentwood, spilled most of its floodwaters overbank, depositing the bulk of sediments and water along the channel rather than conveying it to Big Break (Contra Costa County 1953). Marsh Creek did not flow directly to Big Break until flood control channel improvements were implemented in 1962, only a few years before the Marsh Creek reservoir was completed. Evidence from Slotton et al. (1998) indicates that the reservoir now captures the vast majority of the stream's mercury load.

A CALFED-funded assessment of methylmercury distribution, production, and bioaccumulation in the Delta measured low levels of mercury at the mouth of Marsh Creek and in Franks Tract and Sand Mound Slough (near Dutch Slough) relative to other sites in the Delta (Suchanekl et al. 1999). The study concluded that mercury levels in the Central Delta were relatively low compared to upstream locations where tributaries enter the Delta along its northern, eastern, and southern periphery. Big Break and the mouth of Marsh Creek were about average for the Central Delta. Mercury concentrations in largemouth bass and white catfish from the Delta were also lower than concentrations from the same species sampled in the Sacramento and San Joaquin Rivers (Davis et al. 2002).

Even if Marsh Creek did deliver significant quantities of mercury to Big Break over the last century and a half, a network of levees and berms would have prevented sediment (and mercury) deposition on the Dutch Slough properties, which are surrounded by levees on the northern and western edges. Berms associated with the railroad grade and the Contra Costa Canal both ponded and diverted Marsh Creek floodwaters away from the properties eastward toward the vicinity of Knightsen (Contra Costa County Flood Control and Water Conservation District 1953).

In the planning phase, the project team will evaluate measures for reducing the potential for mercury methylation. With careful project design it may be possible to minimize or avoid any deleterious effects (Davis et al. 2002; Suchanekl 1999). For example, maximizing tidal circulation will reduce the potential for anoxic conditions that could increase mercury methylation. One recent study reported some success utilizing iron amendments to reduce net mercury methylation in wetland sediments (Mehrotra et al. 2003). Prior to project implementation, the project partners will work with experienced scientists to measure baseline levels of mercury in animal tissues in the project vicinity as recommended by Davis et al. (2002). Monitoring will continue after implementation to measure any changes in methylmercury levels. The project team will identify mitigation measures in the design process and implement them if methylmercury levels rise significantly over the long term.

3.2.4 Flood Control and Seepage along the Contra Costa Canal

Because the projects will re-introduce full tidal stages to the lands bordering the Contra Costa Canal, Contra Costa Water District (CCWD) has raised two concerns. First, whether the canal bank would be subject to erosion or high water over topping. And second, whether localized changes in the shallow groundwater table would increase seepage of higher saline waters into the unlined canal. The Knightsen Town Advisory Council has also raised the concern that seepage and elevated groundwater levels may impact septic systems south of Cypress Road. Groundwater levels in this area are already within 18" of the ground surface (Contra Costa County Department of Health Services).

Erosion of the canal bank could be prevented by grading and planting berms or slopes at the base of the canal bank to diffuse wave energy. In the planning stage, evaluation of high stage elevations on the restored site will be necessary to determine if they exceed the elevation of the north bank of the canal, posing an overtopping threat. If the predicted flood stages are greater than the elevation of the north bank, then it may need to be raised to prevent overtopping.

The potential seepage of groundwater from the marsh site into the canal and areas south should be monitored, analyzed, and modeled to determine the magnitude of any impacts. During the planning phase the project management team will coordinate with the Contra Costa Water District to measure groundwater gradients at the site and determine if groundwater seepage into the canal is likely. Potential mitigation measures could include: 1) Engineered features to isolate any southerly migration of shallow groundwaters toward the canal and 2) Cost-sharing with CCWD to isolate this reach of the canal by lining the canal or containing it within a pipeline.

3.2.5 Cow Manure and Nitrate Pollution

Given the Emerson property was previously used as a dairy, the soil is expected to have elevated levels of nitrates. ENGEO, a geotechnical and environmental consulting firm, conducted soil and ground water analyses at seven locations on the Emerson parcel in 2003 when the property was being prepared for sale to DWR (ENGEO, 2003). They measures total nitrogen, NO3, NO2, and total Kjeldahl nitrogen. NO3 or NO2 levels at four wells exceeded regulatory criteria/guidelines for drinking water, but the average NO3 and NO2 levels were below state drinking water criteria. The reported nitrate and nitrite concentrations for the soil samples were well below the residential and aquatic toxicity criteria developed by the USEPA.

Both ENGEO staff who conducted the measurements and DWR staff who reviewed their findings concluded that concentrations of nitrate and nitrite in the soil and groundwater on the Emerson Parcel are not a problem. DWR staff concluded that nitrogen concentrations will not be of "concern from water quality, regulatory, or other standpoints" (DWR, 2003). ENGEO staff stated that "the reported nitrate impacts would not pose long-term impacts to aquatic habitat." ENGEO further reported that the locally high levels of nitrate were to be expected given the annual placement of manure waste across the property, but predicted significant attenuation of total nitrogen levels over the next several years due to the recent cessation of manure disposal on the site.

It may be possible to further attenuate nitrate levels prior to tidal inundation with on-site bio-remediation measures. The most obvious bio-remediation strategy would be to cultivate tules and other wetland vegetation in a non-tidal, managed wetland before opening the parcel to tidal inundation. Many perennial emergent marsh plants have high capacity for uptake and assimilation of nitrogen, and can stabilize it and underlying soils in dense root/rhizome mats. Cattails especially are capable of efficient and rapid nitrogen uptake. Managed marsh (seasonal flooding and drawdown in nontidal conditions) could be developed quickly (probably 3 years for about 70% cover) as an interim management measure to stabilize and sequester excess soil nutrients on the site (Baye, 2004).

3.2.6 Upstream Development and Polluted Run-off

Polluted run-off from the Marsh Creek watershed and on the properties immediately south of the Contra Costa Canal could degrade the quality of habitat on the restored parcels. Over the next two years, the Coastal Conservancy will be managing a watershed awareness and stewardship program to develop programs that will ultimately reduce the amount of polluted run-off discharged to Marsh Creek and the Dutch Slough site. This effort will be coordinated with stormwater management programs currently being planned and implemented by Contra Costa County and local municipalities in the watershed. In the planning phase, it may be worthwhile to consider on-site stormwater management strategies to minimize the impact of poor water quality. These could include diverting the flows of Marsh Creek through a biofiltration wetland as it enters the Dutch Slough site.

3.3 Easements, Utilities, and Infrastructure

Several utility easements traverse various portions (Figure 25) of the Dutch Slough site, and the restoration will need to be designed so that it does not interfere with the operation of these facilities. A PG&E high voltage power line traverses the northeast corner of the Burroughs parcel. Restoration on that parcel will be designed to prevent erosion of the foundations at the base of the towers. A PG&E gas line passes underneath the site across the Burroughs' parcel. The Ironhouse Sanitary District conveys treated sewage effluent through a pipeline along the northwestern border of the Emerson parcel. The pipeline is located at the toe of the interior levee at an elevation that may be inundated by tidal waters. In order to maintain access to the pipeline for maintenance without disrupting future wetlands, it may be necessary re-grade the levee or move the pipeline. Lastly, RD 799 maintains and operates 2 pumping stations on the Burroughs parcel that will need to be restored before restoration commences on that parcel.

3.4 Boating and Recreation

Boating and recreation on Emerson, Dutch, and Little Dutch Sloughs is a popular activity that will not be prohibited by restoration or management of the Dutch Slough parcels. Restoration design, particularly along the levees, should anticipate these uses and potentially accommodate them in a manner that is consistent with the ecological, educational, and research goals of the project.

3.5 Mosquito Control

Mosquitoes and mosquito borne diseases are a significant public health and public perception issue that must be carefully addressed in the design and management of the project. Dr. Karl Malamud-Roam, the environmental specialist for the Contra Costa Mosquito and Vector Control District is an expert in field wetland design and management to minimize the risk of mosquito borne diseases. The Dutch Slough project management team is committed to working closely with Dr. Malamud-Roam to develop an integrated pest management (IPM) program that will guard against harmful mosquito infestations. The IPM program should include a multi-tiered approach that includes habitat design to minimize mosquito habitat, regular monitoring of mosquito populations, cultural practices to reduce the potential for mosquito infestations, biological agents to suppress mosquito populations when necessary, and selective use of pesticides in a manner that minimizes risks to humans and beneficial non-target organisms.

3.6 Gas Wells and Mineral Rights

Under an existing lease, there are eleven gas wells on the Burroughs and Gilbert parcels. Only well #6-1, on the eastern portion of the Burroughs site is still active, all other wells are scheduled to be plugged and abandoned consistent with state regulation on an accelerated schedule. However, DWR does not own the mineral rights for the Dutch Slough property. As part of the purchase agreement, it was agreed that future drill pads would be set aside to allow the mineral rights holders access to gas in the unlikely event that future drilling on the site became economically viable.

3.7 Invasive Exotic Species

Invasion of exotic plant and animal species could significantly limit the benefits of restoration for native species. The majority of tidal wetlands in the Delta are sub-tidal areas dominated by exotic species, particularly *Egeria densa*. If these shallow-water areas are located adjacent to tidal marsh and inundated floodplains, they may diminish the value of these habitats for target native fish species by increasing predator populations. Studies of fish in tidal marshes in the Delta are rare, but there are several studies of fish in its shallow-water habitats (California Department of Fish and Game Resident Fish Monitoring Survey 1980–84, 1995, 1997, 1999 in Brown, in press). They indicate that introduced species are likely to dominate freshwater tidal marsh and associated shallow-water habitats.

If flooded without any grading, more than half of the Dutch Slough site would consist of sub-tidal marsh that is dominated elsewhere in the Delta by exotic species. Tidal inundation of the entire site at its current elevations would create approximately 375 acres of shallow open water and another 225 of sub-tidal emergent marsh.[5] The shallow-water areas on the neighboring flooded islands of Big Break and Franks Tract are infested with dense populations of *Egeria densa* (Figure 26) and other non-native submerged aquatic vegetation (SAV), providing a nearby source of continuous colonization of the Dutch Slough site. Despite the problem of noxious, invasive non-native *Egeria densa* in shallow open water habitats of the Delta, there are several species of native SAV that may provide benefits for waterfowl and native fish. Design and management strategies that favor native SAV species may be an effective approach for reducing dominance by non-native SAV (Baye 2004).

Minimizing the dominance of exotic species will be a major design challenge at Dutch Slough. There are several potential design strategies for achieving this objective, including on-site grading or import of fill materials to minimize sub-tidal elevations and maximize the area of inter-tidal marsh on the assumptions that inter-tidal marsh is less hospitable to exotics and more favorable to natives. While on-site grading would increase the area of inter-tidal habitats, it would necessarily reduce the diversity and area of upland habitats at the site. Similarly, seasonally increasing salinity levels may also favor natives. Intensive cultural practices such as integrated pest management may be necessary to limit submerged aquatic vegetation.

Invasive upland plant species could also prove problematic. In particular, peppergrass and *Arundo donax*, which are present on nearby parcels, could overwhelm the high marsh and low floodplain zones. Star thistle and Russian thistle are already present on the upland and dune areas and could similarly degrade the quality of restored habitats for people and target species.

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[5] This assumes that emergent tule marsh would be able to persist on surfaces 3 feet below mean lower low water.

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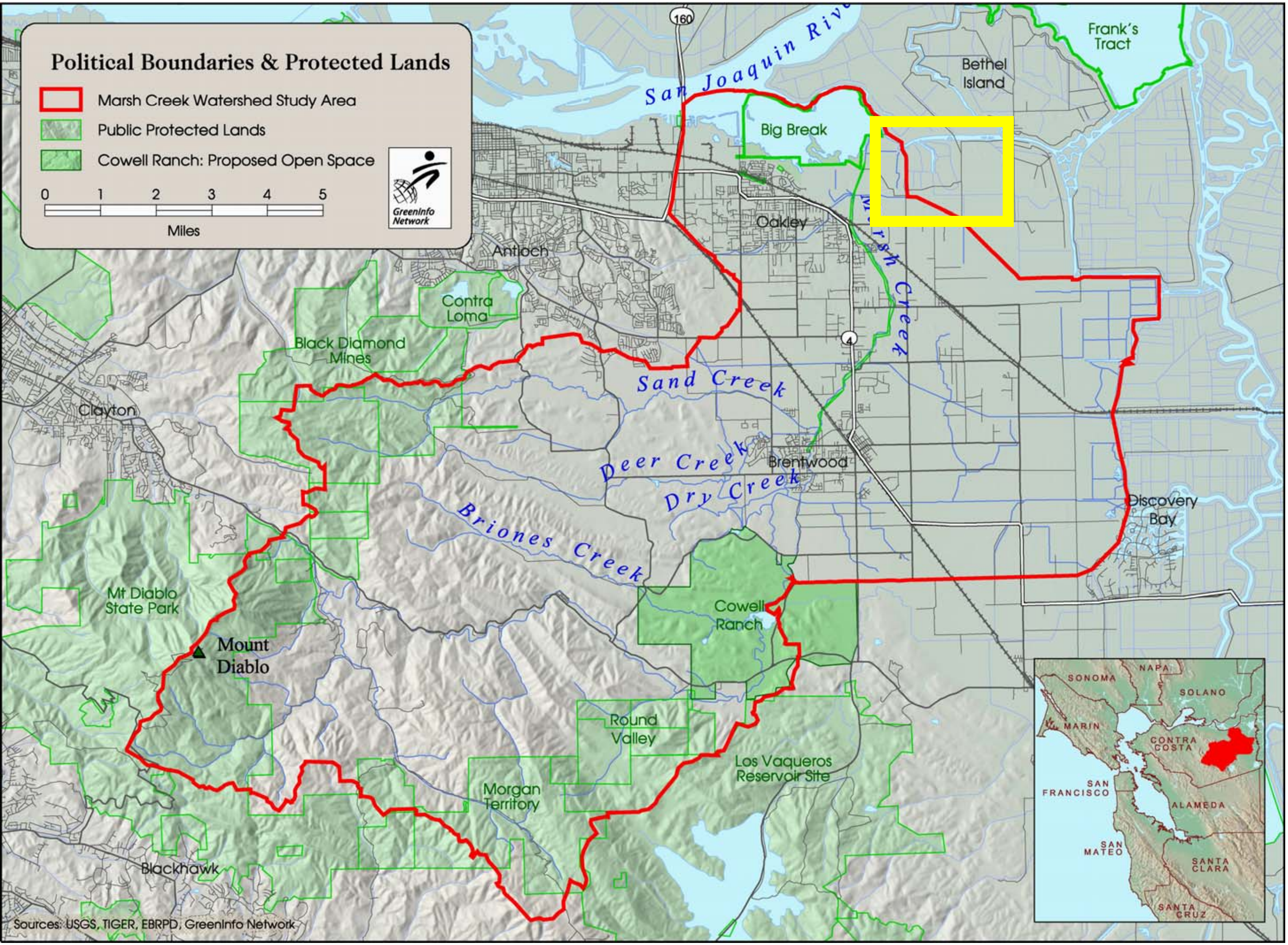


Figure 1. Dutch Slough site location.

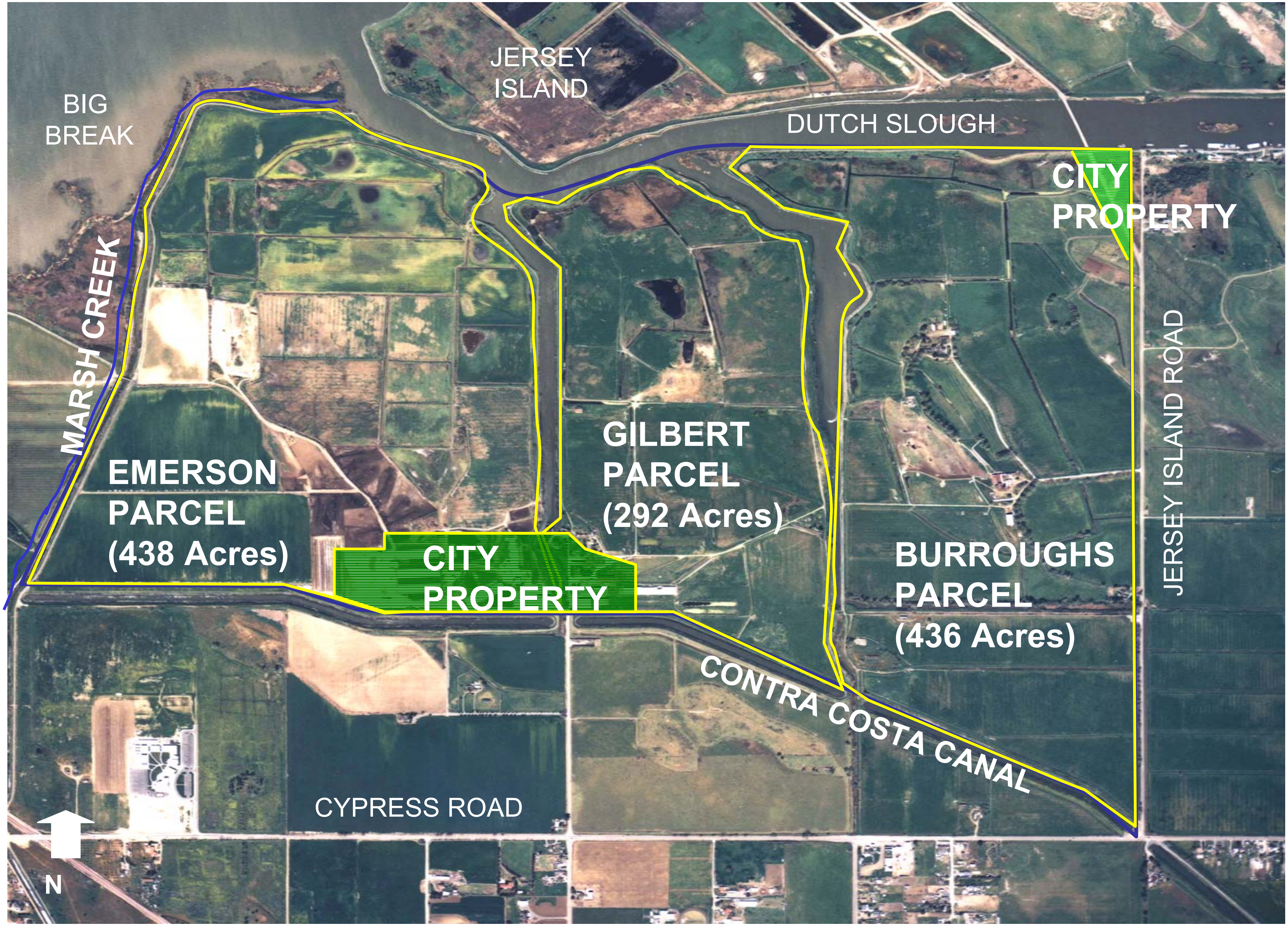


Figure 2. Annotated aerial of the Dutch Slough restoration site.

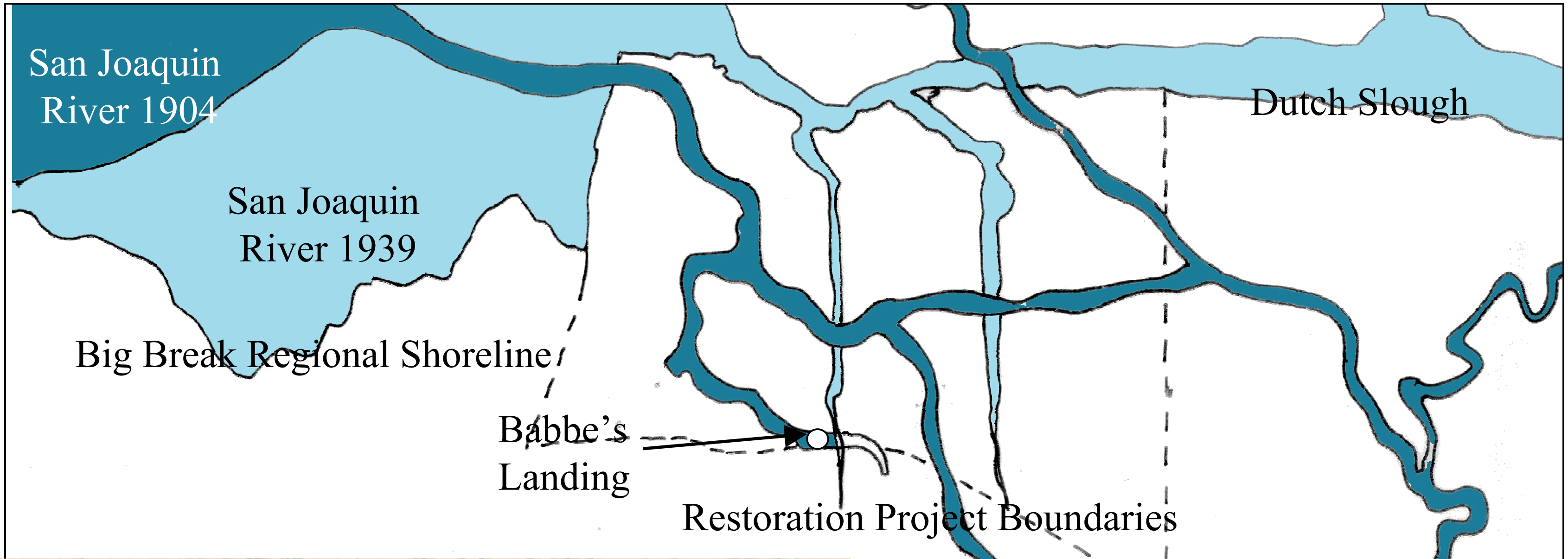


Figure 3a. Historical map and hydrography of the Dutch Slough area.

Figure 3b. Historical map and hydrography of the Dutch Slough area. 1904 and 1850 boundary of the San Joaquin River.

Figure 3c. 1871 historical map and hydrography of the Dutch Slough area. Courtesy of State Geological and US Survey.

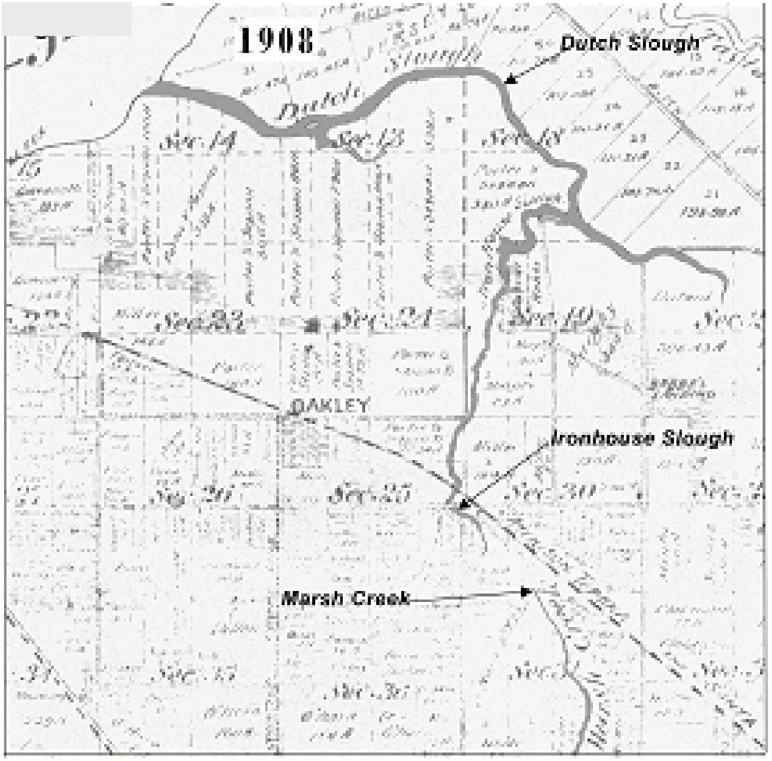


Figure 3d. 1908 historical map and hydrography of the Dutch Slough area. Courtesy of McMahon.

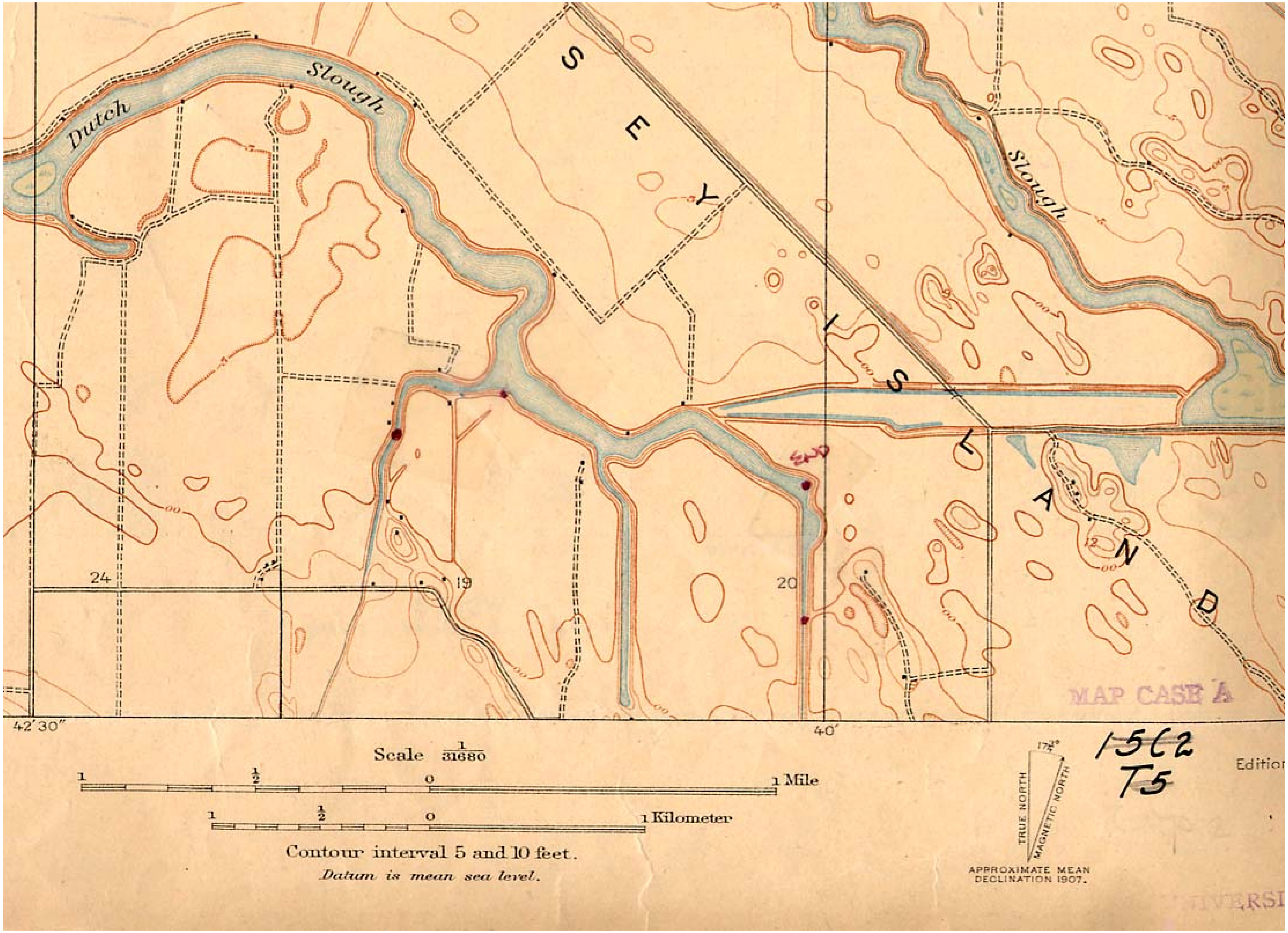


Figure 4. 1910 USGS Jersey Island Quadrangle. Surveyed in 1906-1908.

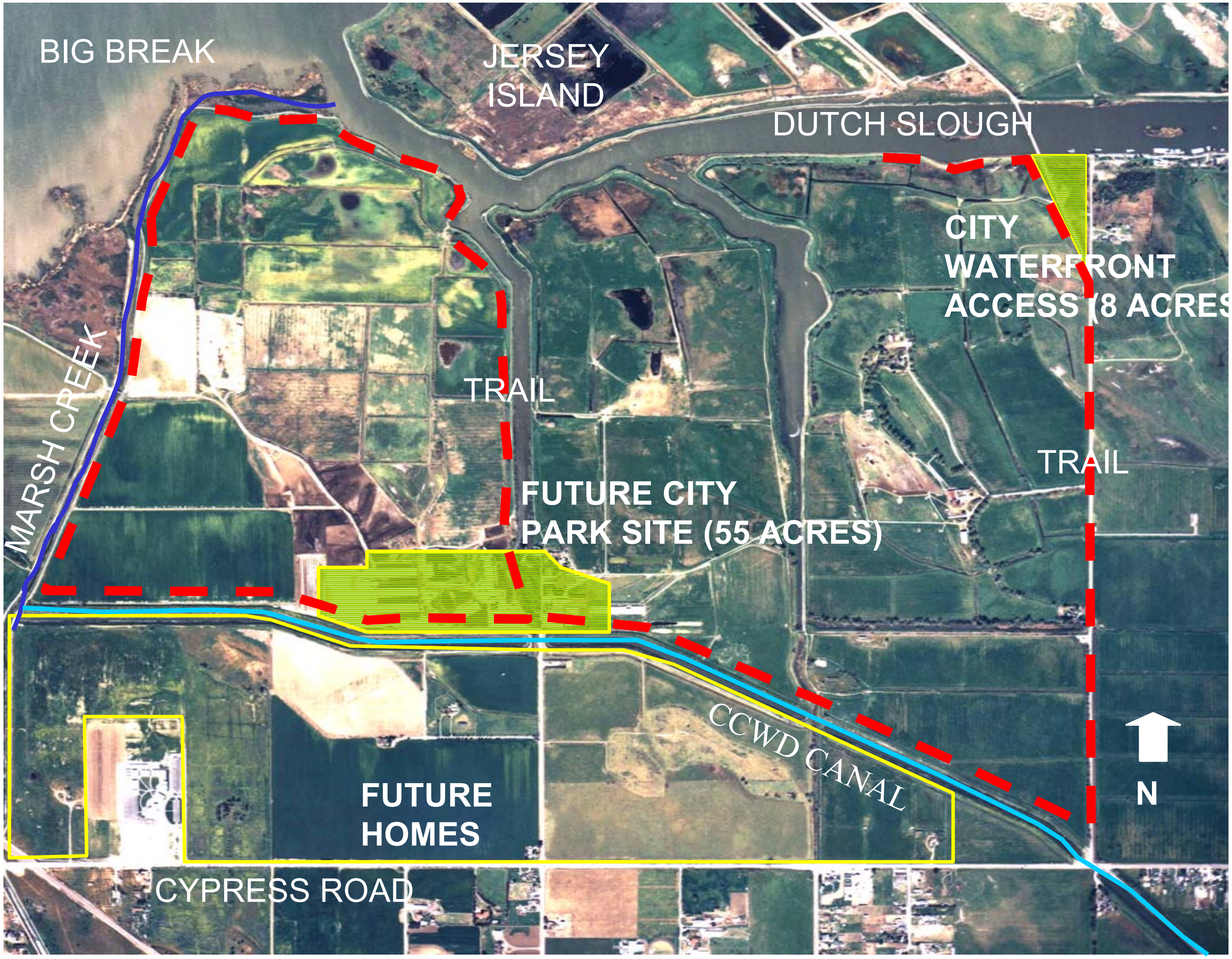
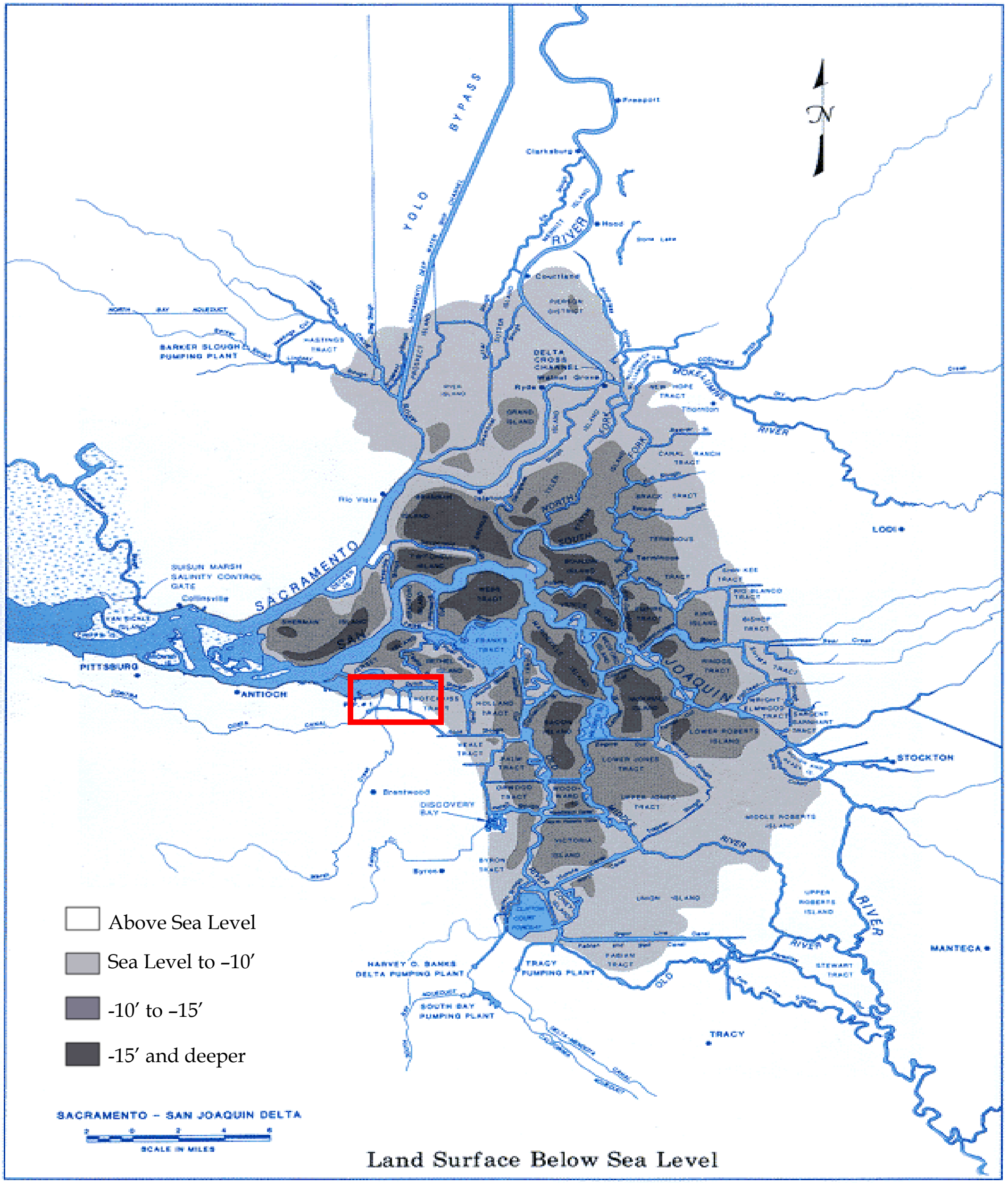


Figure 5. Community park and trails map.

Figure 6. Delta subsidence map.



Sacramento–San Joaquin Delta Atlas *Department of Water Resources*

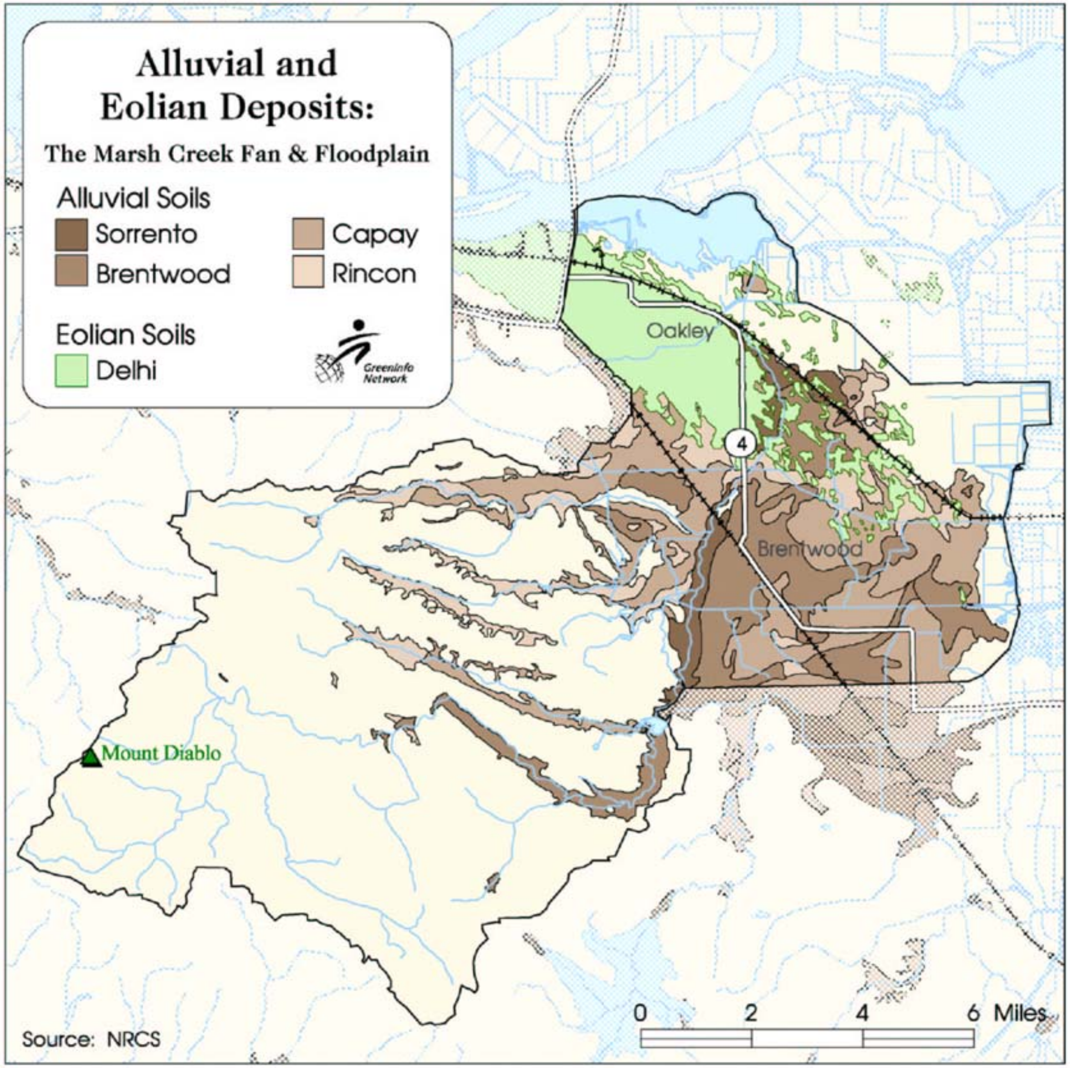


Figure 7. Soils of the Marsh Creek watershed.

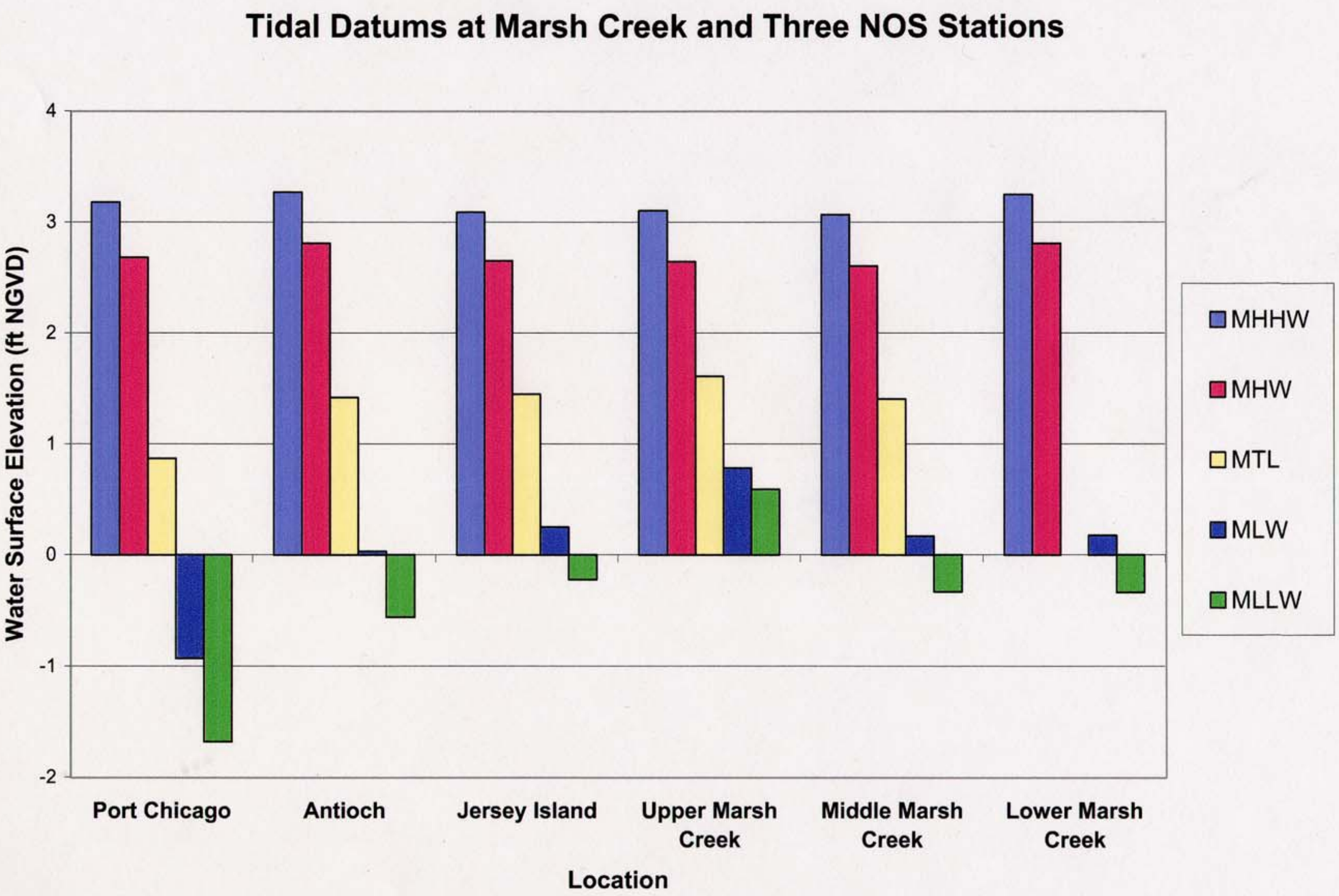


Figure 8. Tidal range at Dutch Slough.

Figure 9. Cross sections of Emerson Slough and location map of cross sections.

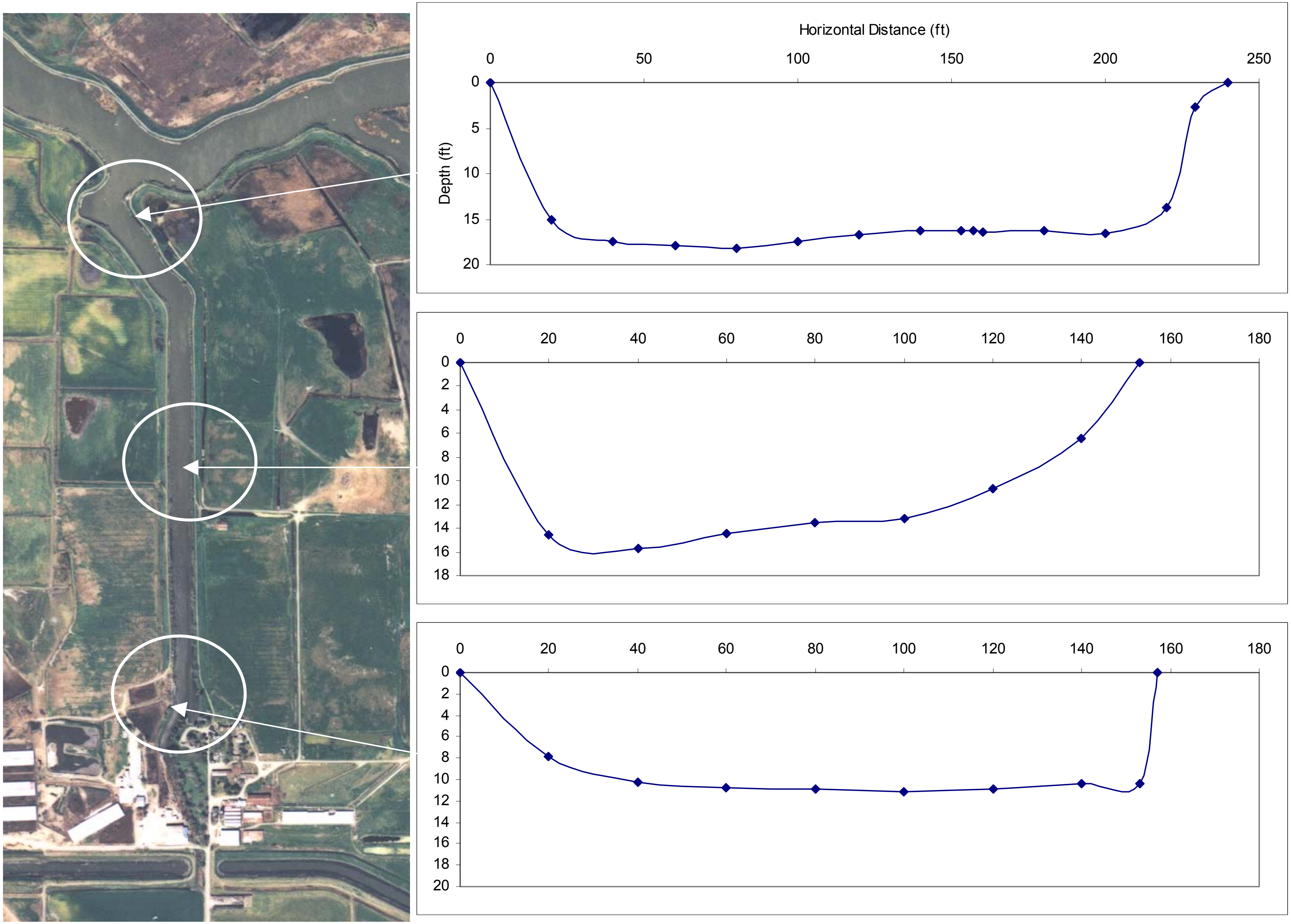
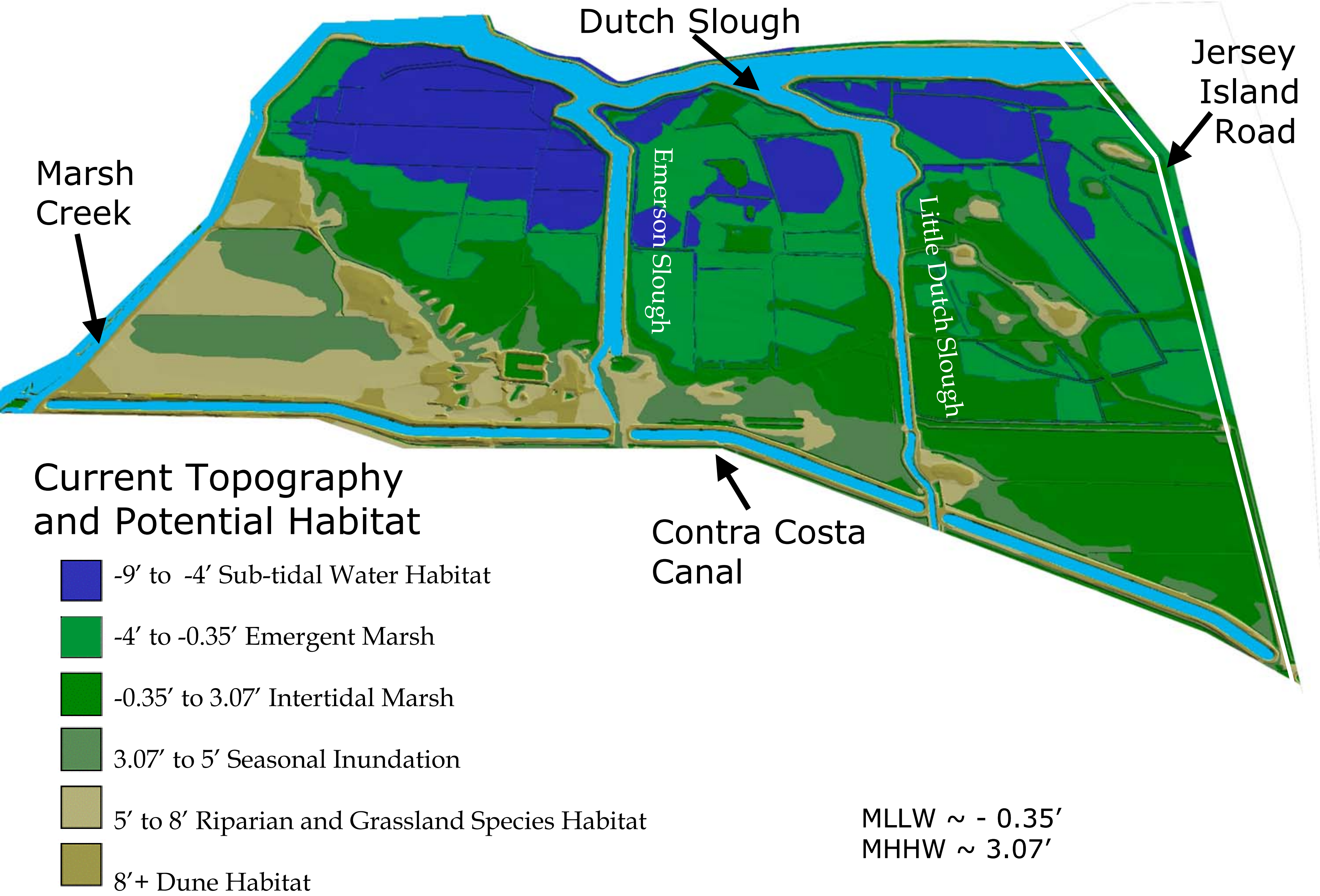


Figure 10. Dutch Slough topography and habitat map.



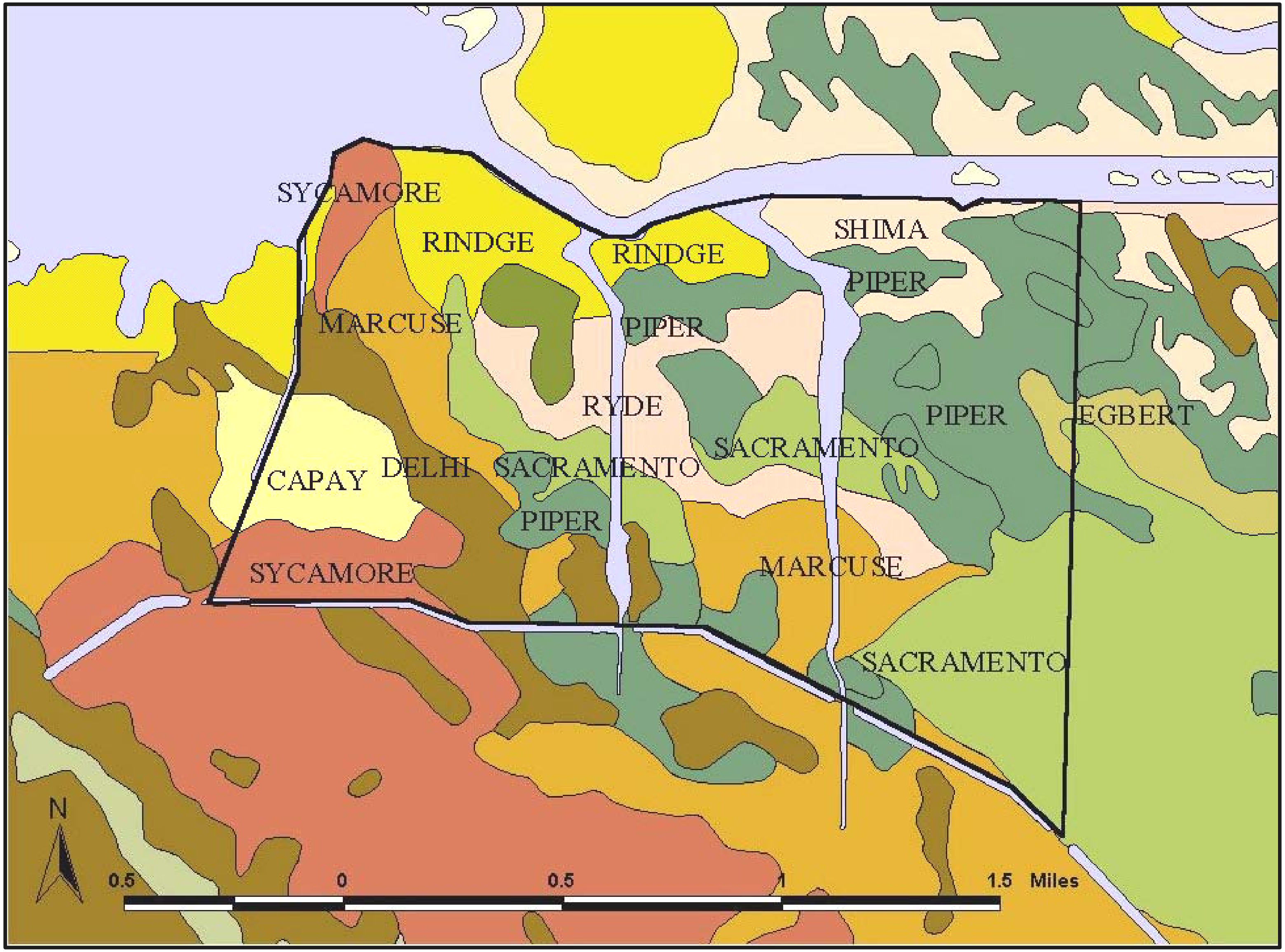


Figure 11. Dutch Slough soils map.

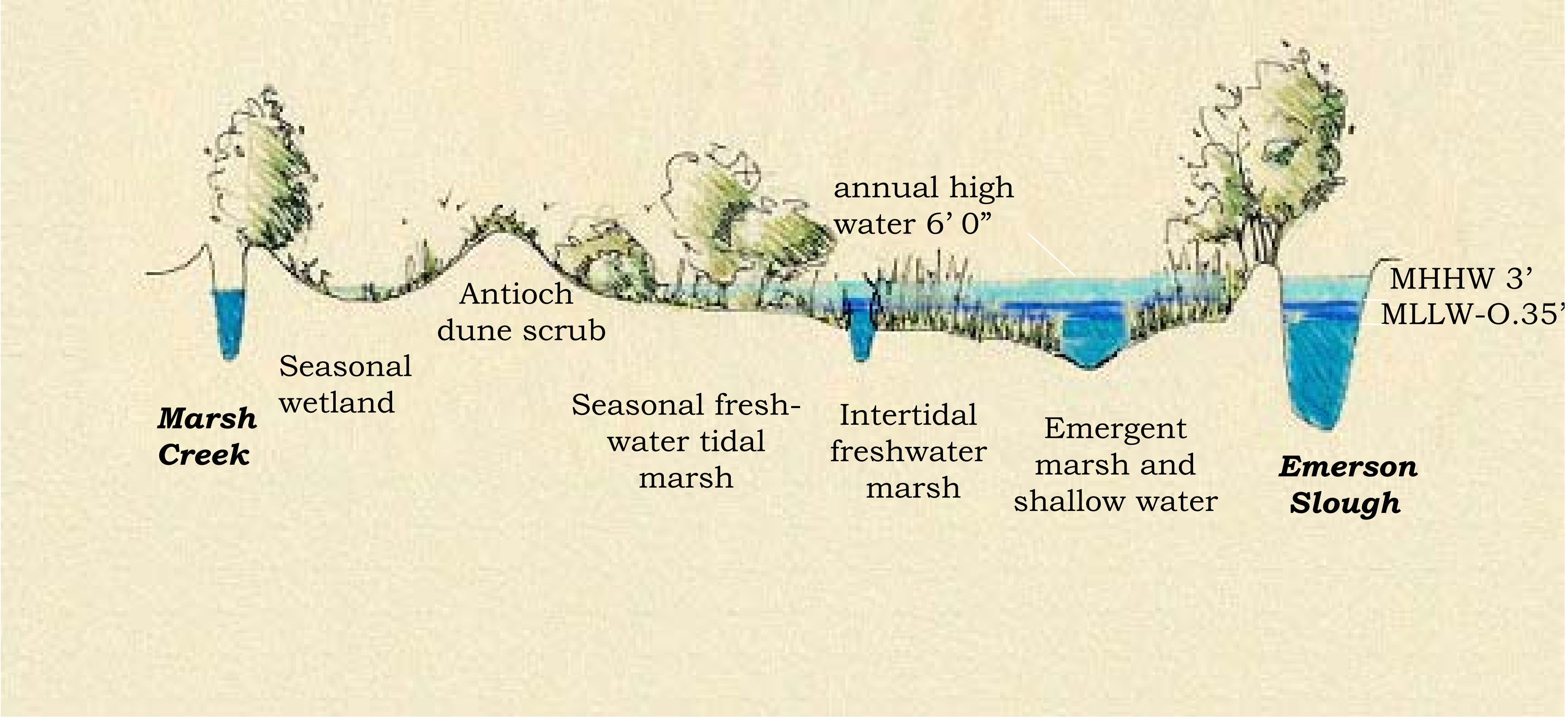
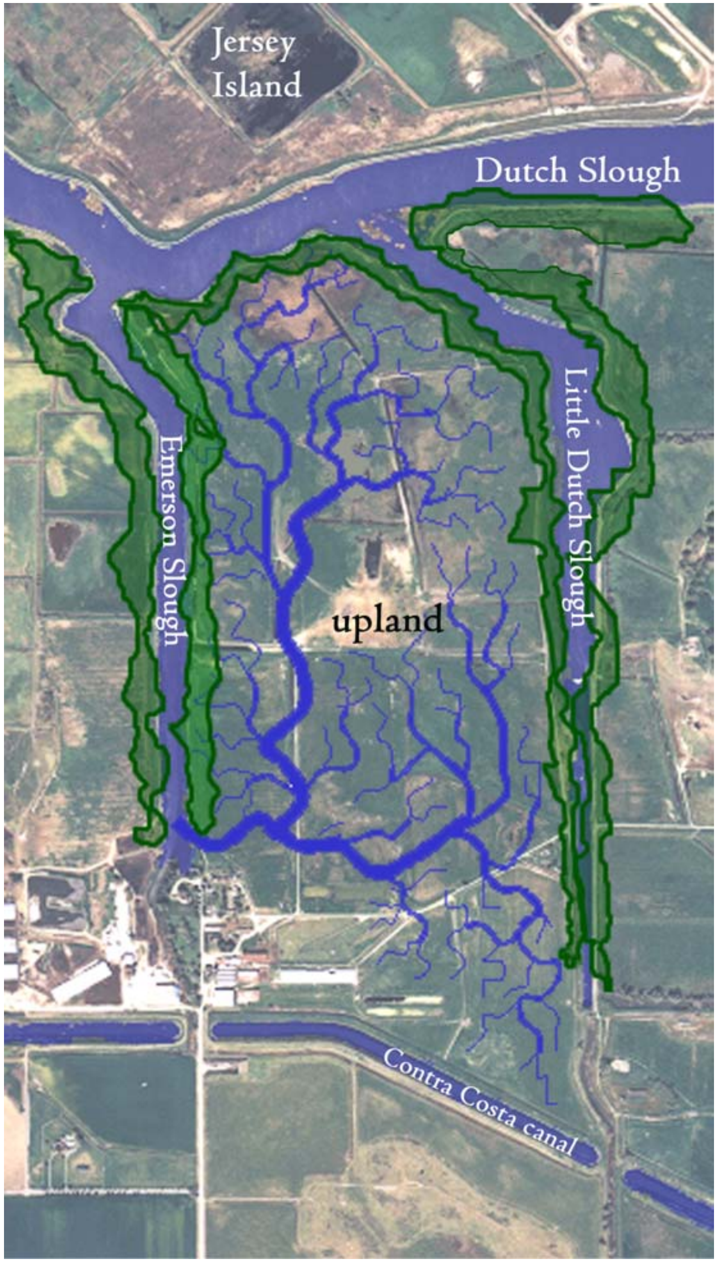
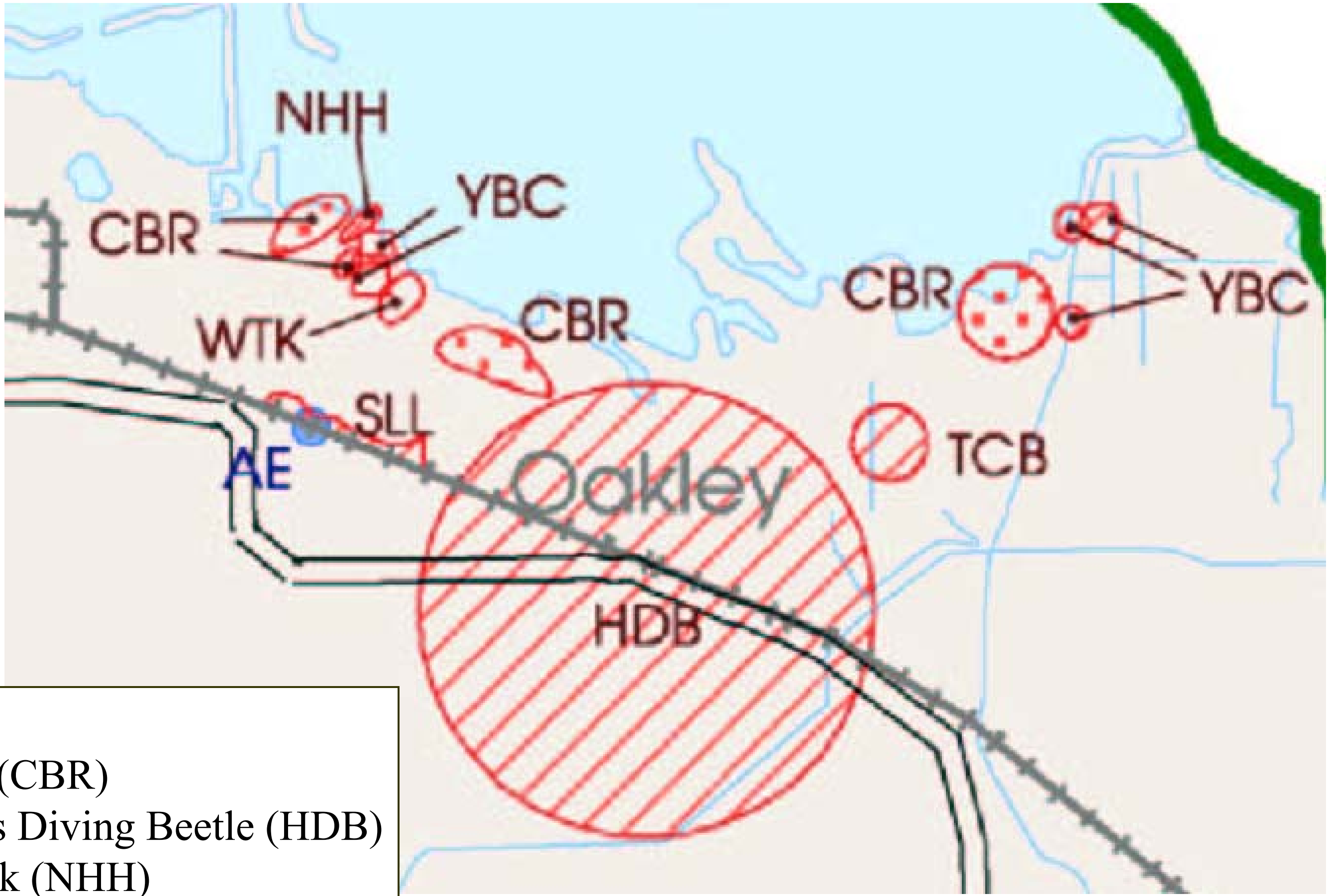


Figure 12. Representative cross section of potential habitat types on the Emerson parcel.

Figure 13. Conceptual design for dendridic channel system.





Animal Species
- California Black Rail (CBR)
- Curved-Foot Hygrotus Diving Beetle (HDB)
- Northern Harrier Hawk (NHH)
- Silvery Legless Lizard (SLL)
- Tri-Colored Blackbird (TCB)
- White-Tailed Kite (WTK)
- Yellow-Breasted Chat (YBC)

Plant Species
- Antioch Evening Primrose (AE)

Figure 14. Map of sensitive species along Big Break shoreline.

Figure 15. Photo of Marsh Creek channel.

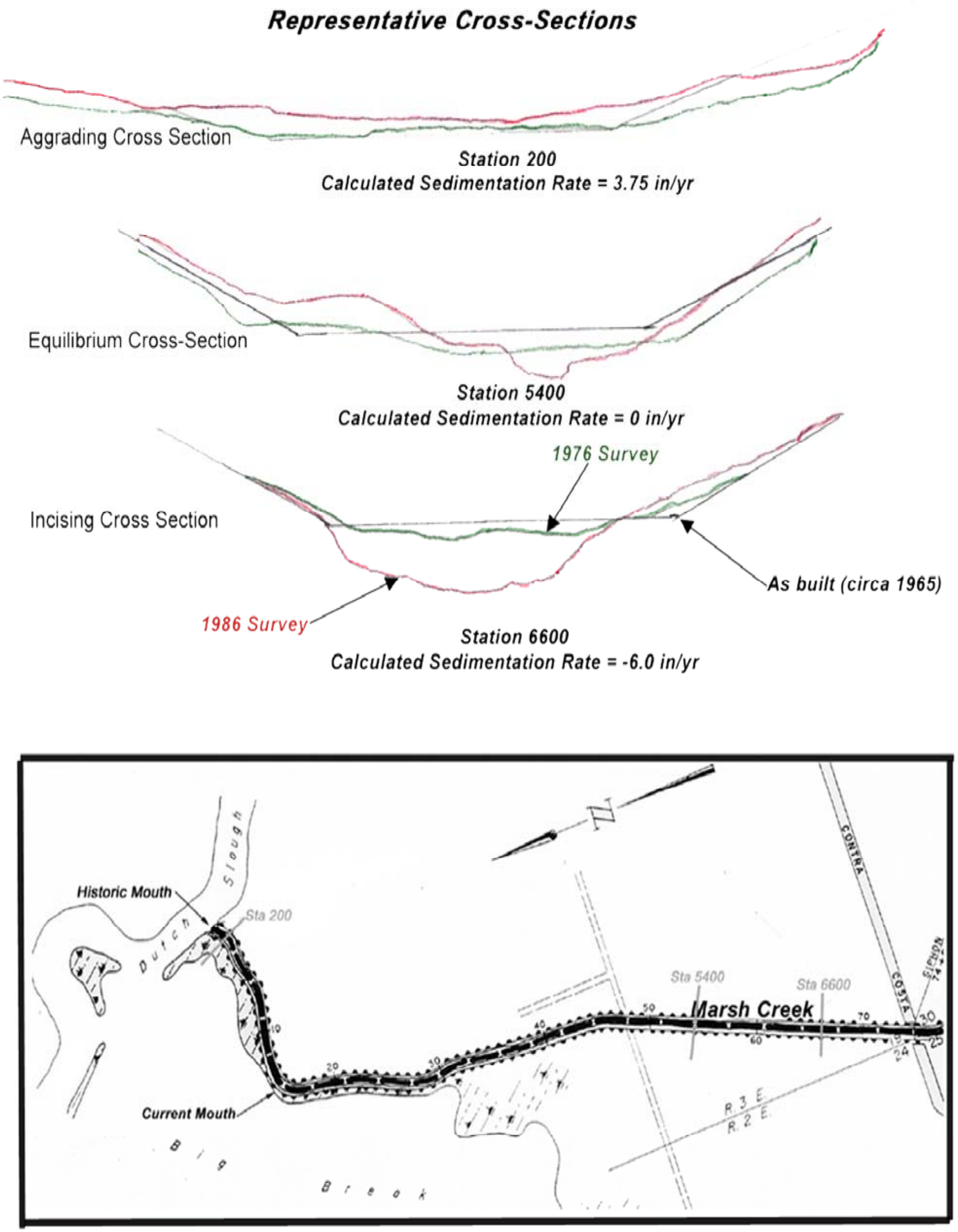


Figure 16. Sedimentation survey cross-sections of Marsh Creek and map of cross-section locations.

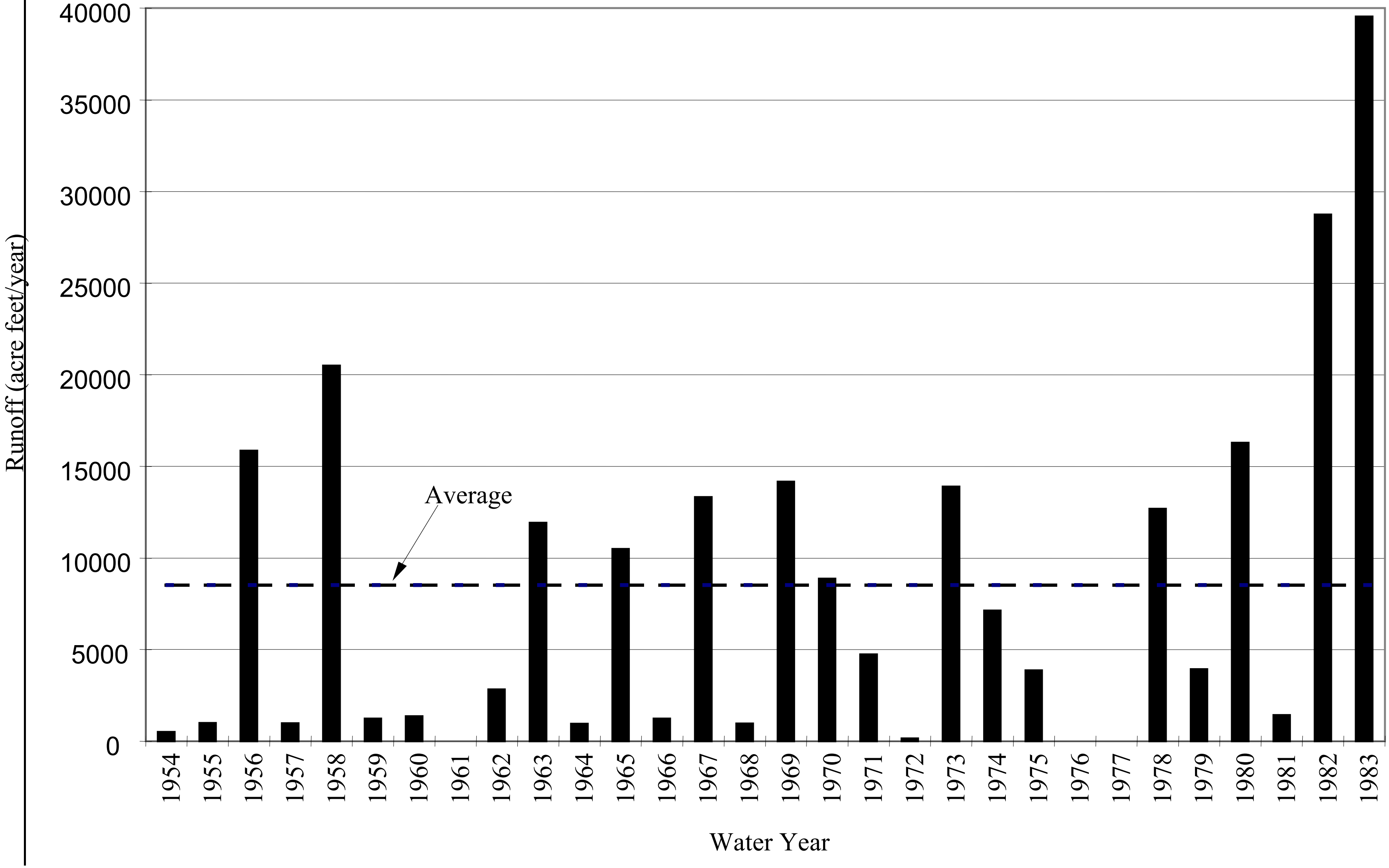


Figure 17. Annual Run-off for Marsh Creek (measured at USGS gauge near Byron). Represents only 38% of watershed area

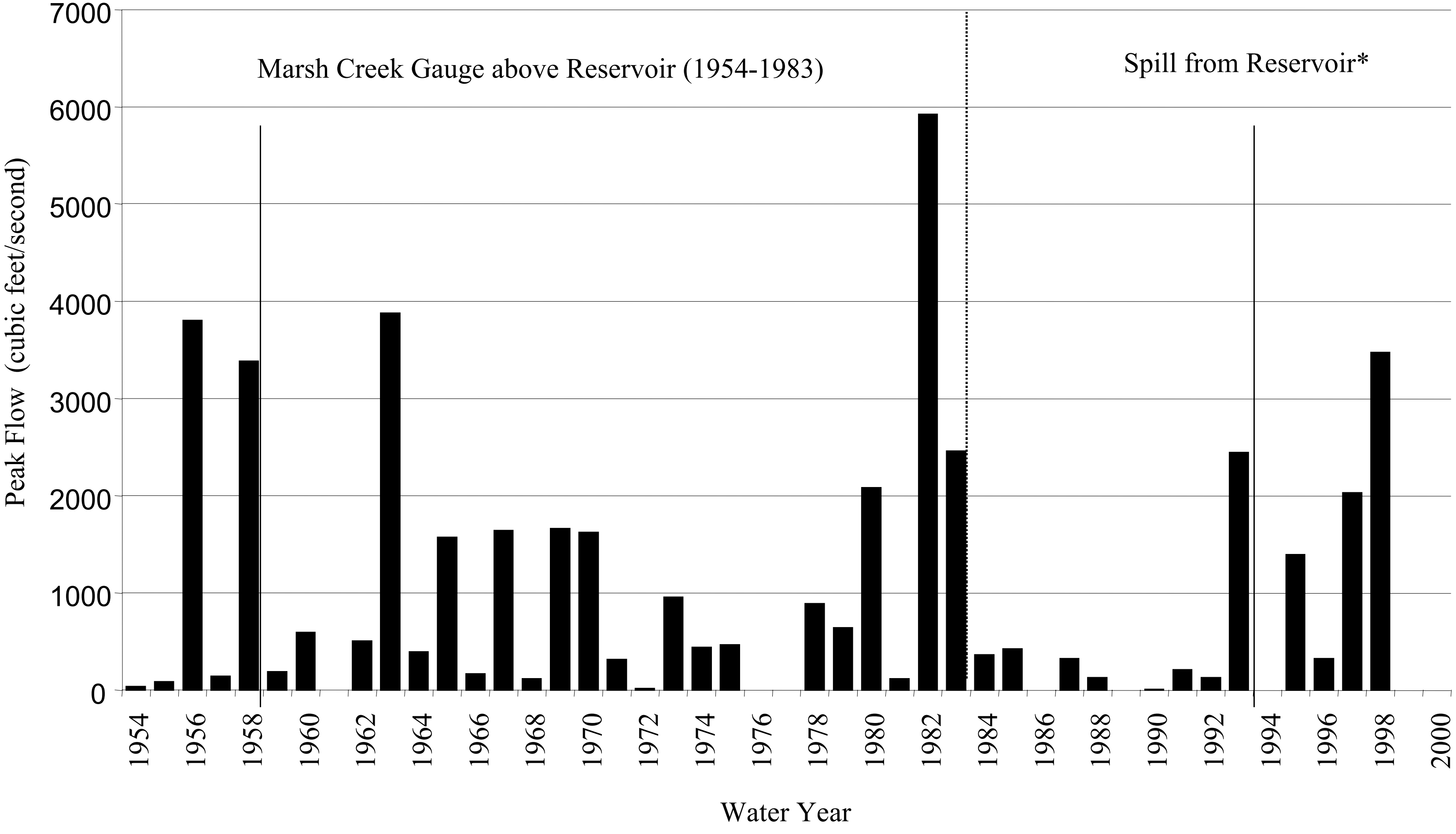


Figure 18. Annual maximum peak flows for Marsh Creek. *Peaks muted by Marsh Creek Dam, but include inflow from Briones Creek.

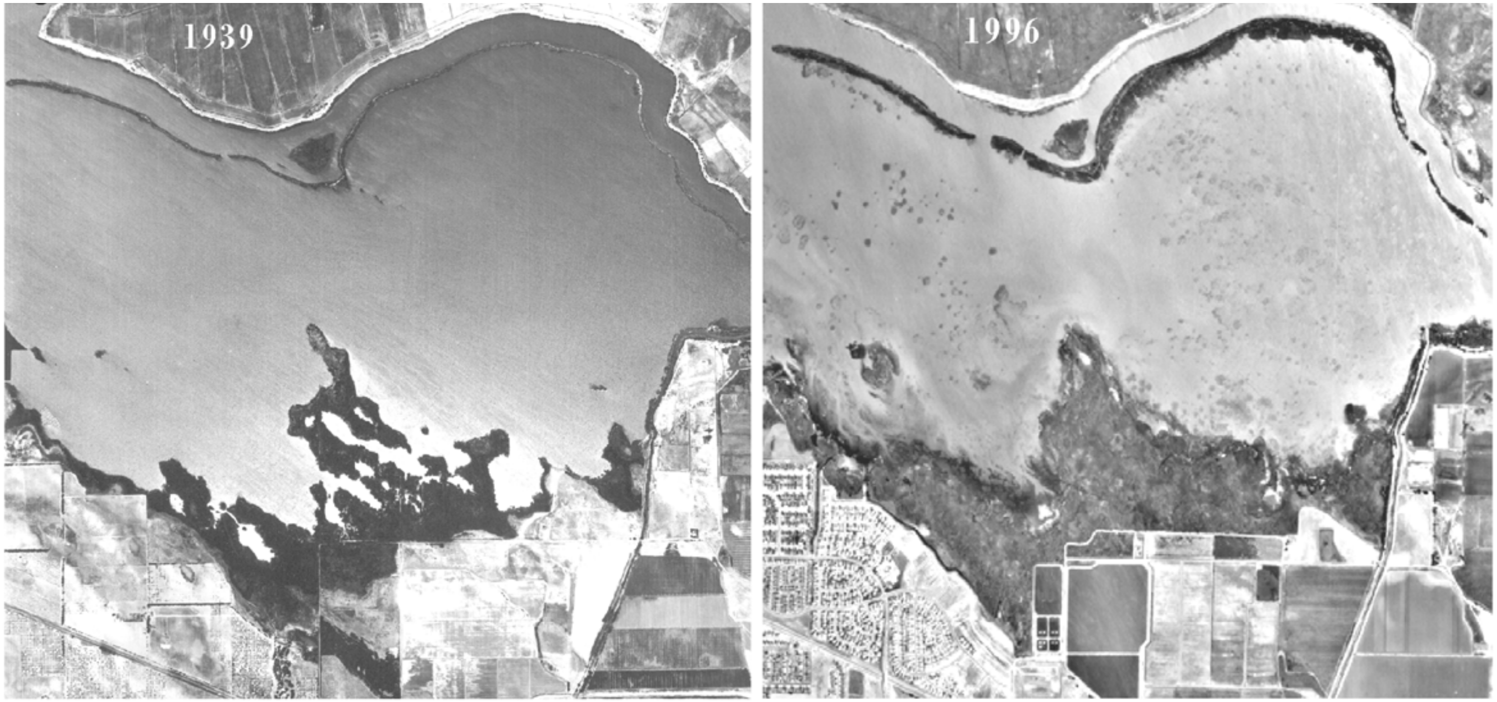


Figure 19. Aerial photo comparison of Big Break from 1939 and 1996.

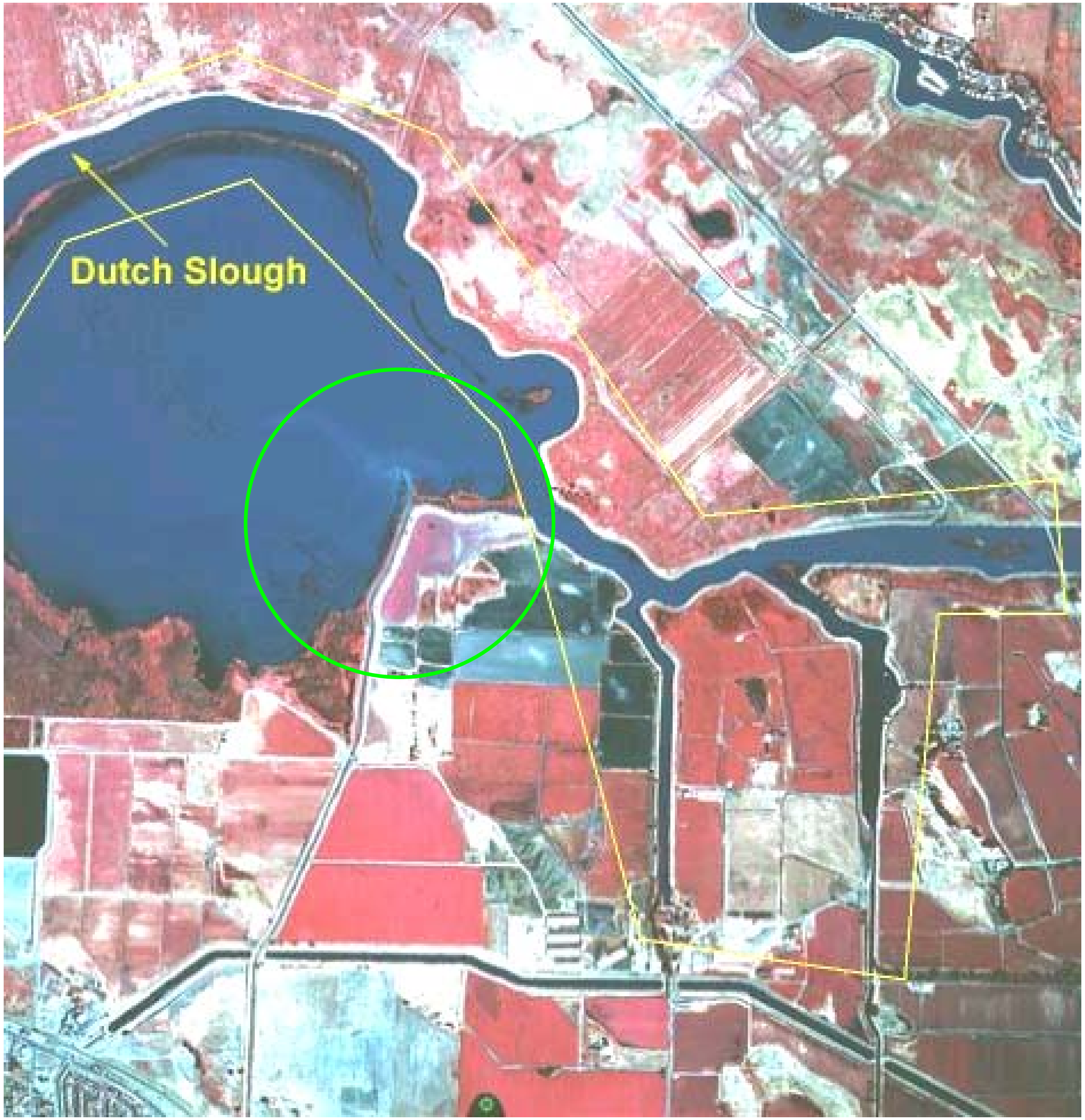


Figure 20. August 1999 aerial photo of Marsh Creek sediment plume. Imagery copyrighted and owned by California Department of Boating and Waterways and SFSU Romberg Tiburon Center for Environmental Studies. http://romberg.sfsu.edu/~egeria/Dutch_Slough/dutch_slough_c5_99_2m.htm.

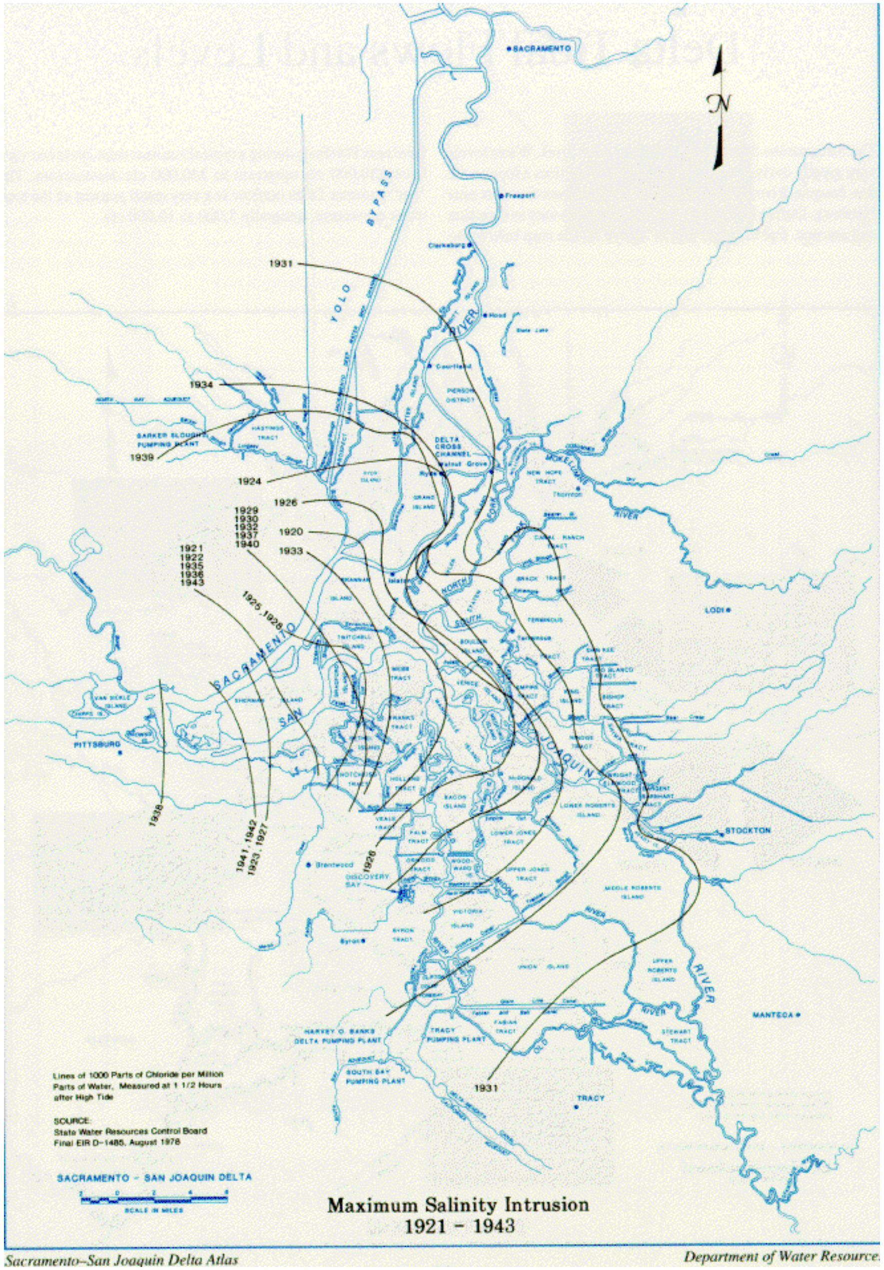


Figure 21a. Map of maximum annual salinity intrusion into the Delta 1923-1943

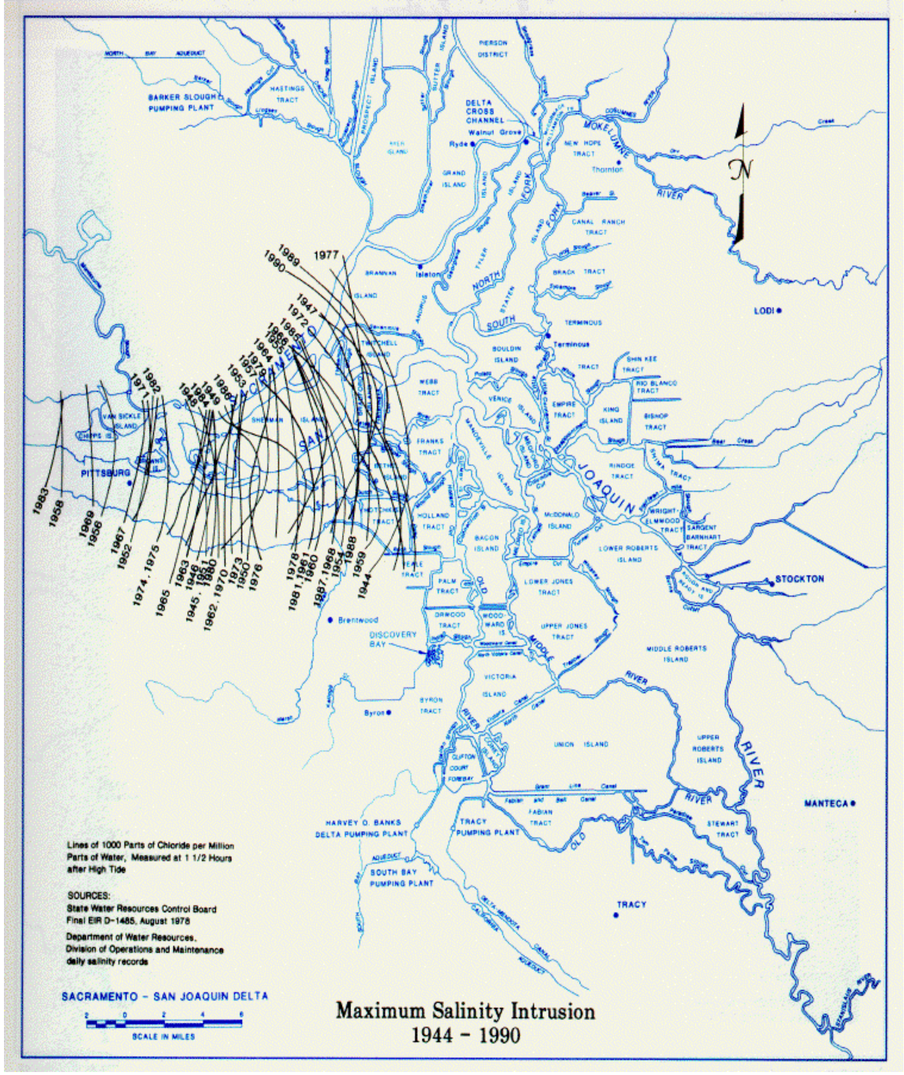


Figure 21b. Map of maximum annual salinity intrusion into the Delta 1944-1990.

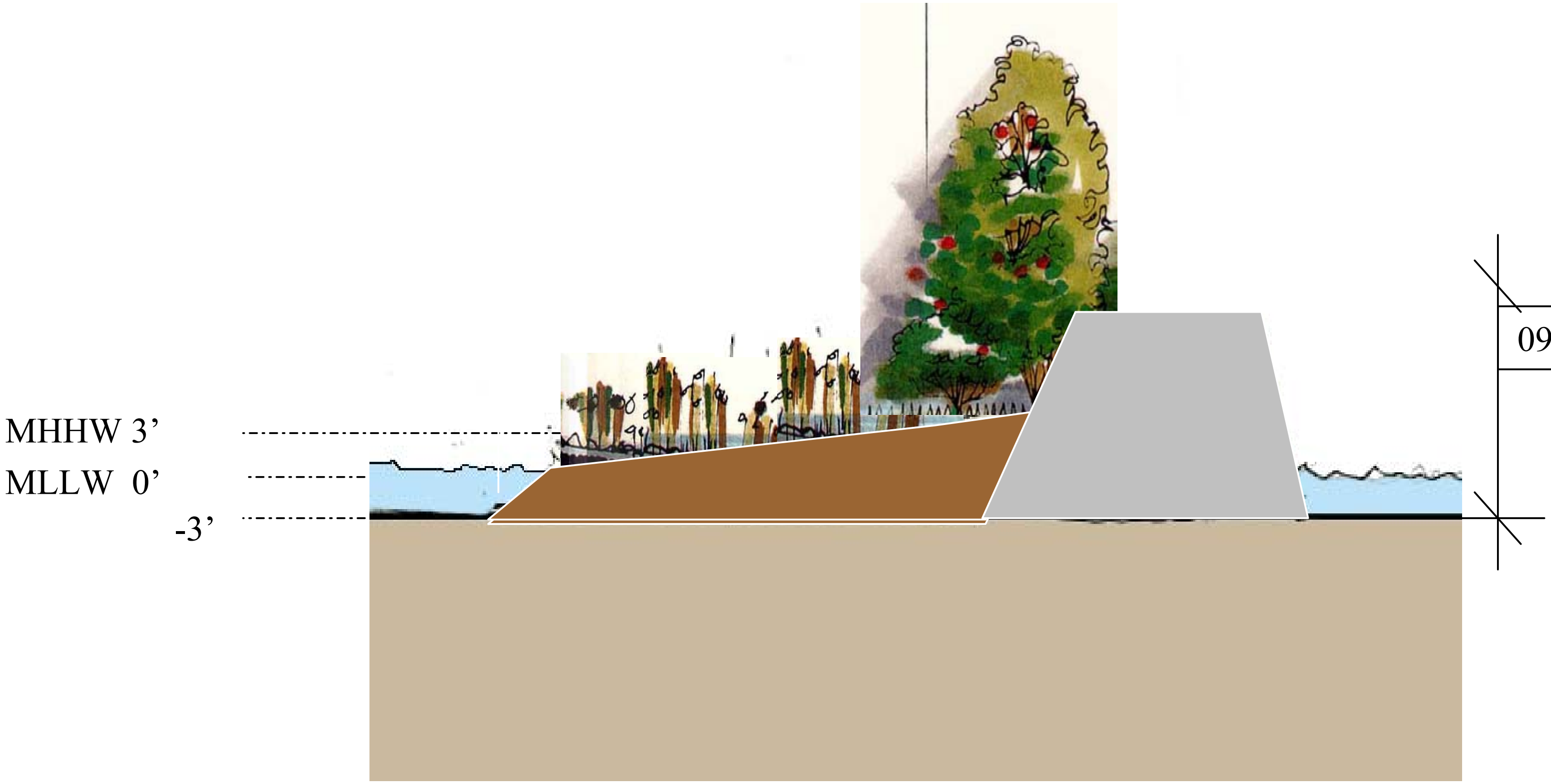


Figure 22. Conceptual bio-engineering design for interior levee. Maintain integrity of interior levees by grading slope 5:1 or 10:1 and planting with vegetation.

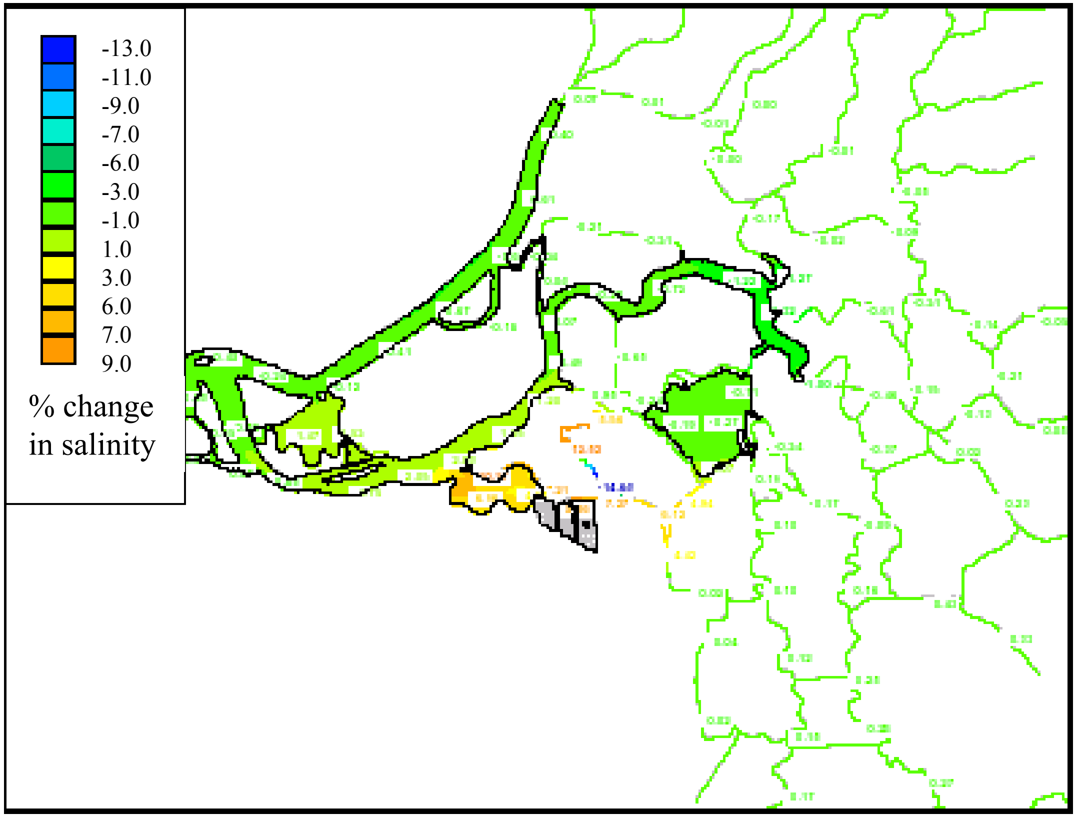
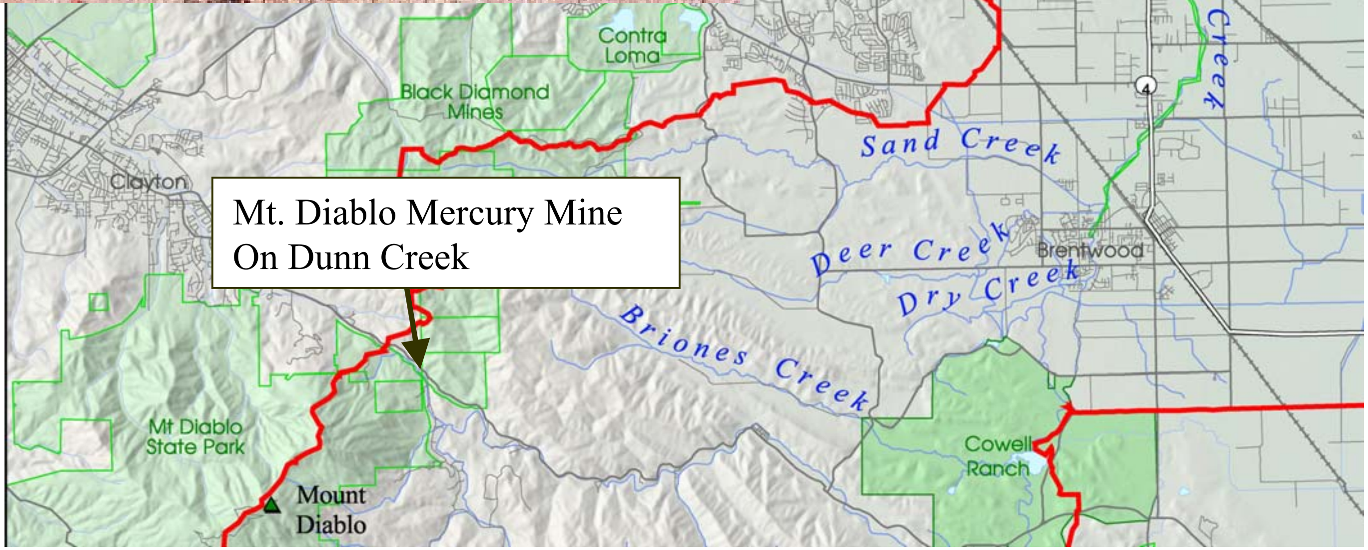


Figure 23. DWR modeling results to determine tidally averaged percent change in base salinity for modeled Dutch Slough levee breach on May 31, 1992.

Figure 24a. Mine tailings from the Mt. Diablo Mercury Mine.



Mt. Diablo Mercury Mine
On Dunn Creek

Figure 24b. Location of Mt. Diablo Mercury Mine on Dunn Creek.

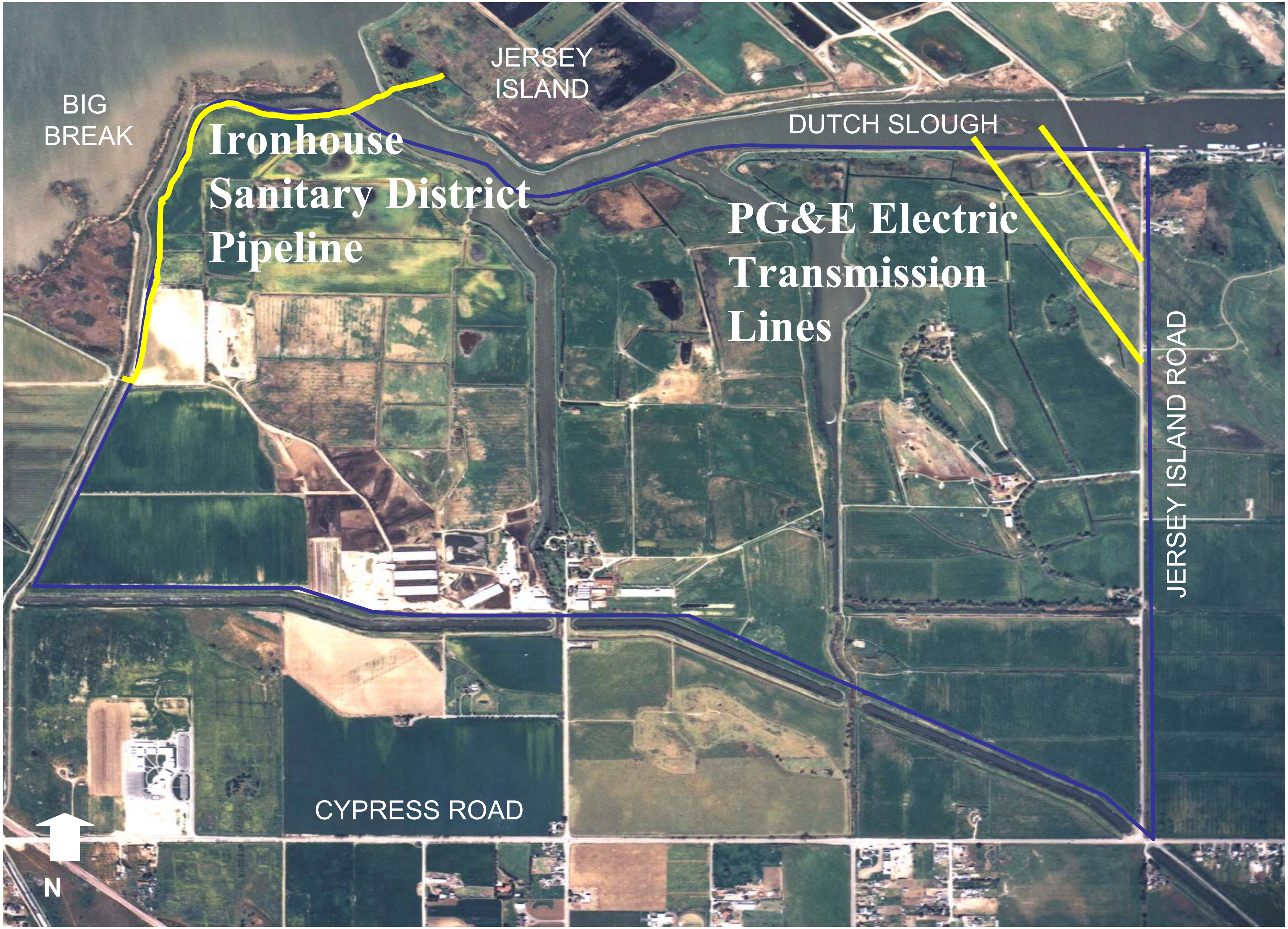
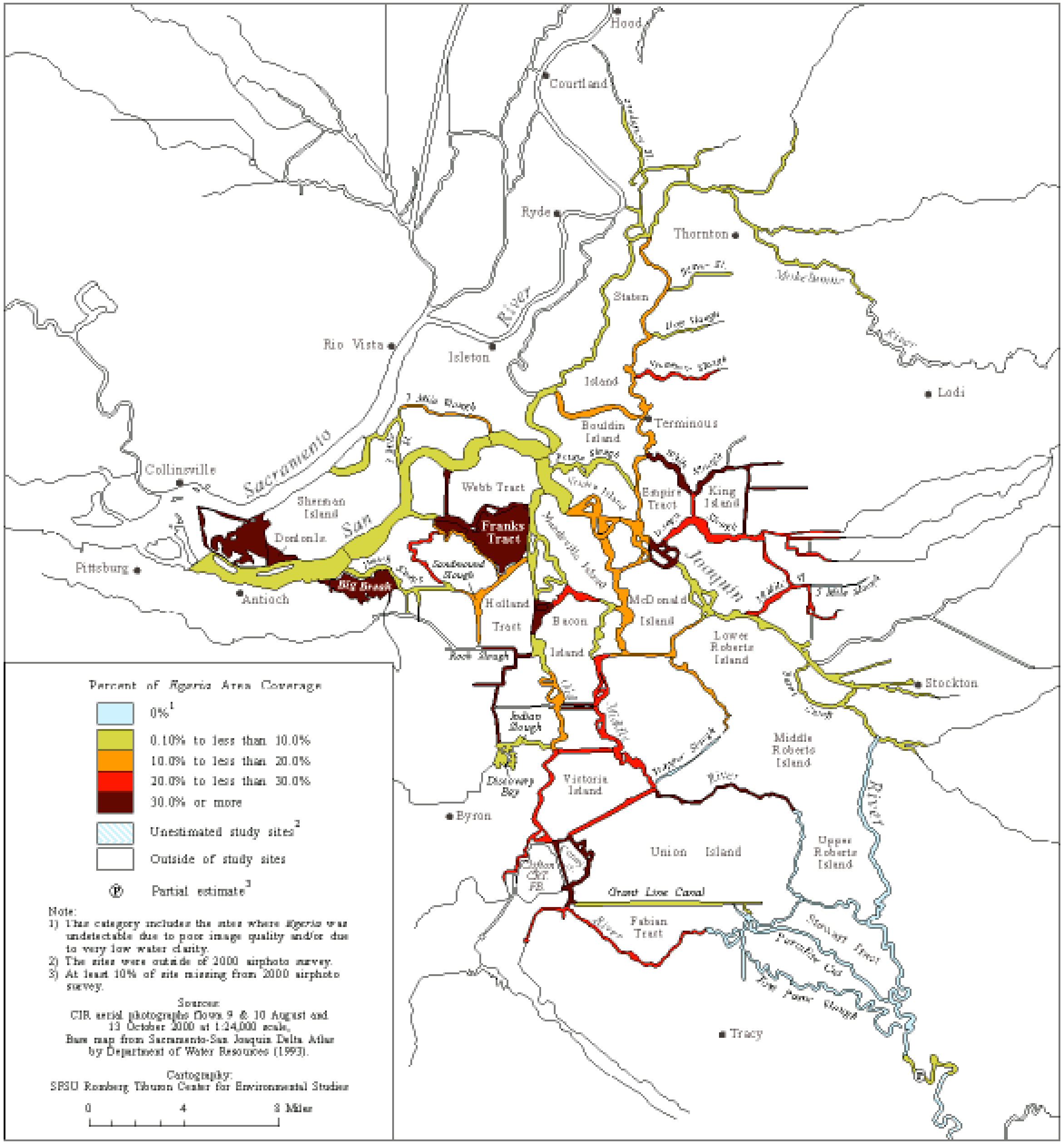


Figure 25. Approximate location of key utility easements on Dutch Slough site.



Note:
1) This category includes the sites where *Egeria* was undetectable due to poor image quality and/or due to very low water clarity.
2) The sites were outside of 2000 airphoto survey.
3) At least 10% of site missing from 2000 airphoto survey.

Sources:
CIR aerial photographs flown 9 & 10 August and 13 October 2000 at 1:24,000 scale,
Base map from Sacramento-San Joaquin Delta Atlas by Department of Water Resources (1993).

Cartography:
SFSU Romberg Tiburon Center for Environmental Studies

Figure 26. Estimate of *Egeria densa* area coverage in the Dutch Slough vicinity. Sacramento-San Joaquin Delta, 2000. http://romberg.sfsu.edu/~egeria/egeria_coverage_estimate_2000.htm.

Table 1: Area of Potential Habitat Types with Existing Topography

Current Elevation (feet below MLLW)	Potential Habitat Type	Total (acres)
-10 to –3	Shallow Water	373
-3 to 0	Emergent Marsh	224
0 to 3	Intertidal Marsh	259
3 to 5	Seasonal Marsh & Floodplain	137
5 to 8	Mixed Riparian-Oak Woodland	82
8 +	Antioch Dune Scrub	91
	Total (acres)	**1,166**

Table 2. Native Avian and Terrestrial Species Observed along Big Break and Marsh Creek (Orlof, 2000; Glover, 2000)

Birds

American Avocet
American Bittern
American Coot
American Crow
American Goldfinch
American Kestrel
American Pipit
American Robin
American White Pelican
American Wigeon
Anna’s Hummingbird
Ash-Throated Flycatcher
Bank Swallow
Barn Owl
Barn Swallow
Belted Kingfisher
Bewick’s Wren
Black Phoebe
Black Rail
Black Tern
Black-Bellied Plover
Black-Crowned Night-Heron
Black-Headed Grosbeak
Black-Necked Stilt
Blue Grosbeak
Bonaparte’s Gull
Brandt’s Cormorant
Brewer’s Blackbird
Brown-Headed Cowbird
Bufflehead
Bullock’s Oriole
Bushtit
California Black rail
California Gull
Canvasback
Caspian Tern
Cattle Egret
Cedar Waxwing
Cinnamon Teal
Cliff Swallow
Common Goldeneye
Common Merganser
Common Moorhen
Common Raven
Common Snipe
Common Yellowthroat
Cooper’s Hawk
Double-Crested Cormorant
Downy Woodpecker
Dunlin
Eared Grebe
European Starling
Forster’s Tern
Fox Sparrow
Gadwall
Glaucous-Winged Gull
Golden-Crowned Sparrow
Great Blue Heron
Great Egret
Great Horned Owl
Greater Scaup
Greater Yellowlegs
Green Heron
Green-Winged Teal
Hermit Thrush
Herring Gull
Hooded Merganser
Hooded Oriole
Horned Grebe
Horned Lark
House Finch
House Sparrow
House Wren
Killdeer
Lark Sparrow
Least Sandpiper
Least Tern
Lesser Scaup
Lesser Yellowlegs
Lincoln’s Sparrow
Loggerhead Shrike
Long-Billed Curlew
Long-billed Dowitcher
Mallard
Marbled Godwit
Marsh Wren
Mew Gull
Mourning Dove
N. Rough-Winged Swallow
Northern Flicker
Northern Harrier
Northern Mockingbird
Northern Rough-Wing Swallow
Northern Shoveler
Nuttall’s Woodpecker
Orange-Crowned Warbler
Osprey
Pied-Billed Grebe
Red-Necked Phalarope
Red-Shouldered Hawk
Red-Tailed Hawk
Red-Winged Blackbird
Ring-Billed Gull
Ring-Necked Pheasant
Rock Dove
Ruby-Crowned Kinglet
Sandhill Crane
Savannah Sparrow
Say’s Phoebe
Scrub Jay
Sharp-Shinned Hawk
Snowy Egret
Song Sparrow
Sora
Spotted Sandpiper
Spotted Towhee
Swainson’s Hawk
Thayer’s Gull
Tree Swallow
Turkey Vulture
Violet–Green Swallow
Virginia Rail
Western Kingbird
Western Meadowlark
Western Sandpiper
Western Scrub-Jay
Western Tanager
Western/Clark’s Grebe
Whimbrel
White-Crowned Sparrow
White-Faced Ibis
White-Tailed Kite
White-Throated Swift
Willet
Willow Flycatcher
Wilson’s Warbler
Wood Duck
Yellow Warbler
Yellow-Breasted Chat
Yellow-Headed Blackbird

Reptiles and Amphibians

Western Pond turtle
Red-legged Frog (upper Marsh Creek)
Silvery Legless Lizard
Alameda Whip Snake
Western Fence Lizard

Mammals

Beaver
California Ground Squirrel
Coyote
Gray Fox
Opossum
Striped Skunk
River Otter

Table 3: Channel Aggradation and Incision in Lower Marsh Creek

Station No.	*Approximate Fill Depth (ft)*	*Calculated Sedimentation Rate (in/yr)*	**Station No.**	*Approximate Fill Depth (ft)*	*Calculated Sedimentation Rate (in/yr)*
200	2.5	3.8	4200	-1.0	-1.5
600	1.8	2.7	4600	-1.5	-2.3
1019	1.8	2.7	5000	-2.5	-3.8
1369	5.0	7.5	5400	0.0	0.0
1800	1.0	1.5	5800	-3.0	-4.5
2200	0.0	0.0	6200	-1.0	-1.5
2600	-2.0	-3.0	6600	-4.0	-6
3000	-1.5	-2.3	7000	-2.5	-3.8
3400	-1.0	-1.5	7397	0.0	0.0
3800	-1.5	-2.3	7800	-2.0	-3.0